



Environment and the Productive Workplace

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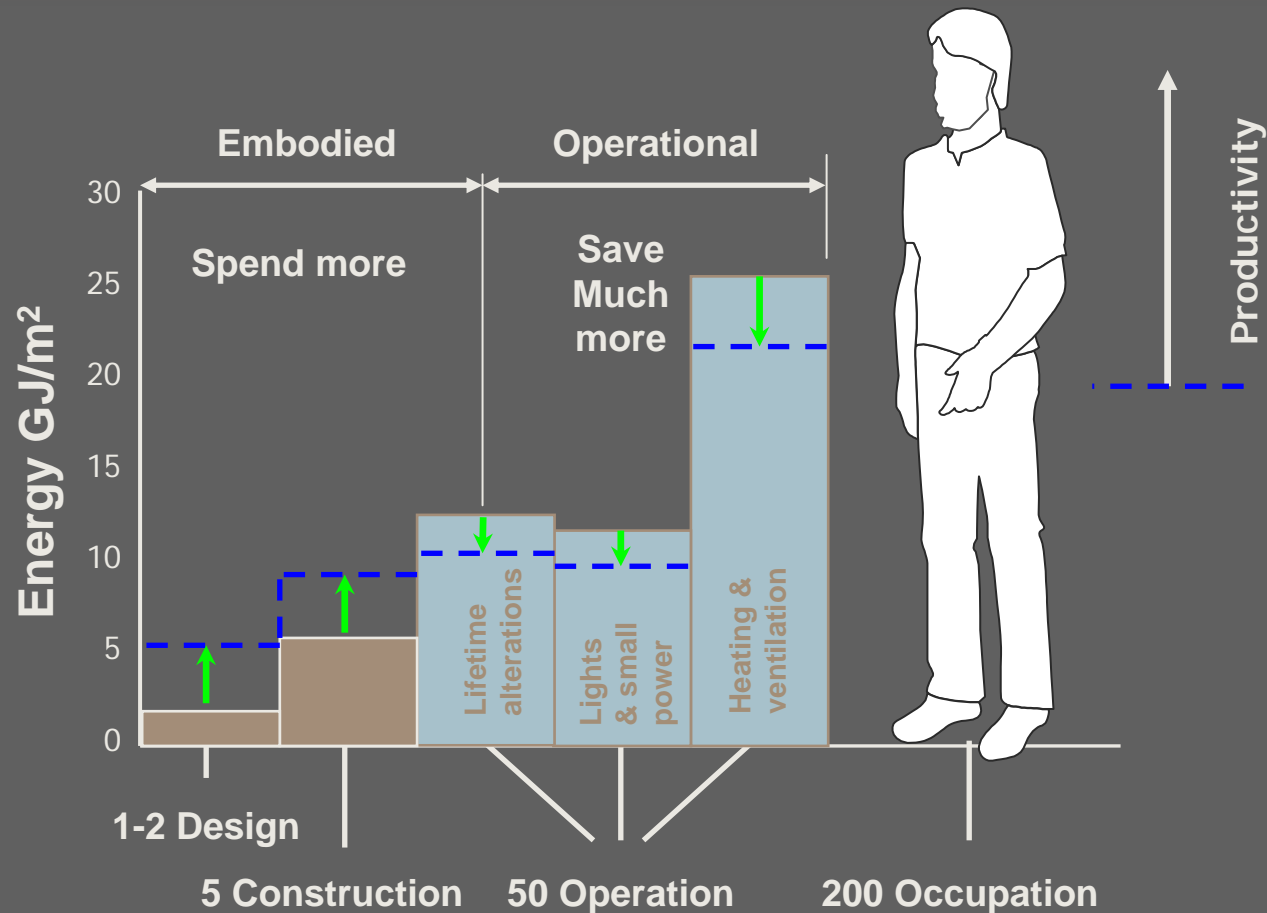
The University of Reading

The south side of MIT's new Stata Centre, designed by Frank Gehry. University officials sought an unconventional building to inspire creativity

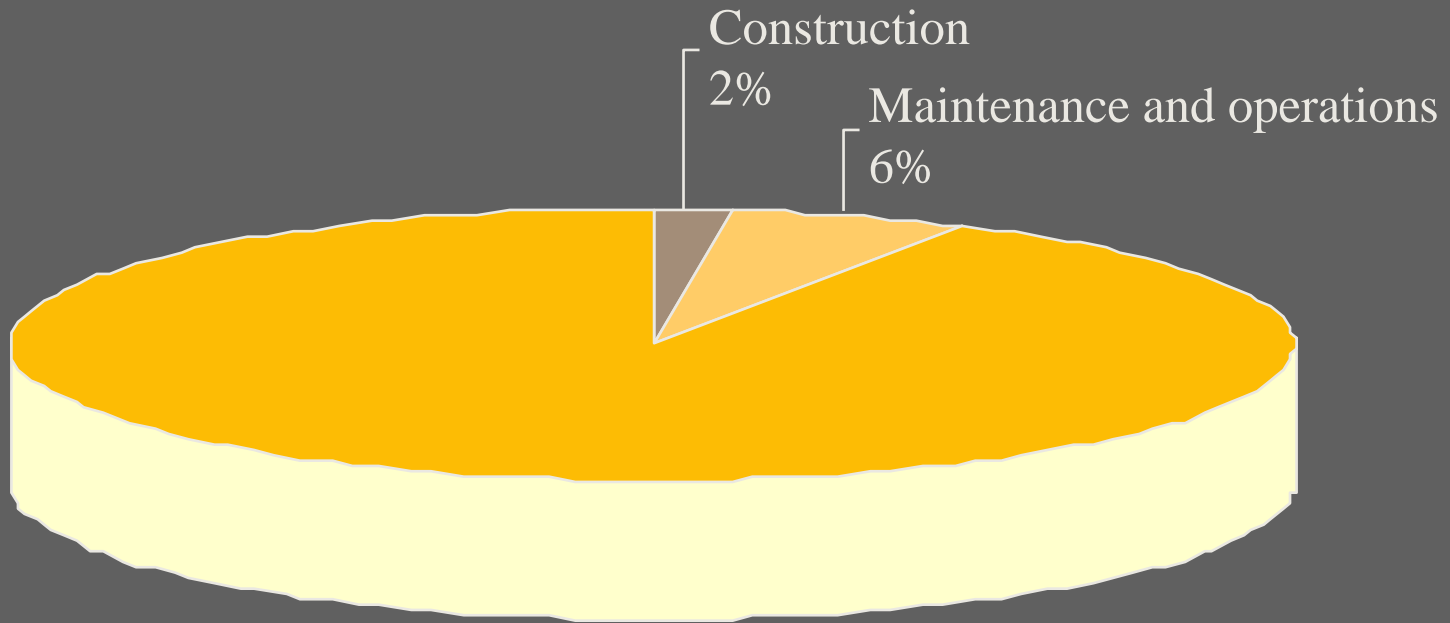


Canada Associated Press 5 May 2004

Embodied, Operational Energy and the Opportunity for Productivity Gains in an Office



Costs of Organisations



Salary costs over buildings life cycle
92%

A well designed office can increase productivity by as much as 15% of a worker's annual salary

*Source: Using Office Design to increase Productivity
Buffalo Organization for Social and Technical Innovation
Michael Brill, President (1987)*

Sacramento Municipal Group Utility District

INCOMING CALL CENTRE WORKER PERFORMANCE

- ⇒ Workers with the *best view* were found to process calls *6% to 12% faster* than those that had no view.
- ⇒ Employees with workstations having *partitioned heights above eye level* on two sides performed *11% to 18% slower* than those with partitions below eye level.
- ⇒ Total variation observed in performance was *2% to 4% in environmental conditions* and *6% to 19% demographic and management information*.

Sacramento Municipal Group Utility District

INCOMING CALL CENTRE WORKER PERFORMANCE

- ⇒ A small increase in air temperature can slow worker performance (74°F to 76°F reduced worker performance by 2%)
- ⇒ Good ventilation and cooler conditions let people work faster. Increasing the rate of outside air by 1ft³/min resulted in 4% faster handling of calls.
- ⇒ *10% improvement in Call Centre worker performance is worth saving a \$9,000 per year employee or \$118/ft² per year. Typical low rise office construction costs in California are \$85/ft² to \$121/ft² hence improving worker performance by 10% would justify doubling construction costs while maintaining a one year payback on investment.*

Effect of the workplace on staff productivity

Productivity issue	Source	Productivity (%)	Confidence
Mean total downtime due to poor facilities, e.g. walking to/waiting at faxes and copiers	Oseland & Bartlett	-12.5	✓ ✓
Increased illuminance from 550 to 1100 lux for paper-based work	Barnaby	+2.8	✓ ✓
Increased illuminance from 100 to 1000 lux for textile plant	Čabák	+20.0	✓ ✓
Introduction of up-lighting for VDU work	Hedge <i>et al</i>	+3.0	✓ ✓
Lighting refurbishment in aircraft production	Romm &	+20.0	✓ ✓
Lighting refurbishment in designers office	Browning	+15.0	✓ ✓
Lighting refurbishment in drawing office		+13.0	✓ ✓
Increasing noise by 10 dB in post room	Kourigin & Mikheyen	-25.0	✓ ✓ ✓
Reducing noise (using ear plugs) for industrial weavers	Weston & Adams	+12.0	✓
Reducing noise in assembly room	Kryter	+68.0	✓

Effect of the workplace on staff productivity

Introducing sound absorbing material into wall of typing pool	Wilson	+29.0	✓
Extreme temperatures in munitions factories	Fox	-30.0	✓ ✓
Warm temperatures in summer months of tin-plate manufacturer	Vernon	-10.0	✓ ✓
High temperature in coal mine	Vernon <i>et al</i>	-27.0	✓ ✓
Introducing AC into utility company		+50.0	✓
Introducing AC into leather manufacturer	Scweisheimer	+8.5	✓
Introducing AC into electrical manufacturing		+3.5	✓
Uncomfortable conditions in typing pool	Wyon	-40.0	✓
Increasing fresh air intake to dilute pollutants	Kemp & Dingle	+3.0	✓
Bringing offices up to current IAQ standards	Dorgan	+4.0	✓
Moving from NV to AC office	Sterling	-6.0	✓
Comparison of NV versus AC offices	Oseland	+3.0	✓

