A Workability Index and Job Profile that addresses the needs of Singapore workers (SWIJP)

A proposal to the WSH Institute, Ministry of Manpower, Singapore

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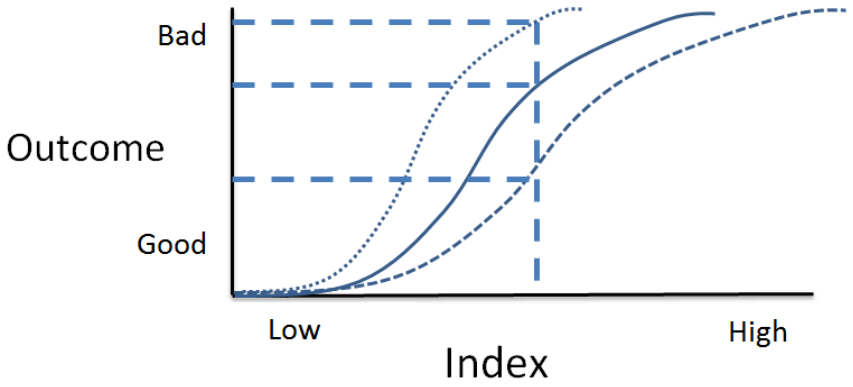
1. **Overview**

   a. A "workability index" is a single composite measure of the multiple factors associated with a job, including the workplace, physical environment, equipment, material, pacing, other operational details and the capability of a particular individual. In general an index has the following form:



   b. The three curves represent the relationship between the Index and the Outcome for average, robust and vulnerable (perhaps elderly) workers. The dashed lines indicate that a cut-off point on the Index will have different Outcomes for different populations. The "Outcome" may also have qualitatively different and perhaps contradictory meanings, such as productivity or safety.

   c. Workability Indices take into account physical factors, such as spatial arrangements, strength, stamina, speed and skill, environmental factors such as heat, cold, noise and vibration, informational factors such as vision, hearing, memory and situational awareness, and operational / temporal factors such as static posture duration, job pacing, job cycle duration and work shift duration. These factors can be assessed individually and the measures combined to produce a "Workability Index" that reflects the physical, cognitive, environmental, social and temporal demands of a job.

   d. Three examples (there are numerous others such as OWAS, HAL, The Strain Index etc.) of widely validated occupational health and safety "Indices" are: the NIOSH Lift Index, RULA and the Snook / Liberty Mutual Psychophysical Tables for manual materials handling. The first two do not formally address the issue of different populations, whereas the Snook Tables are presented as a "percentage of the population who are capable of safely performing a particular task." These tools were all developed in the West and may not be an accurate reflection of the capabilities and limitations of Singaporean workers. The Finnish "Workability Index" is a clinical tool that addresses both work demands and individual factors, including disease. Similarly the International Classification of Function (World Health Organization) is individual centered; it describes

both specific body system function and the capabilities of an individual to perform “acts of daily living.”

e. These “Indices” vary considerably in their complexity and scope, although in trained hands they have been shown to be effective measures of the relationship between work demands and populations of workers. They also may be time consuming to apply. One way of addressing these “efficiency” factors is to have a hierarchy of screening, analytic and in depth investigation tools. This “triage” in the emergency room sense makes efficient use of the time and expertise of health and safety professionals, with different training levels.

f. One lesson learned from the NIOSH Lift Index is that the single index needs to be decomposed into its constituent parts in order to identify and rectify the job if necessary. This is because different engineers have responsibility for different components of the task, such as load (Product Engineer), spatial (Manufacturing Engineer) and temporal (Industrial / Production Engineer) factors. The NIOSH Lift Equation is a “Discounting Equation” with a set of multipliers, each taking a value between 0 and 1. Thus the intervention strategy first addresses “the low hanging fruit” and directs the intervention to the appropriate engineering specialist. One way of addressing this link between analysis and intervention strategy is to use job profiling graphs and matrices or polar graphs. Such communication tools have been used widely in such diverse areas as company financial performance and physical rehabilitation.

g. Another approach (widely used throughout General Motors for the past two decades) is to assign a “common currency” outcome metric to many qualitatively different job stressors, such a load, location, force, frequency and duration. These common currency outcomes are amalgamated to produce an Index of Workability but decomposed into their original dimensions to drive interventions. Also the Physical Work Strain Index uses an activity sampling approach that aspires to determine a balance between high static and high dynamic physical workloads. Some publications by the principal investigator that describe these approaches in more detail include:
    i. A Discounting Model for Task Design, Applied Ergonomics Conference, IIE, 2005, Orlando, Florida
    ii. Rule Based Ergonomics, Ergonomics in Design Vol. 12, No. 4, 2004
    Habitability Measurement in Space Vehicles and Earth Analogs, Chapter 74 in Stanton et al Handbook of Human Factors and Ergonomics Methods CRC press,
    iii. Measurement in Manufacturing Ergonomics, Chapter 8 in Handbook of Human Factors Testing and Evaluation, Charlton and O’Brien, Lawrence Erlbaum, 2002
    iv. (with Jen Gwo Chen and Hwa S Jung) "A Fuzzy Sets Modeling Approach for Ergonomic Workload Stress Analysis", International Journal of Industrial Ergonomics 13, 189 – 216, 1994