Effect of the workplace on staff productivity

Control over environmental conditions	Drake <i>et al</i>	+9.0	✓ ✓
Control over environmental conditions	Kroner <i>et al</i>	+2.8	✓ ✓ ✓
Office refurbishment		+12.9	✓ ✓ ✓
Refurbishment of bank	Romm &	+15.0	✓ ✓
Office refurbishment of post sorting office	Browning	+6.0	✓ ✓ ✓
Office refurbishment and restructuring	Sullivan	+67.0	✓ ✓
New furniture		+15.0	✓ ✓ ✓
Properly design workstation	Springer	+10.0	✓
Increasing privacy through cellular offices	Brill <i>et al</i>	+12.3	✓
Voice response systems in call-up centres	Lewis	+10.0	✓ ✓
General improvement in environment	Wyon	+15.0	✓
General improvement in environment	Brill <i>et al</i>	+15.0	✓

The ticks indicate level of confidence in the study, where 3 ticks is the highest confidence

High Performance Buildings Conference

Non-Energy Effects Reported (N=26)	+%	-%
Increased employee morale & satisfaction	30	8
Decreased operating cost (non-energy)	30	-
Decreased maintenance costs	19	4
Increased productivity	19	-
Increased equipment life	19	-
Decreased waste generation	15	-
Decreased illness & injuries	15	4
Decreased personnel needs	11	4
Decreased defects & error rates	4	-

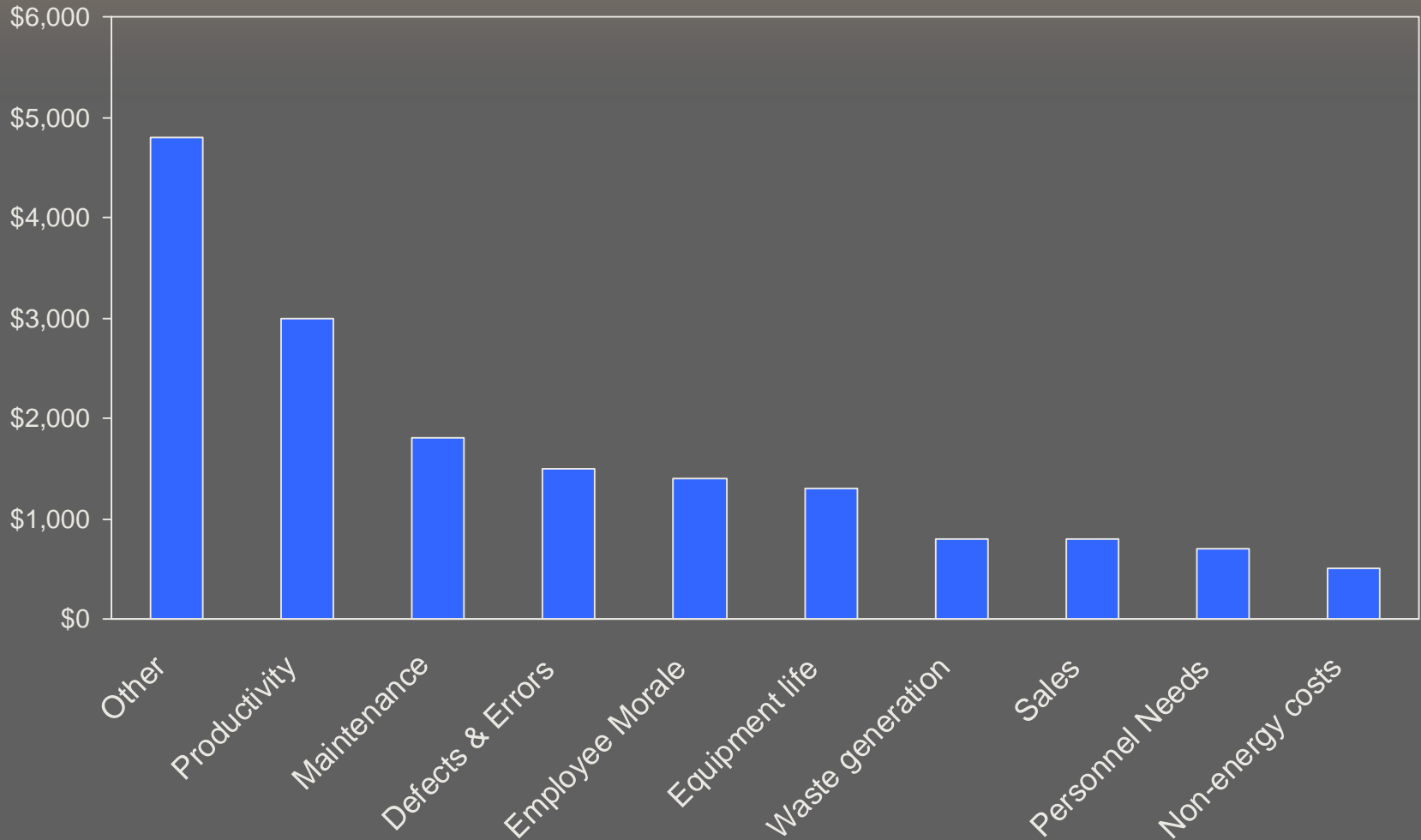
Non-Energy Benefits Brown Bag Seminar (Nick Hall 2004)
Association of Energy Service Professionals International (AESP)

Advanced Management for Compressed Air Systems Workshop

Non-Energy Effects Reported (N=26)	+%	-%
Increased employee morale & satisfaction	27	7
Decreased operating cost (non-energy)	47	7
Decreased maintenance costs	40	-
Increased productivity	33	-
Increased equipment life	7	-
Decreased waste generation	20	-
Decreased personnel needs	13	-
Decreased defects & error rates	20	7

Non-Energy Benefits Brown Bag Seminar (Nick Hall 2004)
Association of Energy Service Professionals International (AESP)

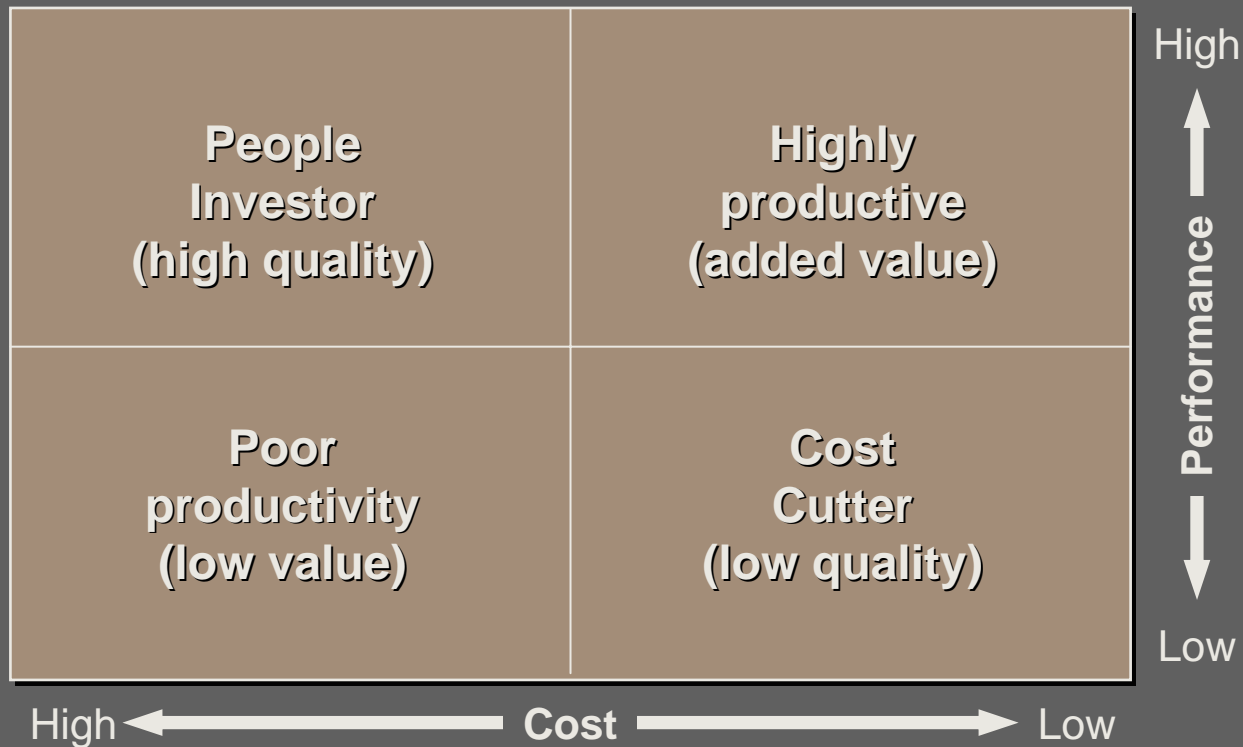
Mean Values of Non-Energy Benefits to all Respondents



Benefit Category (Nick Hall 2004)

Association of Energy Service Professionals International (AESP)

The relationship between cost and performance on productivity



Environmental factors affecting performance

Source paper	Factors affecting motivation, job satisfaction and performance
Aronoff and Kaplan	<i>Physical setting</i> , motivation, camaraderie, respect, satisfaction with goals, trade-offs, expectations and equity.
Arvey et al	<i>Locus of control</i> , neuroticism, affectivity related to job satisfaction, education, age, cognitive ability, socio-economic status, career goals, task identity, autonomy, skill variety, feedback, congruence between personality and work environment.
Bakke	<i>Job specification and requirements</i> , communication system, status, reward, pay, organisational charter, identity, knowing job, initiatives, job security, control, pride and self-respect.
Blackler and Williams	<i>Identity</i> , meaning of work, social interaction, responsibility to peer group, goal setting, equity, expectancy, group cohesiveness, peer pressure.
Brown	<i>Relationship with management</i> , relationship with co-workers, responsibility, pride of craft, selfrespect, status, sense of usefulness and control over work.
Sundstrom	<i>Responsibility and autonomy</i> , pay, job security, relationship with co-workers, promotion prospects, company policy, supervision, the work itself and physical environment.

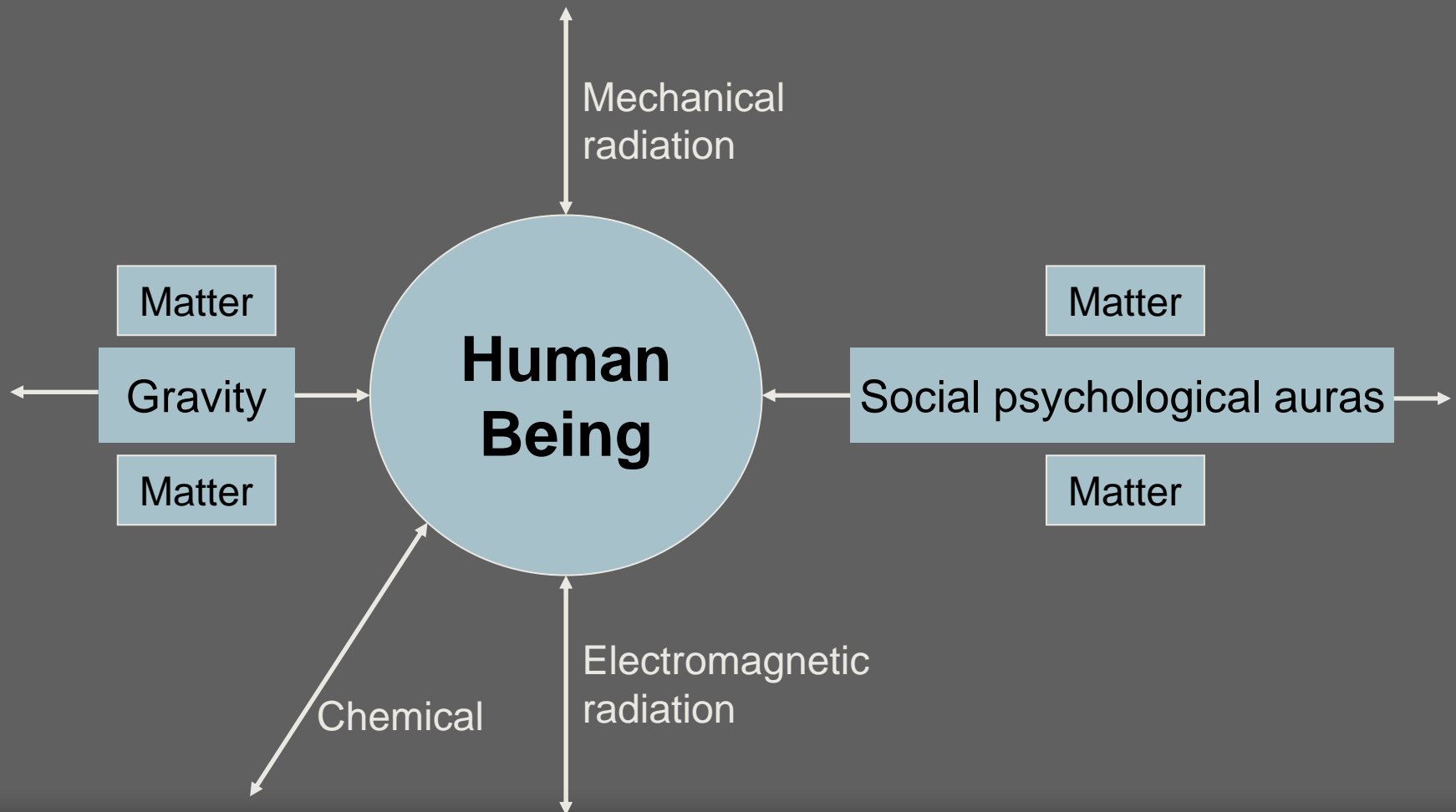
Achieving Maslow's hierarchy of needs in the workplace

Need	Achieved by
Physiological	Good working conditions, attractive salary, subsidised housing, free catering
Safety	Private health care, pension, safe working conditions, job security.
Social	Good relationships, team spirit, company sports, office parties, informal activities, open communication.
Esteem	Regular positive feedback, prestige job titles, write-up in company news sheets, promotion and reward.
Self-actualisation	Challenging job, discretion over work activity, promotion on opportunities, encouraging creativity, autonomy and responsibility

Deficiencies in these areas can rapidly fatigue office workers

- ⇒ Aural/acoustic quality
- ⇒ Visual illumination quality
- ⇒ Thermal quality
- ⇒ Air quality
- ⇒ Building amenities
- ⇒ Functional ergonomics

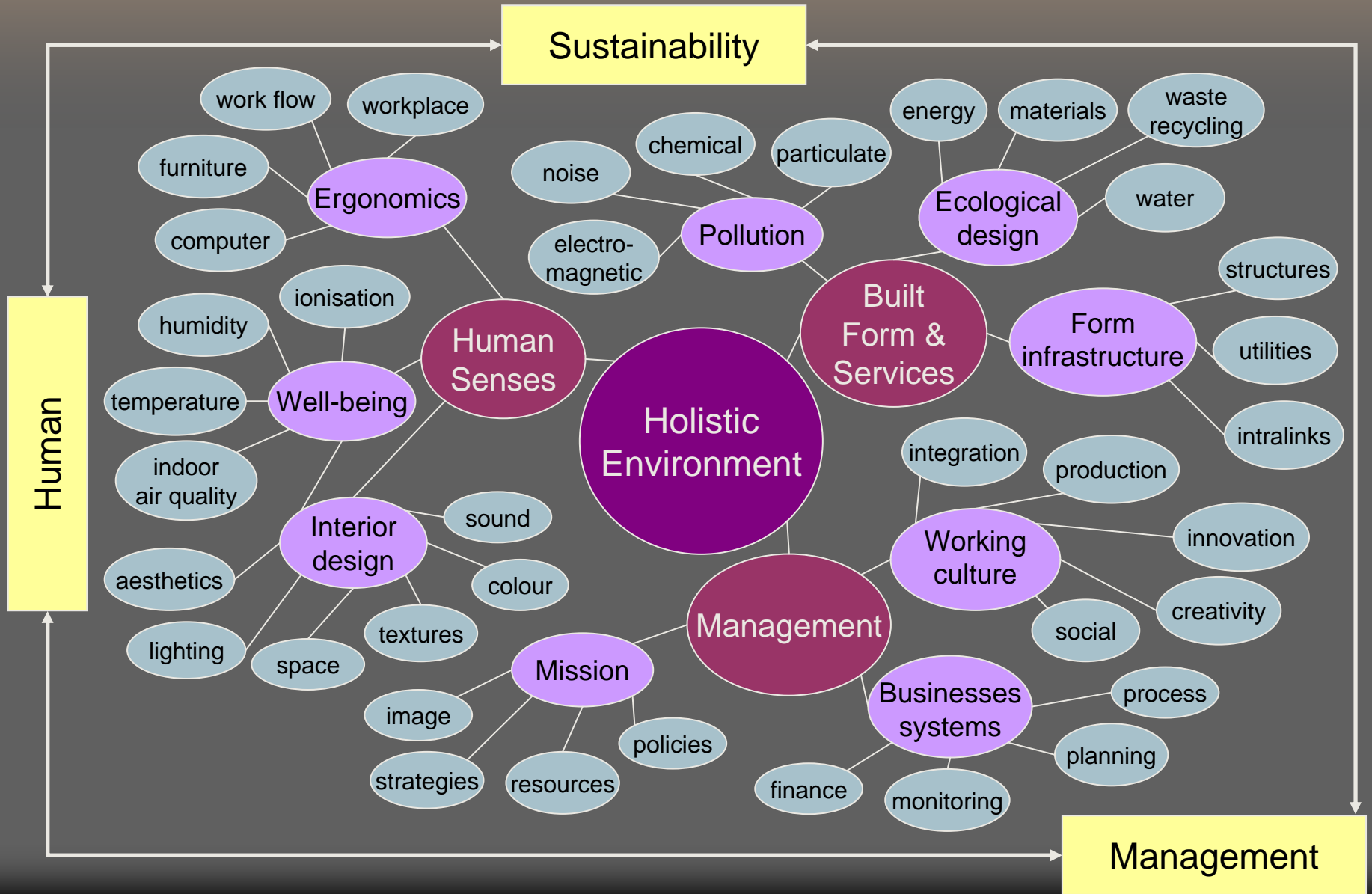
People, environments and matter



Effects of partial climates

Partial climate	Induces Organic Reactions	Stimulates Sensors Organs	Create Associations	Describes The Environment
Light	*	*	*	*
Sound	*	*	*	*
Smell	*	*	*	
Heat	*	*		
Air quality	*			
Electric climate	*			