v. (with J. G. Chen and R. E. Schlegel) "An Observational Technique for Physical Work Stress Analysis", International Journal of Industrial Ergonomics, No.3 (1989)

h. This proposal involves the adaptation or development of a Workability Index and Job Profile for application in Singapore (SWIJP), with particular reference to vulnerable populations, including the elderly worker. The principles and operational format of internationally validated tools will form the basis of the SWJIP development. It is likely also that enhancements could be made to include greater attention to the temporal dimension of static and dynamic work demands. The parameters will be subject to validation for local use in a wide variety of workplaces – from construction through logistics to the office.

2. Proposed Plan of Study / Time Line

Item	Description of work	Duration
1	Survey of workability indices and job profiles around the world. Identification of elements and processes to include in the proposed toolset.	Three months
2	Design of a measurement, analysis and communication instrument for Singapore. (SWIJP) Pre-testing the instrument.	Two months
3	Development of training material to accompany the SWIJP	Two months
3	Field testing and validating the SWIJP instrument.	Three months
4	Modifications and final changes to the SWIJP instrument.	Two months

3. Budget (one year)

Principal Investigator (Dr Brian Peacock)	$40,000
Co Principal Investigator (Dr Tan Kay Chuan)	$40,000
Research assistants (4 X $15,000 pa)	$60,000
Materials	$10,000
Field Test Administration	$10,000
Overseas Travel (Conference and consultation)	$20,000
Total	$180,000

4. Background – The Older Worker in Singapore

a. Work is a tangible way in which individuals can contribute to society. It is also a means by which individuals can receive financial rewards and personal fulfillment. A complication of this symbiotic relationship is the wide variability among individual's knowledge, experience, capabilities, limitations and aspirations on the one hand and the enormous variation in employment opportunities on the other. The matching of opportunities with individual capabilities and interests presents complex technical and organizational challenges. A particular challenge for employment is the process of aging.

b. The following chart (Figure 1) shows the number of persons in each 5 year age group for the years 2000 and 2010. This "age pyramid" shows clearly that the Singapore population is ageing. Singapore's situation in this regard is not unique. The same observations are made in Europe, North America and Japan. The primary causes of these changes are the birth rate and the contributions of public health and medical interventions to prevent and treat otherwise fatal diseases.

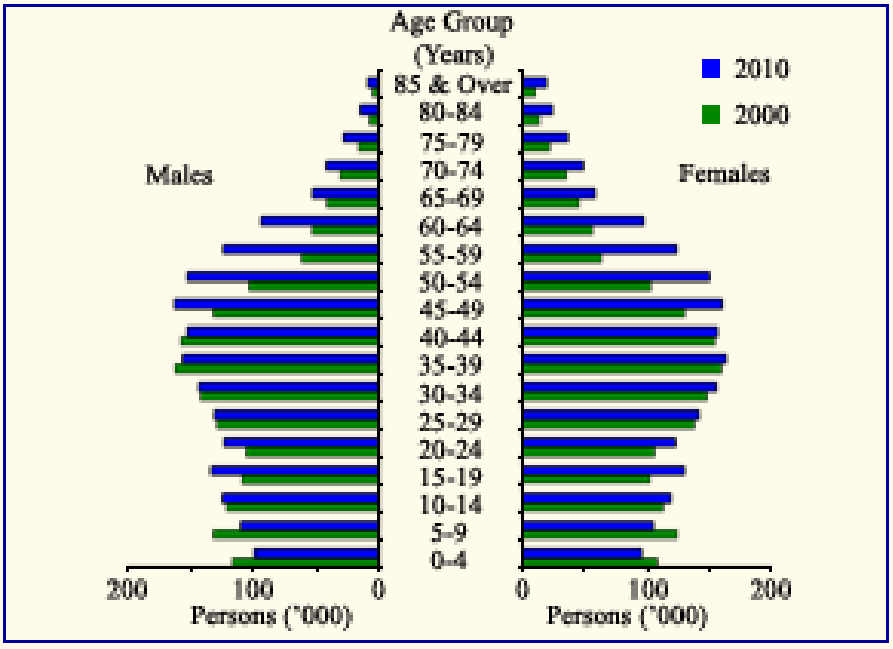


Figure 1 Singapore age pyramid

(Source: from [www.singstat.gov)](www.singstat.gov)

c. Figure 2 shows that the participation of Singaporeans in the workforce is also "aging". The decline in numbers begins to increase significantly after the age of 55 compared with a turning point at 50 in 1999. There are also many more people working after the age of 70. Minister Mentor Lee is quoted as saying that "there should be no retirement

age for workers". The philosophy behind this statement is that not only will the working capacity of Singaporeans be increased, but also that individuals will remain healthier and happier due to the stimulation associated with work. It should be noted that there is an alternative point of view. Some older people, who are less intrinsically motivated by their employment, look forward to a phase in life when they can "smell the roses" and spend quality time with their grandchildren and hobbies. They argue that this is a reward for a lifetime's contribution to society. The key to these alternative viewpoints is the fundamental fact that all people, including elderly people, differ in their interests and aspirations.