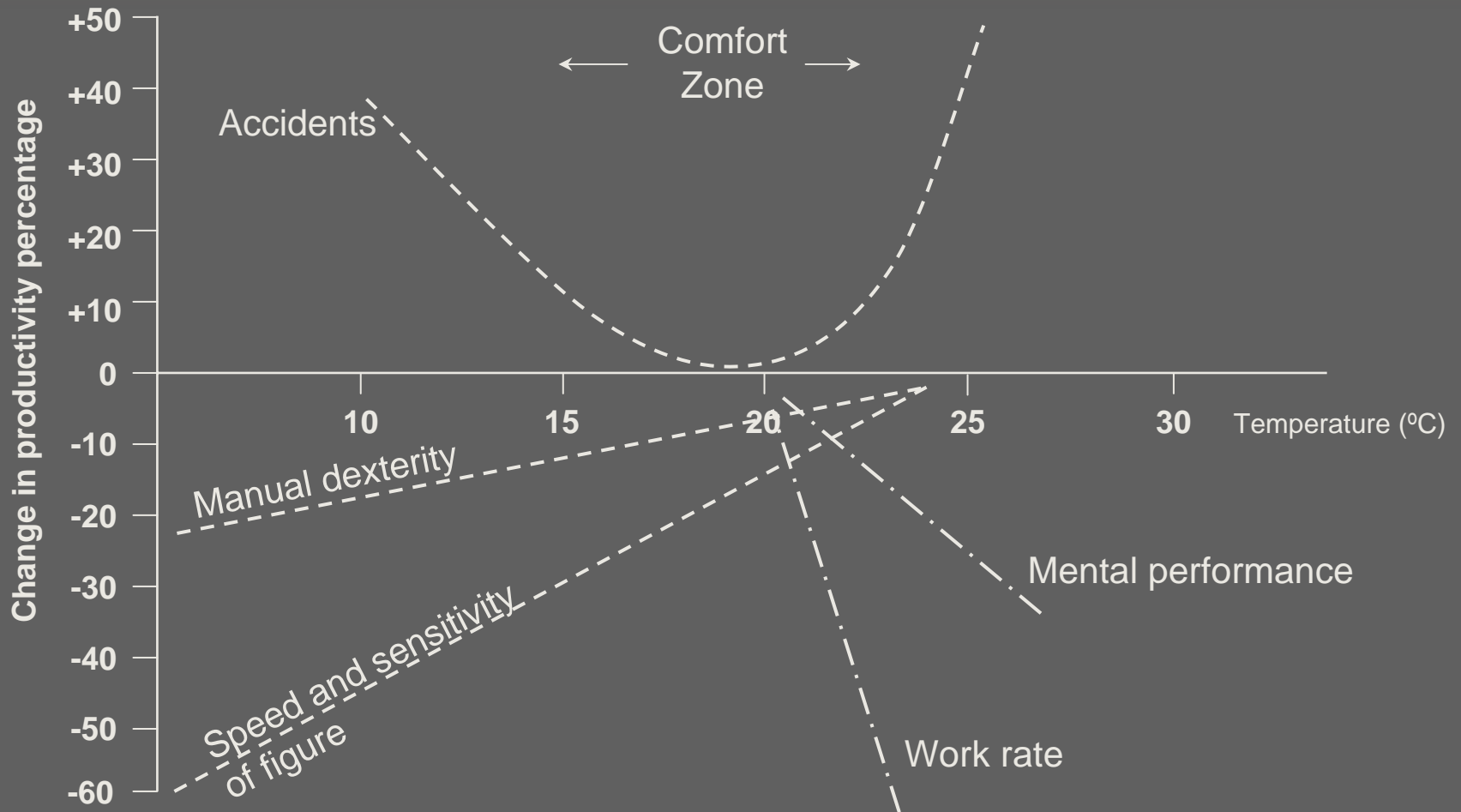
Holistic Environmental Model



Lorsch and Abdou (1994b)

- ⇒ *Conclude that temperatures which provide optimum comfort may not necessarily give rise to maximum efficiency in terms of work output.*
- ⇒ The difficulty here is that this may be true for relatively short periods of time, but if a person is feeling uncomfortable over a long period of time it may lead to a decrement in work performance.

The relationship between temperature and performance



Source: Wyon 1986, CIBSE, 1999

Indoor Environment and Productivity

- ⇒ Traditionally thermal comfort has been emphasised as being necessary in buildings, but *is comfort compatible with health and well-being? The mind and body need to be in a state of health and well-being for work and concentration.* This is a prime prerequisite for productivity. High productivity brings a sense of achievement for the individual as well as increased profits for the work organization.

Researcher	Method	Productivity	
		increase	decrease
Rohr and Brightman (2003) (USA)	Self-reported productivity	Increased space and daylight: reduce complaints	
Chao et al (2003) (Taiwan, USA)	Epidemiological longitudinal study using computer test		Wheezing shortness of breath: high temperature and relative humidity
Korhonen et al (2003) (Finland)	Self reported productivity		Temperatures higher than 24°C
Leyten and Booerstra (2003) (Holland)	review	good IAQ low pollutants: fresh air: temperature control: effective use of space	
Niskikawa et al (2003) (Japan)	Voice patterns	Low light levels (3 lux) can cause fatigue	
Nishihara et al (2003) (Japan)	Climate chamber using typing tasks	Individual control of air gives less fatigue	
Tanabe (2003) (Japan)	Climate chamber		fatigue
Kosenen and Tan (2003) (Finland, Singapore)	Theoretical study based on Fanger's work	Good IAQ: Occupancy density/ventilation rate: temperature	

Subjective Well-being

- ⇒ Awareness
- ⇒ Satisfaction with life
- ⇒ Comfort – discomfort
- ⇒ Good body – mental health

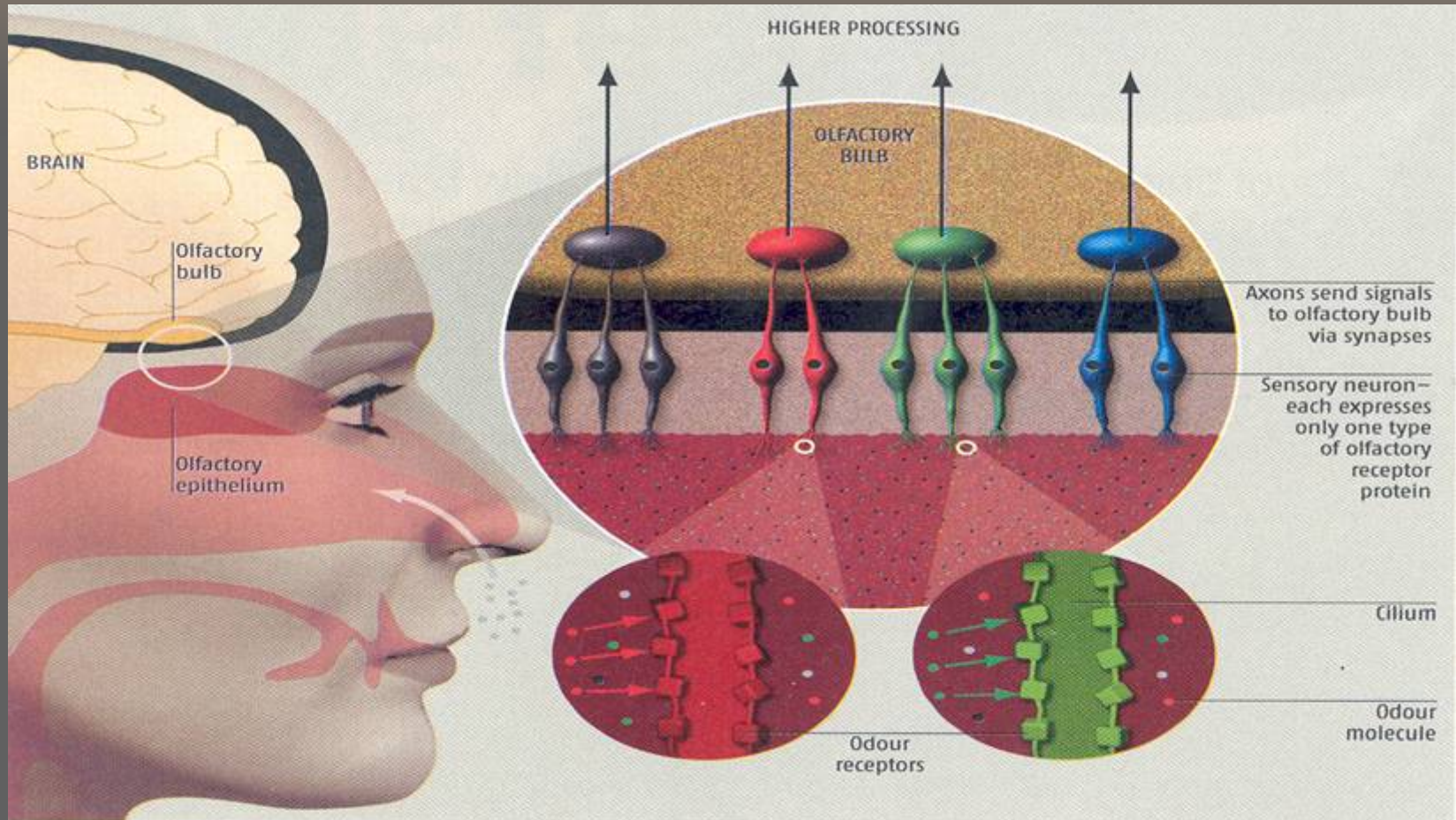
Architecture and the senses

- ⇒ Although the five basic senses are often studied as individual systems covering visual, auditory, taste–smell, orientation and the haptic sensations, *there is an interplay between the senses.*

In Buddhism there are nine levels of consciousness (Allwright, 1998)

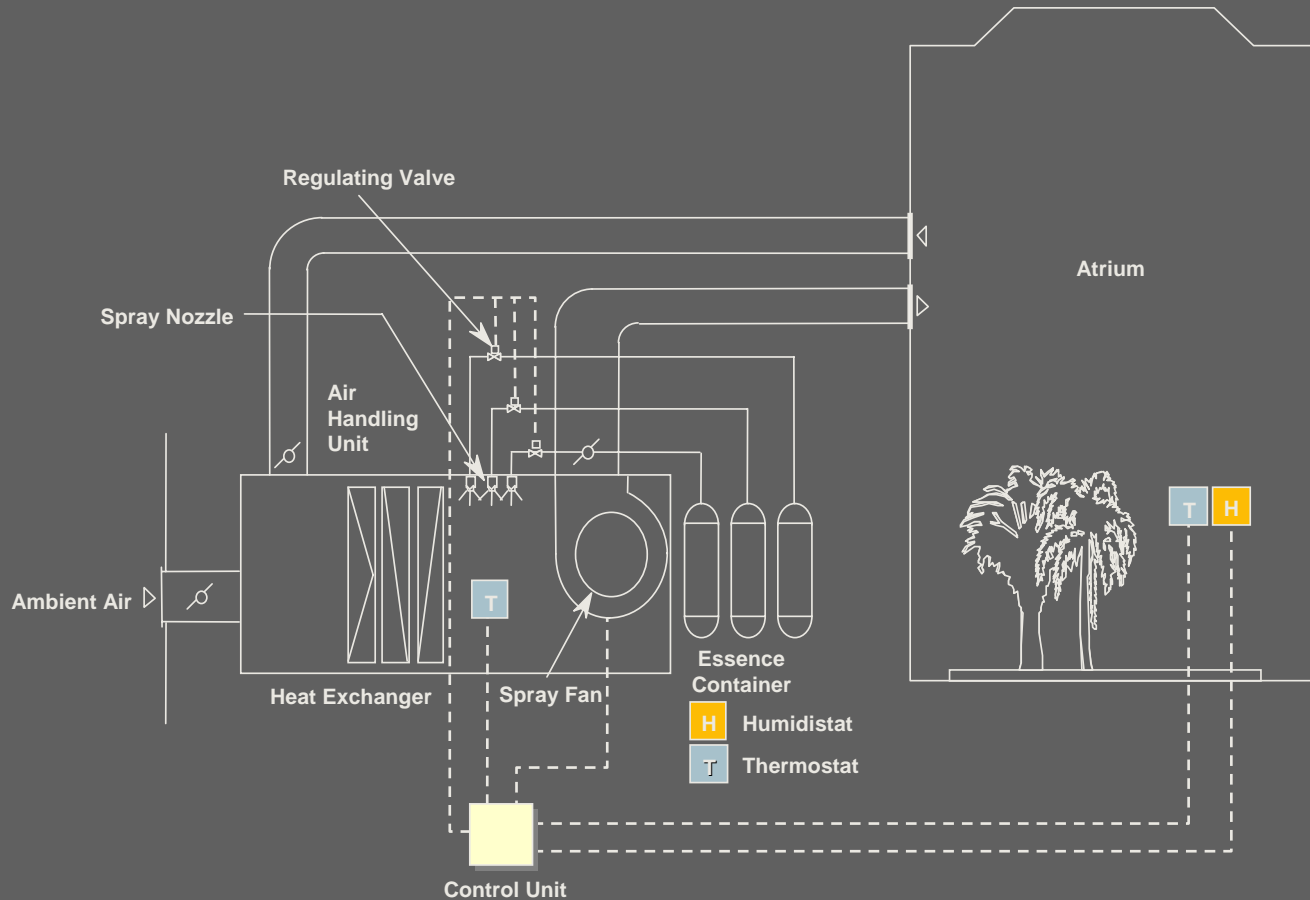
- ⇒ The **five senses** felt by the eyes, ears, nose mouth and skin
- ⇒ The **integration of senses** using reason and logic
- ⇒ **Rational thought** expressed via self awareness and intuition
- ⇒ The **stores of experience in the long and short term memories**
- ⇒ **Pure consciousness** within the inner self; this also involves emotion.

How do you smell?

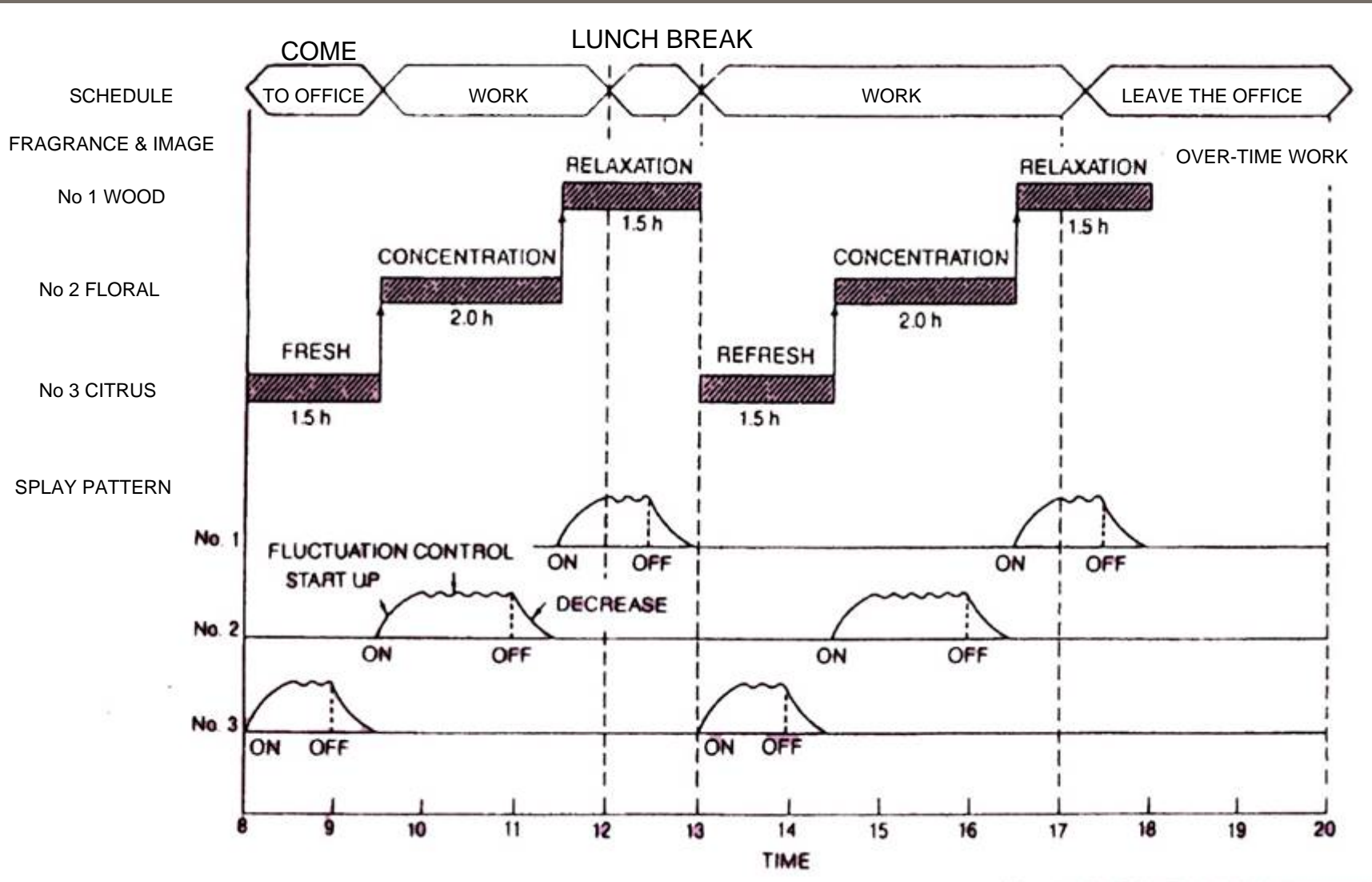


The average person has about 400 different types of olfactory reception, but not everyone has the same set

Atrium fragrance control system for Kajima building in Tokyo



Atrium fragrance and control scenario for Kajima building in Tokyo



Health Affects Productivity

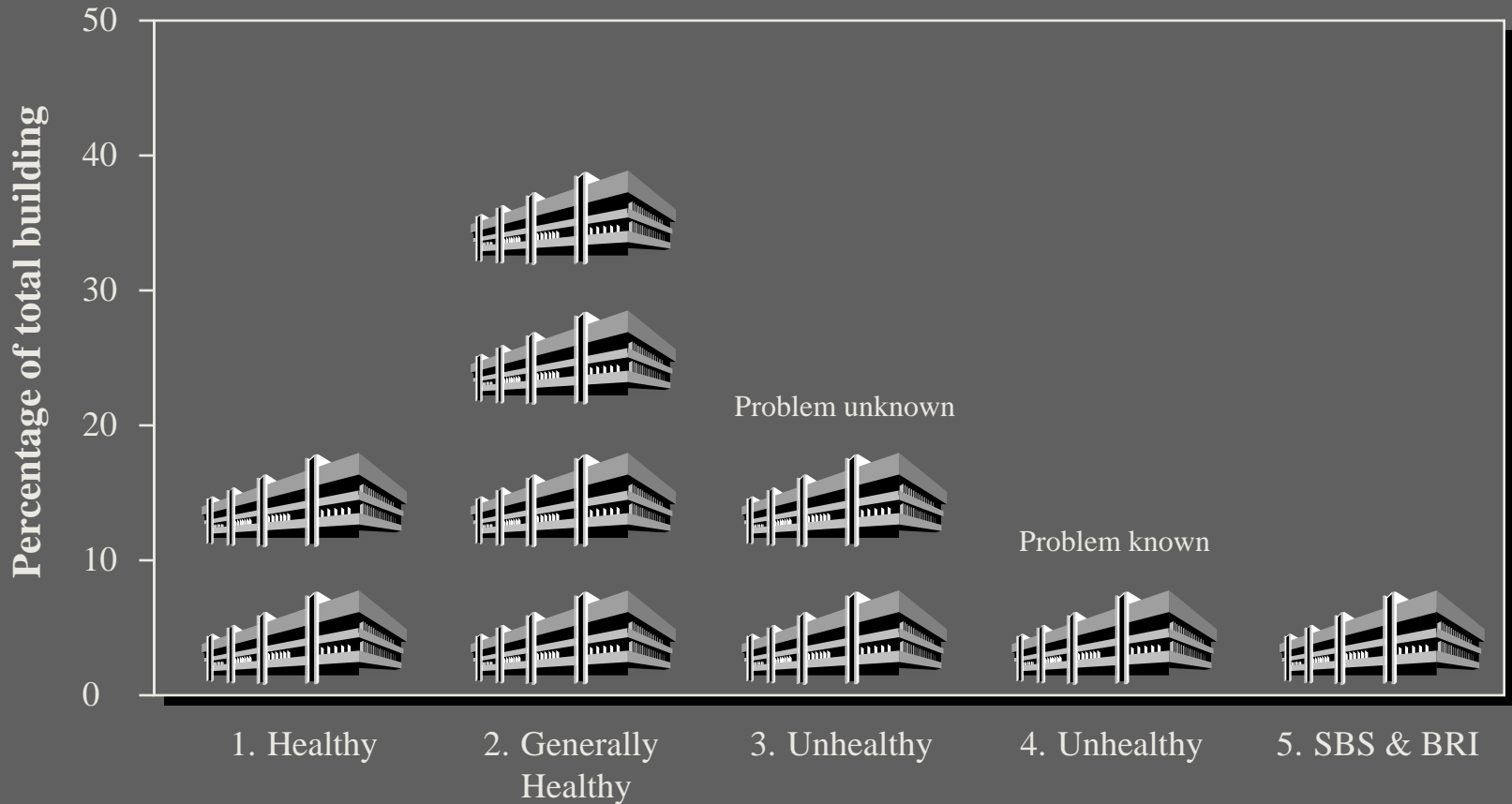
- ⇒ Productivity can be related to quality and satisfaction of the service or functional performance. Studies have shown that productivity at work bears a close relationship to the work environment. Burge (1987) demonstrates that there is a *strong relationship between self-reports of productivity and ill health symptoms related to buildings: productivity decreases as ill health symptoms increase.*

Burge (1987)

- ⇒ Conducted a study of *building sickness* among 4373 office workers in 42 UK office buildings having 47 different ventilation conditions. The data was further analysed by Raw (1990). The principal conclusions were that as *individuals reported more than two symptoms, the subjects reported a decrease in productivity.*