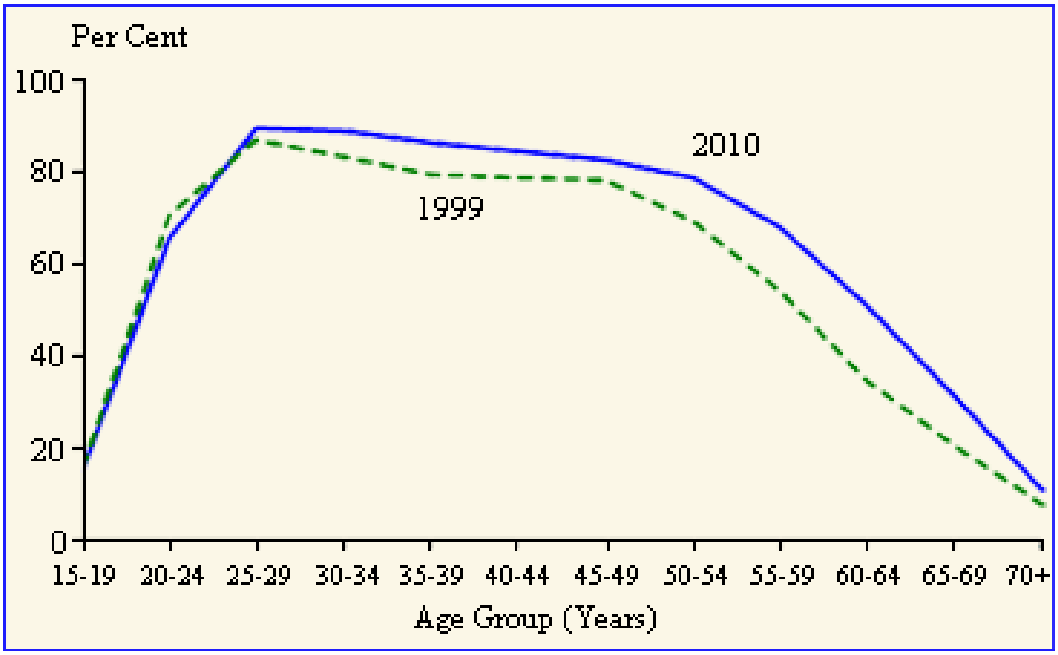


Figure 2 Participation in the workforce

(Source: [http://www.singstat.gov.sg/stats/charts/popn-area.html)](http://www.singstat.gov.sg/stats/charts/popn-area.html)

d. More importantly, one implication of the changes in the age pyramid is shown in Figure 3. This shows a dramatic decrease in the ratio of the population above and below the age of 65. This fact, together with the increasing trend for both husband and wife to pursue careers, for personal fulfillment, social or financial reasons, results in an increasing likelihood that unemployed elderly people will remain at home alone, or need attention from a domestic servant.

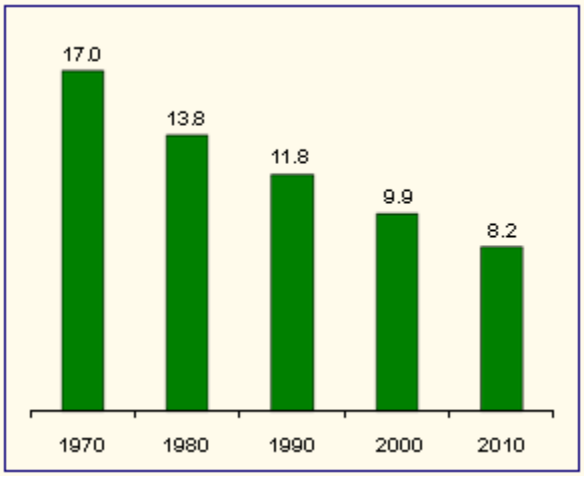


Figure 3 Old Age Support Ratio - Number of Residents Aged 15-64 Years per Elderly (> 65) Resident
(Source: http://www.singstat.gov.sg/stats/charts/popn-area.html#popnC)

e. The challenges that these trends present are the provision of opportunities for an increasing number of elderly people to find personally, socially and financially fulfilling work. One contribution to the resolution of this challenge is the application of ergonomics to the analysis and design of equipment, workplaces and jobs that match the capabilities and limitations of this cohort.

6. Factors associated with aging

There are wide individual differences among older people that have genetic, medical and life style underpinnings. These factors may not be due to ageing *per se*, rather they may simply be associated with ageing. Either way the "solution" to the ageing issue may be to address these associated or "confounding" factors:

a. **Disease** Aging in general and with particular body systems is affected by genetic factors. There are genetic markers for many diseases. This early available information can be used to intervene in the disease process and thus prevent or reduce the effects of this disease as a person ages. One strategy to increase the "active longevity" of ageing people is regular and enhanced medical attention. Disease processes affecting vital functions such as circulation, vision, cognition etc. can have considerable effect on the "aging process" of other human functions. Medical intervention through drugs, replacement parts such as joints, dental, vision and hearing devices or rehabilitation may offset some disease factors associated with ageing.

b. **Lifestyle** Diet, exercise, cognitive and social activity affect the rate of decline of human capabilities. This decline can therefore be slowed significantly by lifestyle intervention among ageing people. For example poor diets and low levels of physical activity give rise to obesity, which in turn leads to metabolic disorders, such as diabetes. As employment is a significant element of "lifestyle" the design of jobs that are historically sedentary in nature should be addressed to include a greater opportunity for routine physical activity and social interaction. This philosophy may contradict short term objectives of productivity, but over the long term will maintain the physical and motivational capabilities of employees.

c. **Training and Experience** Specific experience with equipment, tasks or contexts will offset the age based decline in cognitive abilities. Routine specific job related training will be appropriate to facilitate the capabilities of older people as they interact with new technology or contexts

d. **Generational effect** Older people may have difficulty with contemporary technology, not due to ageing *per se*, but rather due to their exposure to such technology or to their perceptions regarding the need for the technology. Again the routine inclusion of ongoing training with contemporary technology in the workplace will go a long way towards offsetting this generational effect.

e. **Motivation** Individuals vary considerably in their motivation to work and participate in physical, cognitive and social activities. The intrinsic nature and context of these activities will generate positive or negative effects on motivation. In the workplace, it is the responsibility of employers / supervisors to consider these issues in the monitoring of individual behavior and performance, and the design of jobs.

f. **Support** The declines associated with ageing can be offset by family, employment and community support structures. If society and employers wish to prolong the active employment of individuals then there will be a need for support structures and processes that address such things as transportation, counseling, health care, continuing education etc.

g. **Economic factors** Some older people need to work to provide for their basic life needs of shelter and sustenance. An important responsibility of society, employers and families is therefore the mitigation of economic stressors among ageing people. The principle of "social security" of course has political ramifications. However an active rather than passive process of support can go a long way towards maintaining the contributions to society by people as they age.

h. **Affect** Older people are like all other people in their affective behaviors. They often express opinions and make decisions based on "likeability" rather than objectivity or function. However the affective behavior of older people differs from younger people in that they favor familiarity rather than novelty. Their opinions become entrenched, their behaviors more rigid and their performance abilities less flexible. When faced with challenging situations older people may revert to over learned, but situationally inappropriate behaviors. These characteristics of older people are a natural learned result of activities that have been repeated many times. Tasks and situations that take older people out of their "comfort zone" may cause stress and performance failures.

i. **Job Design** As people age the decline in physical, mental and social abilities is inevitable, although the rate of decline may be mitigated by the interventions discussed earlier. One other mitigation approach is to reduce the demands on older people by such strategies as reducing the length of their work day, the amount of work done over a certain time or other job responsibilities. The socialist slogan articulated by Karl Marx (1875): "From each according to his ability, to each according to his need", is in fact a truism. People do vary in ability and contribution and capitalist societies do protect the weak, for humanitarian and long term economic reasons. In the context of the ageing workforce these issues need sophisticated consideration.

j. **Ergonomics Analysis and Design** The primary contributions of ergonomics are the design of workplaces, equipment, contexts and tasks to accommodate these age related changes. Necessary precursors of design are incisive and reliable analysis and domain knowledge. The ergonomics community is trained in the use of many physical, sensory, cognitive, behavioral, performance and affect measurement tools. Also there are many standard principles and rules that can be applied to design for ageing populations. The success of ergonomics interventions is also dependent on substantial domain knowledge. This knowledge can be obtained first hand or more commonly by working with individuals that are well versed in the context of interest. These principles of "participation" and harnessing the "voice of the customer" are essential ingredients of the ergonomics analysis and design process.

k. All these factors present opportunities to explain and address the declines associated with ageing. In practice the most successful approach to ageing should involve in depth consideration these factors.