Buildings by health category

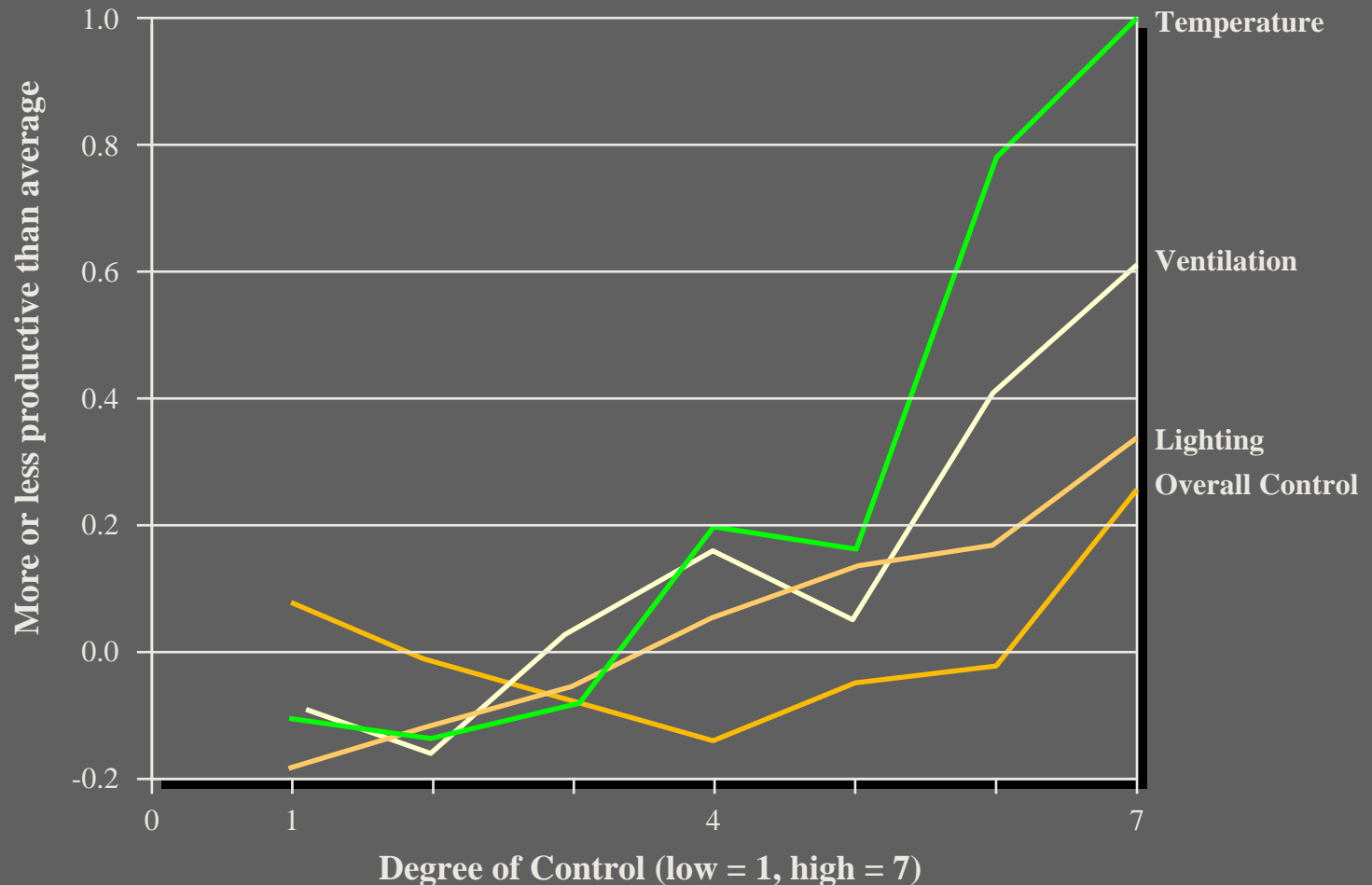
(Dorgan, 1994)



Estimated potential gains from improvements in indoor environments (Fisk, 1999)

Source of Productivity Gain	Potential Annual Health Benefits	Potential U.S. Annual Savings or Productivity Gain (1996 \$U.S.)
Reduced respiratory disease	16 to 37 million avoided cases of common cold or influenza	\$6 - \$14 billion
Reduced allergies and asthma	10% to 30% decrease in symptoms within 53 million allergy sufferers and 16 million asthmatics	\$2 - \$4 billion
Reduced sick building syndrome symptoms	20% to 50% reduction in SBS health symptoms experienced frequently at work by approximately 15 million workers	\$15 - \$38 billion
Improved worker performance from changes in thermal environment and lighting	Not applicable	\$20 - \$200 billion

Relationship between self-reports of productivity and levels of control over temperature, ventilation, lighting and overall control



Assessment of Productivity (Ilgen, 1991)

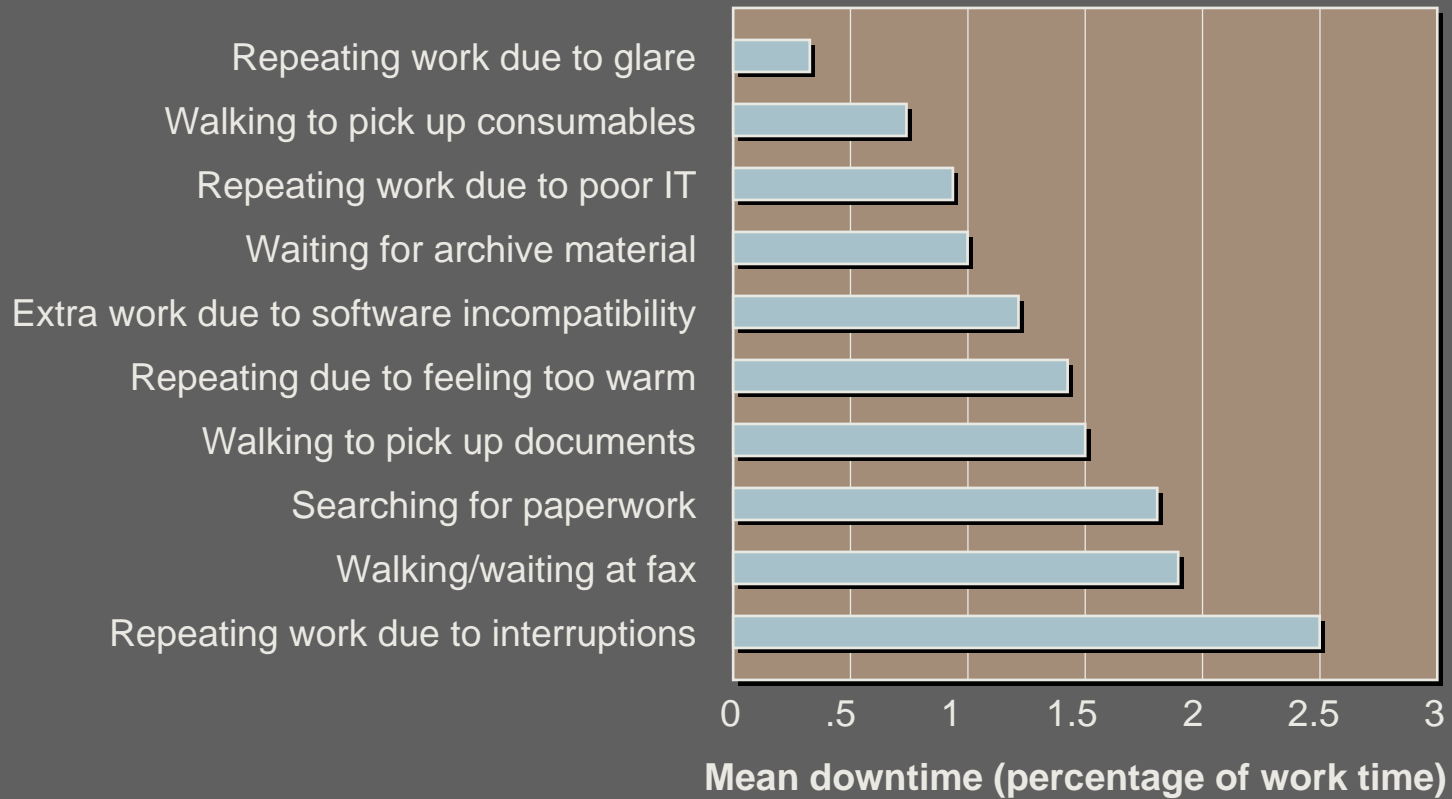
⇒ states that the methods of performance measurement can be classified into three categories:

- Physiological
- Objective
- Subjective

Indicators of increased productivity

- Performing tasks more accurately
- Performing faster without loss of accuracy
- Capability to perform longer without tiring
- Learning more effectively
- Being more creative
- Sustaining stress more effectively
- Working together more harmoniously
- Being more able to cope with unforeseen circumstances
- Feeling healthier and so spending more time at work
- Accepting more responsibility
- Responding more positively to requests

Average downtime attributed to a range of factors



Productivity Measures

- ➔ At an ASHRAE Workshop on Indoor Quality held in Baltimore in September 1992 the following productivity measures were recommended as being significant.
 - Absence from work, or work station.
 - Health costs including sick leave, accidents and injuries.
 - Interruptions to work.
 - Controlled independent judgements of work quality.
 - Self assessments of productivity.
 - Speed and accuracy of work.
 - Output from pre-existing work groups.
 - Cost for the product or service.
 - Exchanging output in response to graded reward.
 - Volunteer overtime.
 - Cycle time from initiation to completion of process.
 - Multiple measures at all organisational levels.
 - Visual measures of performance, health and well-being at work.
 - Development of measures and patterns of change over time.

Measures of Productivity

Absolute Methods	
Direct	Objective measures e.g. work output quality and speed
Indirect	Physiological measures e.g. brain rhythms
Comparative Methods	Rating scales, questionnaires, semi structured interviews

Measurement of Productivity

- ⇒ *Simulated work* where the subject performs a realistic but artificial task
- ⇒ *Diagnostic test* where the subject performs a test procedure unlike any real task
- ⇒ *Embedded tasks* where the outcome metric is derived from part of an existing task
- ⇒ *Existing measures* where the existing outcome metrics are made available
- ⇒ *Absenteeism* the records of sick leave are used, this may also be extended to include medical records.