7. The International Classification of Function Disability and Health (ICF)

a. The International classification of function is primarily a medical tool, developed to complement the International Classification of Disease. However the principles and methods that comprise the ICF may be used or adapted to evaluate the effects of aging on task performance.

b. The ICF is structured around the following broad components:
   i. Body functions and structure
   ii. Activities (related to tasks and actions by an individual) and participation (involvement in a life situation)
   iii. Additional information on severity and environmental factors

c. ICF is described as the complex interaction between the health of an individual and his or her context. This description clearly links the knowledge and practice of ergonomics to the purposes of the ICF:

Functioning and disability are viewed as a complex interaction between the health condition of the individual and the contextual factors of the environment as well as personal factors. The picture produced by this combination of factors and dimensions is of "the person in his or her world". The classification treats these dimensions as interactive and dynamic rather than linear or static. It allows for an assessment of the degree of disability, although it is not a measurement instrument. It is applicable to all people, whatever their health condition. The language of the ICF is neutral as to etiology, placing the emphasis on function rather than condition or disease. It also is carefully designed to be relevant across cultures as well as age groups and genders, making it highly appropriate for heterogeneous populations."

From: *http://en.wikipedia.org/wiki/International_Classification_of_Functioning,_Disability_and_Health*

d. Whereas the usual focus of the ICF relates to people who are incapacitated for reasons of disease, the approach is relevant to all levels and causes of incapacity, particularly as related to an individual's interaction with his or her context. Both the normal deterioration associated with aging and the concomitant health issues make the ICF a pertinent tool for consideration of the functioning of older people at work. The ICF is generally completed by a team of analysts, each with a different perspective on the unique individual / context interaction. Whereas the team members often have a medical bias, there is no reason why a similar approach with operational team members should not be applied to the unique problem of ageing individuals. The results of this analysis can be used to guide ergonomics interventions.

An outline of the ICF can be found through the following link:
http://www.who.int/classifications/icf/training/icfchecklist.pdf

8. Ergonomics intervention opportunities

Ergonomics interventions may be developed from the following first principles:

a. **Space** The management of spatial factors must address two extremes. First because of mobility and physiological limitations movement distances should be reduced: these will involve interventions to reduce such things as the distance of walking, climbing, lifting carrying, pulling pushing etc. The Liberty Mutual (Snook) Tables provide guidelines for such activities that identify the proportion of the (adult) population capable of completing tasks of this nature with defined parameters. These tables were developed for the North American adult population so there will be a need to either transform the data to fit the Singaporean elderly population or carry out a substantial local research project to accommodate Singaporeans.

b. **Skills** The second spatial intervention principle is based on perceptual and motor skill requirements and involves the size and contrasts of fonts, objects and targets. In general the sensory – motor skills of older people are less than those of their younger counterparts. These deficiencies may be compensated for by allowing a greater amount of time for task completion. However a more appropriate intervention is to increase the contrasts and size of targets, such as boxes on forms or buttons on web pages. Other size and skills related design issues are associated with gross body movements. Older people, being less agile will generally require more space to carry out these movements. Other sensory motor skill declines are associated with balance. Tasks should be designed to avoid or mitigate the effects of loss of balance, by not requiring the negotiation of steps or stairs or by providing convenient hand rails.

c. **Strength** Older people generally have a decline in strength; this requires a reduction in the forces or moments necessary to perform materials handling or manipulation tasks. Analysis of materials handling tasks can be carried out using the NIOSH lift equation, the Liberty Mutual Tables and various other ergonomics analysis tools, such as RULA. Interpretation of the results of such analyses for the strength characteristics of the Singapore population can be carried out by reducing the derived index cut off point.

d. **Speed** Older people are generally slower than younger people in the time it takes for task completion, despite similar amounts of “effort.” Thus it is necessary to make allowances in job content and pacing.

e. **Stamina** Older people generally have reduced ability to perform physical work over time (Stamina) because of decreased cardiac, respiratory and muscular capacities. The rate of decline may be offset to some extent by physical training, but usually the decline is increased by diseases associated with disuse and abuse, such as heart conditions and osteo arthritis. In work terms this involves the reduction of distances and

loads or an increased time to accomplish materials handling or walking tasks. There are numerous performance measures of individual fitness, but these are not usually used in the ergonomics and work design context. Tools that can be used include estimates of the caloric demands of jobs or subjective estimates of physical stress, such as the Borg scale.

f. **Intensity** Intensity is a characteristic of size, brightness, loudness, force etc. Such variables are generally perceived in the context of "noise" or distracting background information. Older people require greater signal to noise ratios in the presentation of visual, audible, touch, taste, smell and force information. The distracting effects of noise also require greater concentration / effort on the task at hand; older people find background "noise" especially irritating. Tasks designed for older people should seek to minimize distractions such as audible noise or peripheral activity / movement.

g. **Information** The information content of tasks in terms of understanding, decision difficulty or memory needs to be reduced to offset the decline in these capabilities associated with ageing. However such declines can be offset by experience and practice. Older people may require longer times and more practice to acquire specific information handling and control skills. As with physical tasks the remedy for information intensive tasks is a reduction of the task demands imposed on elderly employees.

Older people have difficulty or delays in switching attention; they are particularly attracted to familiar and salient stimuli. Paradoxically they also have a lower tolerance for sustained attention or vigilance. Tasks that require the rapid shifting of attention, such short duration customer relations transactions or process control (e.g. driving) should be designed to provide more time for attention shifts. Tasks that require long periods of focused attention, such as inspection or monitoring tasks should be alternated with less demanding, perhaps more physical tasks.

The ability to deal with complexity and to "multi-task" declines with age. Older people should be given the opportunity to self-pace their tasks and avoid interruptions / distractions. Working or operational memory decline is a notorious characteristic of ageing. Tasks should be designed to limit the demands on working memory or supplemented by the provision of memory aids. Examples include the literal transfer of information such as codes – sequences of numbers, acronyms, abbreviations; these sequences should be kept as short as possible or grouped, and replaced by meaningful information wherever feasible. Semantic long term memory persists and is consolidated with age. Older people perform better with familiar tasks than with high information content tasks. Decision making capabilities also decline especially where decision difficulty is increased. The ergonomics interventions include increasing the ease of decisions by increasing signal to noise ratios or probabilities associated with the correct decision.

h. **Context** The physical, operational and social context of tasks must be managed to reduce their distracting effects on task focus and performance. Older people are less tolerant of extreme or sub extreme physical environments, such as light, heat and noise. For example visual decline requires that greater amounts of lighting are required for fine detail perception.

i. **Time** All the previously mentioned factors (space, force, information, and context) are time dependent. At one extreme it may be necessary to reduce the exposure duration or repetition frequencies; while at the other extreme human functions may be facilitated by providing more time.

j. **Affect** Older people generally prefer the familiar to the novel. This affective characteristic should be addressed by reducing the amount of change associated with any task, function or context. Older people may be hypersensitive to overt changes associated with ageing, such as body shape, strength and stamina and sensory, cognitive, memory and motor abilities. Such sensitivities may create stress, generate over reactive behaviors and exacerbate performance decrements.

k. **Learning and Training** Older adults will respond positively to learning or training opportunities and thus increase their resilience in the face of task stressors. To be successful these learning and training opportunities should be graduated, individually paced and combined with positive feedback of success and clear, non-punitive feedback associated with failure. Generally older people are slower than younger people at learning new procedures and skills. Therefore the learning process should be addressed in designing products and procedures for use by older people. A particular difficulty is found when older people use products or procedures infrequently. This issue is addressed by improving the memorability of products and procedures by highlighting important features and sequences and removing distractions. A negative effect of learning commonly experienced by older people is that previously acquired stimulus response relationships, including both correct and incorrect relationships persist. Therefore tasks requiring new or changed relationships should be avoided. The "repetition of errors" problem requires more extensive rehabilitation and even then, when an individual is under stress, the old incorrect response may be selected. Part task training, based on previously acquired skills and a global overview of the overall process, should be self-paced and applied with clear positive feedback

l. **Combinations** Most everyday tasks involve combinations of the stressors described above. The complexity and impact of these combinations should be reduced.

9. **Strategies**

a. **Research and Development** The phenomenon of aging and mechanisms to reduce the functional implications of ageing have both received considerable attention over the past two decades. There exist in Singapore many opportunities for both basic research into ageing and employment and applied research and development to accommodate the ageing workforce.

b. **New Technology** "Designing for Older Adults", Fisk et al (2004) describes the challenges faced by older people and design opportunities to assist them in their daily functions. One focus of this book is towards the challenges faced by elderly people with contemporary information technology, such as smart phones, tablets and the internet, and various automated service interfaces, such as banking, ticket purchase. A third exploration opportunity is on-line shopping, which has the advantage of reducing personal journeys, but the disadvantage of non user friendly error correction. Currently older people are reluctant to use this technology – this presents a research opportunity into the general issue of adoption of contemporary technology by older people.

c. **Transportation** The General Motors ACCESS Car program in 1988 – 1989 was focused on the challenges faced by older drivers and interventions that could make their experience more successful. This program had both practical and commercial intentions. This program explored physical, cognitive, medical, behavioral and social characteristics, capabilities, limitations and aspirations of the elderly car user. Many of the products of this research program have been incorporated in contemporary vehicles. However the transportation alternatives for older adults merits continued investigation. One strategy that is particularly appropriate for Singapore is to explore the various alternatives to personal and mass transportation through expansion of taxi, small bus and other for hire services. Another local transportation opportunity is in the expansion of small electrically powered personal vehicles.