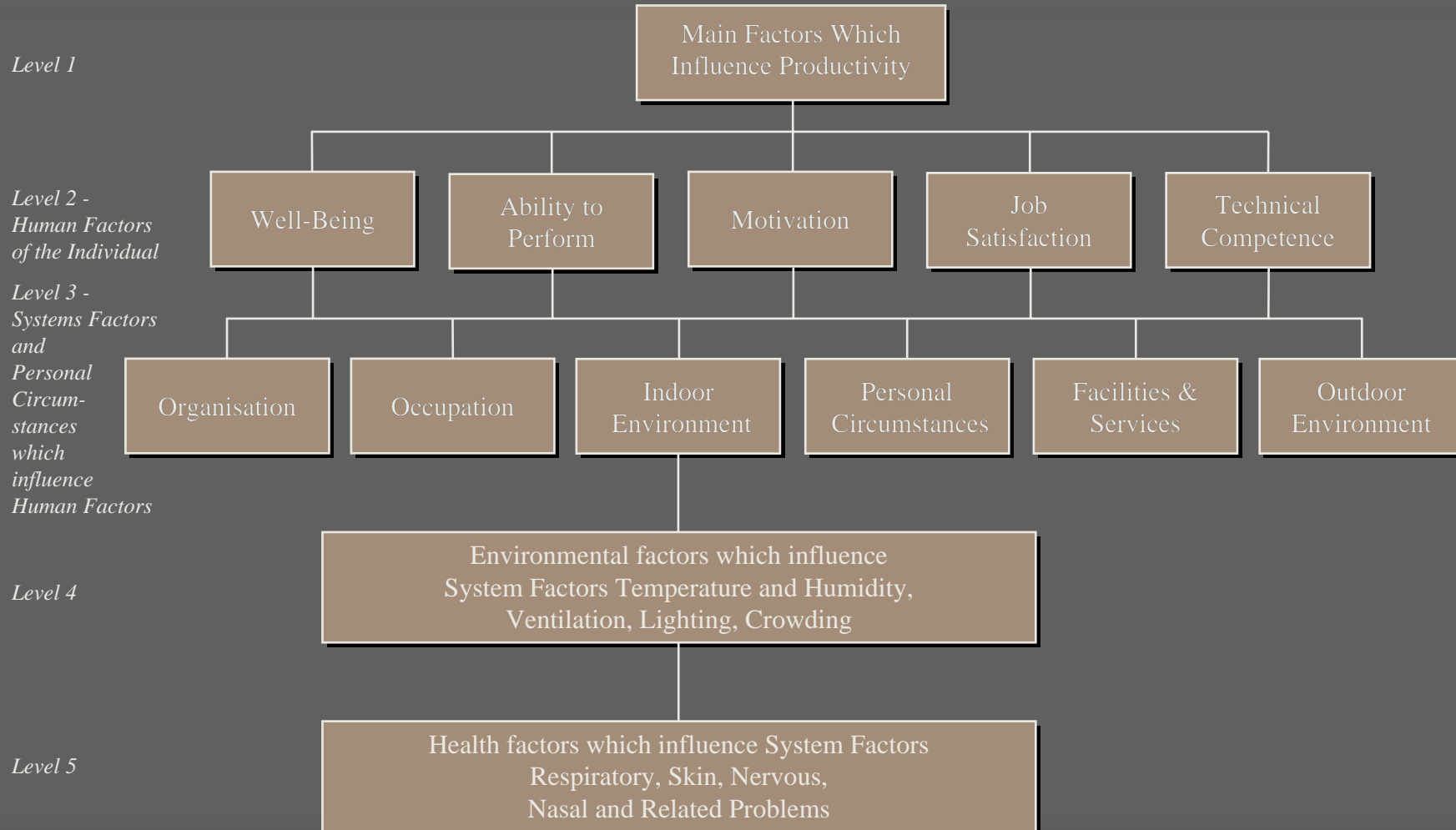
Physiological Measures

- ⇒ Brain waves
- ⇒ Muscle tension
- ⇒ Eye pupil dilation
- ⇒ Speech patterns
- ⇒ Cerebral blood oxygenation

Questionnaire

- ⇒ Background information about the organisation and the workplace
- ⇒ How much the environment and the job causes dissatisfaction
- ⇒ The feelings of the subject about their current work situation
- ⇒ The principal causal factors influencing health symptoms of occupants
- ⇒ Which factors influence job satisfaction and productivity

The Analytic Hierarchy Process



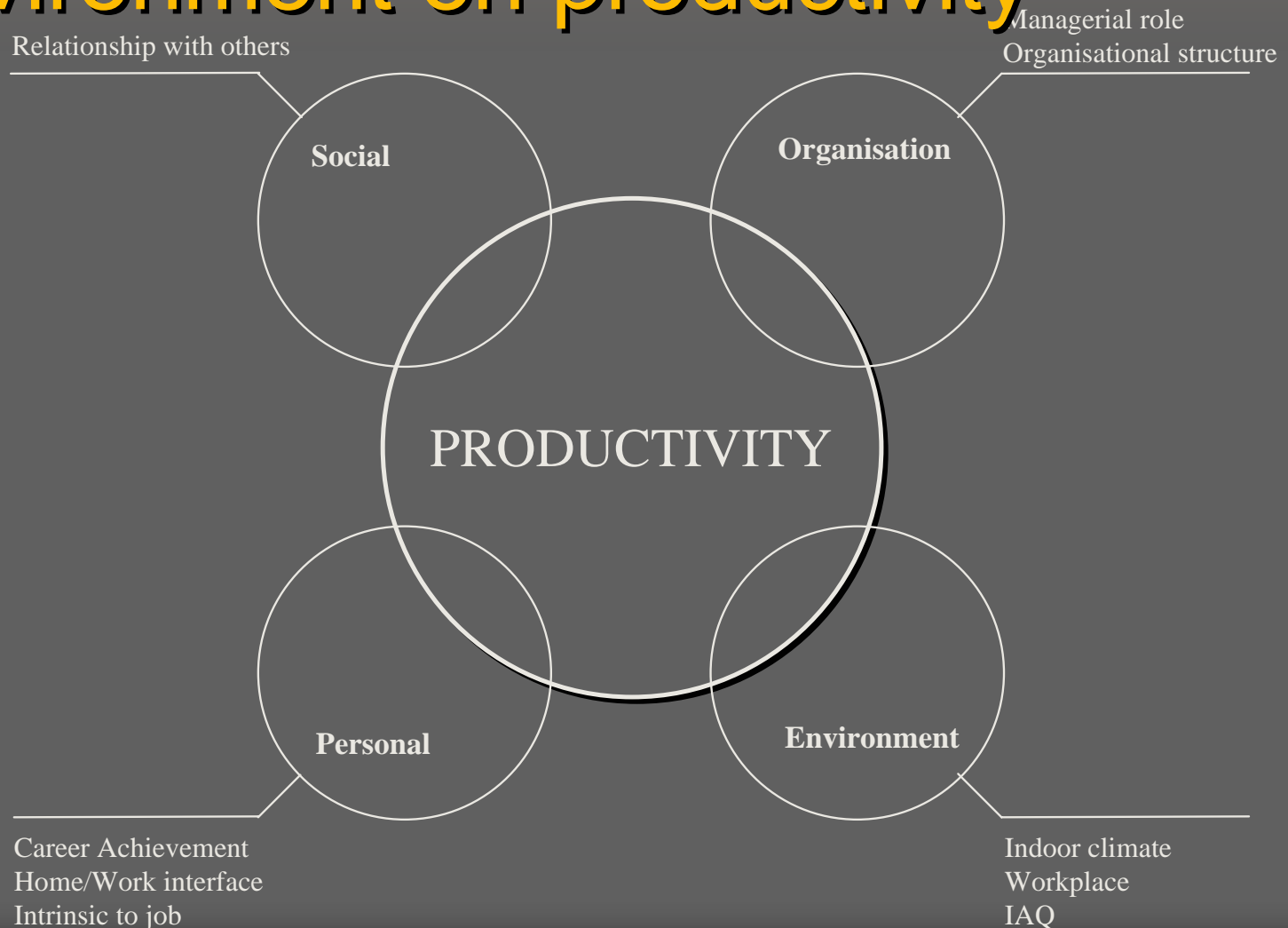
Self-assessed productivity

$$\text{SAP} = 6.8510 - 0.3625 * \text{En} - 0.1542 * \text{JD} - 0.1329 * \text{CS}$$

$$(r = 0.5083, F = 14.86 > F_{\alpha = 0.01} [3, 132] = 3.94)$$

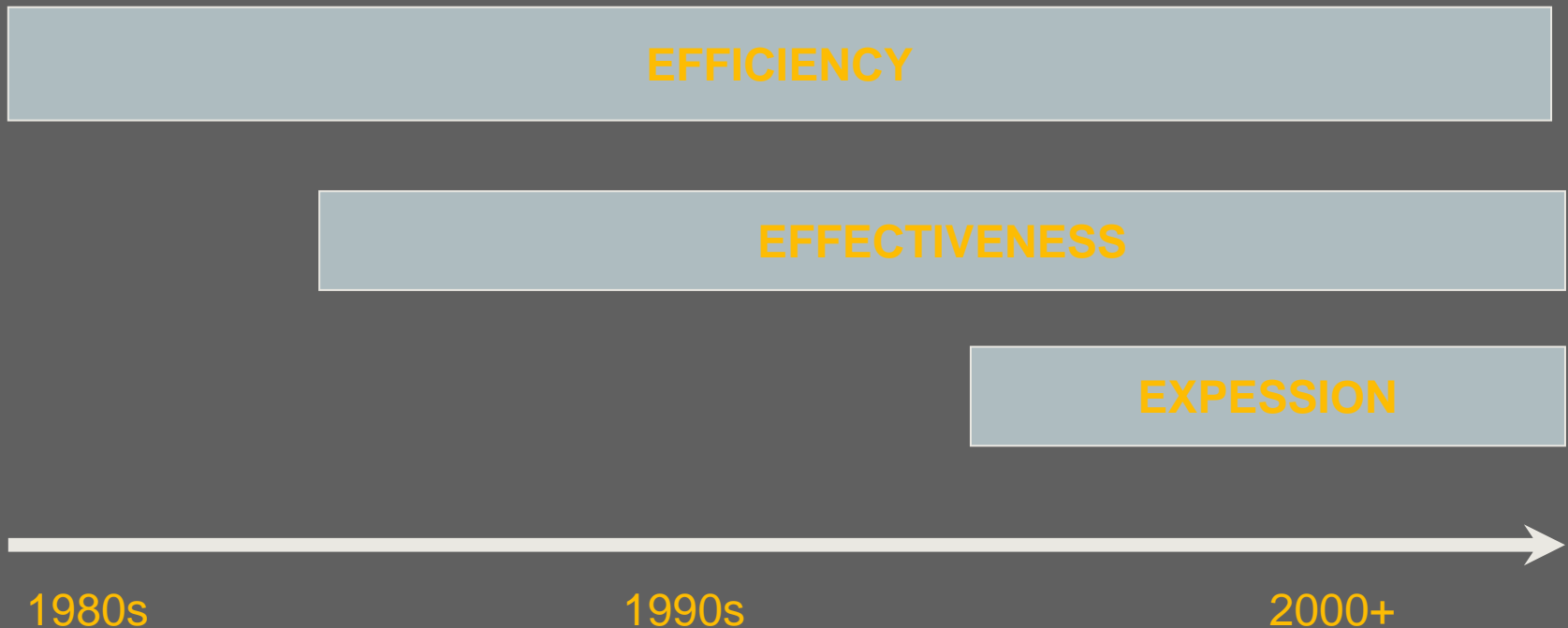
The principal factors which affect self-assessed productivity (SAP) in the offices surveyed were an overall unsatisfactory environment (En), crowded workspace (CS) and job dissatisfaction (JD).