d. **Employment** A second aspect of the ACCESS program addressed the challenges faced by the older worker in vehicle manufacturing. Auto workers in the USA are represented by a strong and sometimes combative union – the United Auto Workers (UAW). The cornerstone of unionism is that of seniority where individuals with longer service in the company had first choice of jobs. This policy would often result in "bumping" where more senior employees would replace junior ones in a desirable job (such as fork truck driving around the plant.) Generally speaking seniority is correlated with age, so this policy provided a rational basis for self-selection to protect older workers from the more (perceived) stressful jobs. This principle of self-selection based on age and seniority is relevant in Singapore. However, the precise mechanism requires incisive research, including field research in selected organizations.

e. **Physical Work Design** The physical characteristics, capabilities and limitations (Size, Shape, Strength, Speed, Stamina) of Singaporeans are different from those of their Western counterparts for whom extensive data exist. Furthermore many of the work

analysis and design models that exist are based on this Western data. A major research thrust should be a comprehensive survey of the Singaporean population in areas such as anthropometry, biomechanics and work physiology, with particular reference to age related differences.

f. **Education and Training** Management, unions and employees should receive formal training regarding the processes and effects of aging, and the choice of engineering and administrative interventions. A comprehensive program should be developed to communicate ergonomics principles to management, ergonomics monitors, ergonomics specialists and employees with particular focus on the effects of aging. The material for such education and training programs should be a blend of basic science, human science and mathematics, outcomes associated with appropriate and inappropriate equipment, workplace and job designs, and a collection of ergonomics analysis tools and design guidelines. There is also a shortage of ergonomics practitioners at the Doctorate and Masters levels in Singapore. Specific provisions should be made to support education and research programs in Ergonomics and Safety in Singapore's tertiary education institutions.

g. **Product Design** Older people tend to favor familiar products and functions, and need concrete evidence of the utility of new products before they adopt them. Products for older people should be designed for basic functions without the distraction of unused optional functions. This issue is especially important where errors in product use lead to difficult mitigation or recovery pathways. Such frustrations are behind the reluctance of older people to adopt new products. Products that require manipulation should provide appropriate control and grip surfaces, forces and targets. Examples include smart phone interfaces and the many similar fixed and portable devices such as personal medical products, remote controllers, timepieces and vehicle controls.

h. **Workplace Design** The spatial, contextual and operational arrangements of workplaces should accommodate the reach, fit and limited mobility of older adults. Materials, tools, equipment, assists and products should be arranged conveniently at the discretion of the older worker. Workplace design strategies should be considered along with operations design changes and geared towards providing physical variety rather than long duration fixed postures. Examples include the provision of variable height work surfaces and seats along with the operational requirement for postural variety.

i. **Sensory Interface Design** The deterioration of sensory processes, especially vision and hearing, should be addressed by increasing intensity, size and contrast. An initial strategy for vision is the provision of higher levels of general and task lighting and the avoidance of shadows and reflected glare. A second strategy to accommodate the vision deficits of older people is to design adjustability into task interfaces. An example of such adjustability is the gesture based zoom function in touch screen devices. Another intervention in hard copy material is to increase the minimum font size and item contrasts. Hearing decline among older workers is a particularly troublesome issue, both for the reliability of communication and the frustration associated with unheard or

misinterpreted communications. To some extent this issue can be resolved by “volume control”, but a more insidious problem is signal to noise ratio. Older people perform better acoustically when the background noise levels are reduced. Similar sensory declines associated with ageing occur in the other senses, such as touch, taste and smell. Where these senses are important for task function the interfaces should provide greater intensity and discrimination levels.

j. **Cognitive Interface Design** The cognitive interface should involve simple compatible relationships, task sequences and feedback. The cognitive interface between people and their tasks is perhaps the greatest challenge associated with aging. Whereas the cognitive interface is improved by experience in familiar tasks, tasks with higher information content and choice are both harder to perform and harder to learn by older people. One consequence is an increased probability of error; another is an increased amount of time taken to perform a given task. Where the task is externally paced this increased time demand may also lead to an increased probability of error. An example of these problems in cognitive interface design is in the familiar task of driving. Older people are slower and less reliable at making key decisions, such as stopping at lights, braking, clearances, and lane changes. Whereas some compensation is possible through slower driving, the individual cannot control the behaviors and speeds of other drivers. The strategy for cognitive task design for older people lies in analysis and design on the one hand and appropriate facilitators and training on the other. The strategic responsibility for these interventions is dependent on detailed cognitive task analysis followed by appropriate equipment, interface and operations choices. Next supervision is responsible for appropriate training and task assignment. An example of a complex cognitive task can be found in the checkout jobs in grocery and other stores, especially those with a wide variety of products and services. Whereas technology, such as bar codes and readers, goes some way towards the avoidance of errors, employees are continually faced with resolving exceptions, either introduced by the customer or by a change of store policy, such as the introduction of temporary price reductions. A general strategy for addressing the declining cognitive abilities of older people is the provision of less complexity and greater learning time, accompanied by sensitive learning strategies that build on previous knowledge.

k. **Operations Design**. Many functions required of older adults can be achieved effectively and safely if more time is made available. One strategy suited to older adults is to substitute self-paced work for line or team based work. Other strategies can be to assign older adults to trouble shooting tasks that make use of their experience. One phrase that is often used by older employees regarding workplace procedures is “we have always done it this way.” On the one hand this may be an appropriate use of experience. On the other hand it may simply be a defense mechanism against change. Operations design is also affected by new technology, such as internet forums, webinars, cloud computing, shared files, social, company and professional networks, apps for personal smart phones and so on. Older employees may be reluctant to adopt

such changes or need more time or specialized instruction to facilitate these contemporary business processes.

l. **Job Design** Older people may tire more quickly that younger people thus a useful intervention is to expect less work output and reduce the length of the work day or week. Such a strategy my involve less financial rewards but may offer satisfying and motivating employment. In general older adults do not respond well to the challenges of shift work or commuting. Opportunities can be explored for shorter, non-rotating shifts that avoid the commuter rush hours. Older people are particularly motivated by task content and success. Tasks should be designed so that procedures and objectives are clear and feedback provided in a timely and unequivocal manner.

m. **Context Design** The design and maintenance of the physical, operational and social context of the work place and job should address unwanted "hygiene factors" that serve to demotivate the older adult. Examples of these "hygiene factors" include extreme and fluctuating physical, operational, procedural, supervisory and job compensation stresses. Older adults are more comfortable with predictable contexts and may become uncomfortable with sudden contextual changes that may either threaten their position or procedures.

n. **Assistive Technology** Older workers may function satisfactorily with the help of assistive technology such as aids to mobility, postural support, materials handling, vision, hearing, materials and tool support, manipulation etc. Such aids may have the unwanted effect of increasing task time, however they will generally reduce the likelihood of physical injury and increase the consistency and quality of physical operations. Cognitive decline may be compensated for by appropriate job aids, such as user friendly instructions and procedures.

10. A Discounting Model for Physical Work Design

a. The NIOSH lift equation is a "discounting model". The actual physical load is divided by a theoretical maximum load which is multiplied by a series of fractions according to the spatial and temporal conditions of work to produce a "Lift Index". Critics of this model argue that it is invalid in the context of other work stressors not accounted for in the equation. Other critics question the accuracy and precision of the discounting factors. One particular criticism is that the discounting factors are linear, whereas in reality a non linear model may be more accurate. Despite these criticisms the method is logical and intuitive, and has stood the test of time to emerge as one of the most widely used tools in physical ergonomics.
Peacock B. (2004) A Discounting Model for Task Design, Applied Ergonomics Conference, IIE, Orlando, Florida

b. The principles of this discounting model may be used to assess personal factors, such as age and sex, environmental factors, such as heat, and other factors including physical encumbrance imposed by heavy restrictive clothing, such as a fireman's turnouts or a space suit. Because of human physical capability variability, no single values for the discounting factors will be accurate. Consequently the model should be used as a guideline for task analysis and design rather than an absolute standard.

c. The model is derived as follows:
   i. A hypothetically maximum possible task for a well-conditioned and trained young male is set as 100%.
   ii. The following discounting factors are then applied:

iii.	Female	* 0.7	
iv.	Age	*(1 - (age – 30)*2/100)	
v.	Thermal environment	*(1- (^{O}C - 20)*5 / 100)	
vi.	Task encumbrance	*(1 – (kg*2/100))	(clothing and load)
vii.	Task spatial context	*(1-(Distance from hips (cm)* 1/100))	
viii.	Horizontal distance factor	*(1-(Distance moved (meters)*0.01/100))	
ix.	Vertical distance factor	*(1-(Vertical distance climbed (meters)*2/100))	
x.	Task Intensity	*(1-(Exertions per minute*10/100))	
xi.	Task Duration Factor	*(1-(Shift Length (hours)*5/100))	

d. Note that all these discounting factors are linear and the suggested parameters may be subject to debate. Also for each factor the multiplier declines to zero when a maximum stressor level is reached. For a given task some or all the factors may be applied. The NIOSH Lift Equation multipliers may be substituted for the above task factors.

e. **Conclusion** The older employee can make important contributions to the productivity of all industry sectors. Also the continued employment of older people enhances their independence and reduces the atrophy associated with a reduction of physical, cognitive and social demands. However this continued employment must be intrinsically motivating and appropriately rewarding. Task contexts must also be

designed to reduce the unwanted stressors arising from physical and operational environments. Finally job design should be sensitive to the characteristics, capabilities, limitations and aspirations of older people.

11. A Preliminary Workability Index

There exist many validated and incisive ergonomics research, analysis and evaluation tools and standards that vary from simple checklists, through more elaborate worksheets to high level analysis and simulations. This preliminary design of a Singapore Workability Index is derived from extensive experience with many workplace ergonomics tools (see Appendix) This device will be evaluated and improved and adapted for widespread use throughout Singapore manufacturing and service industries.