Conceptual basis for impact of environment on productivity



Measures for workplace evaluation

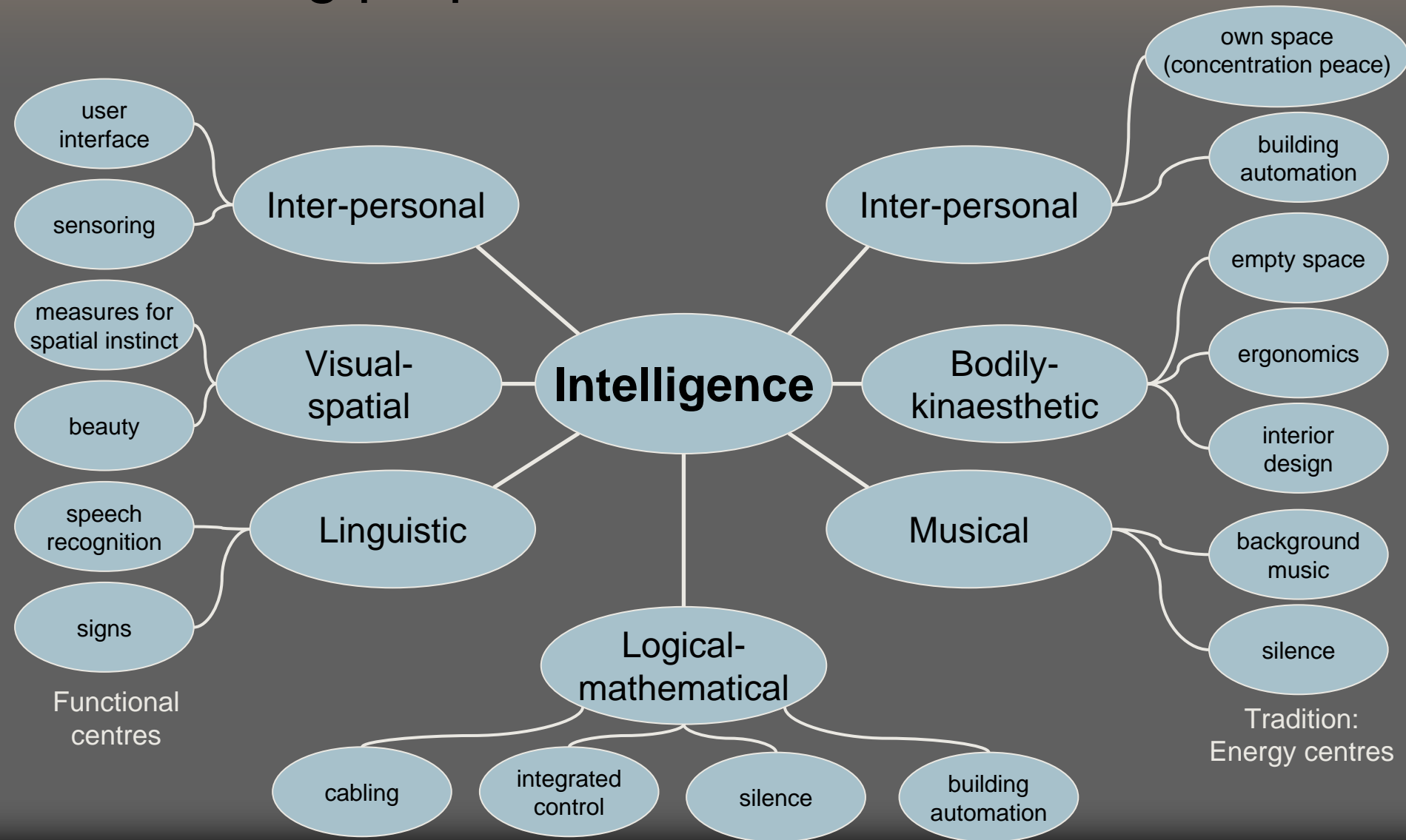
- Expression and identity issues
- Sustainability and corporate social responsibility
- Efficiency and effectiveness



Patterns of Space and Time

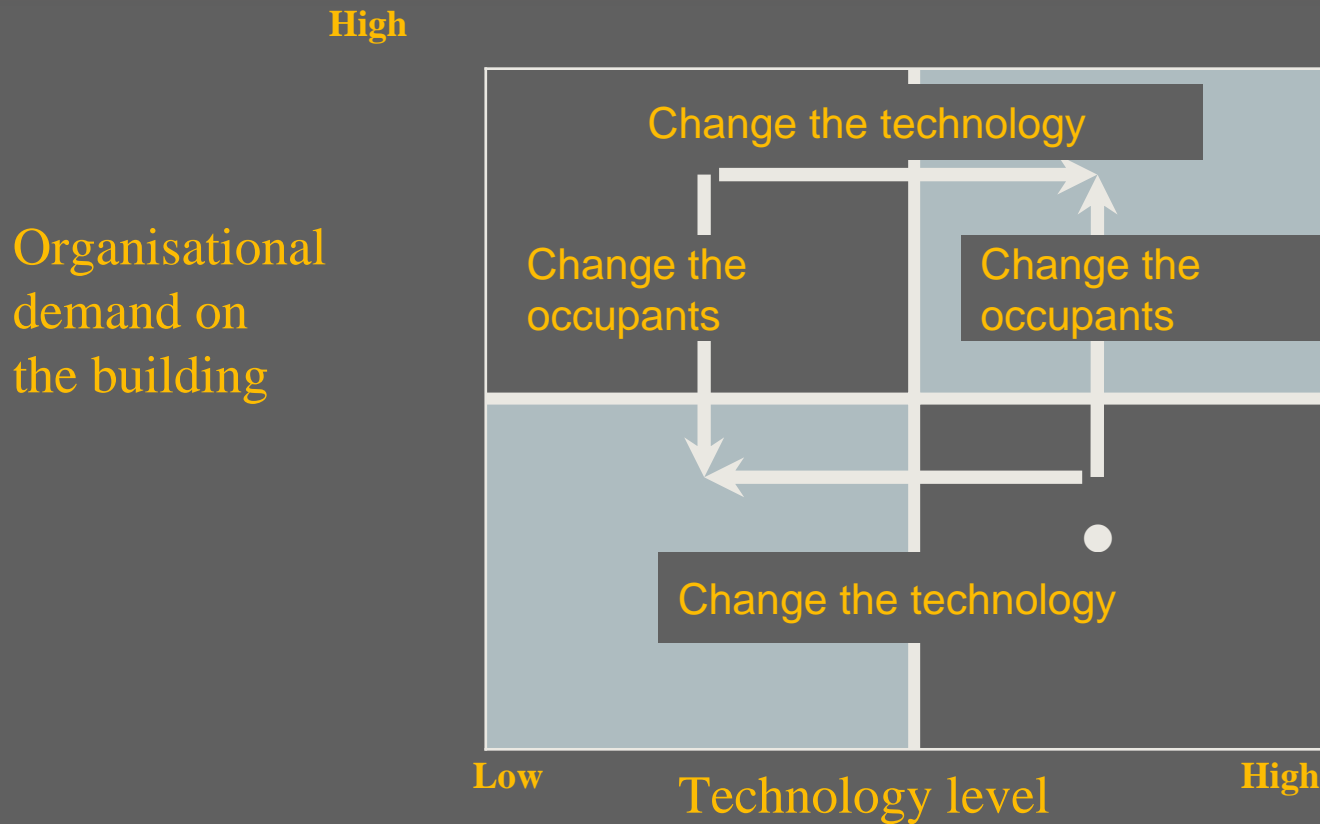
- ⇒ Building envelope modifies light, air, sound and energy
- ⇒ Scale and texture of space
- ⇒ Dynamic arrangement of space
- ⇒ 24 Hour society
- ⇒ Temporal patterns of concentration
- ⇒ Nature and patterns of working

Examples of human intelligence and building properties (Lehto, 2002)

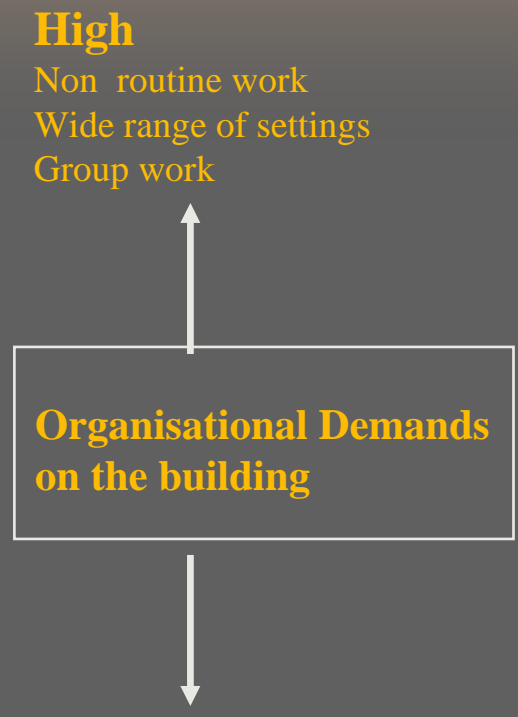


IB intervention stages

Organisational and technology change



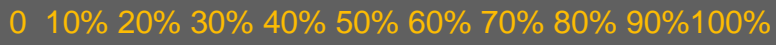
IB Technologies scoring matrix



Low
 Routine work
 Individual work
 Limited work settings



Underachieving IB Building Constraining the organisation	Business Value IB (high tech) Good match between organisational demand and technology provision
Business Value IB (low tech) Good match between organisational demand and technology provision	Showcase IB Advanced technologies not linked to organisational requirements



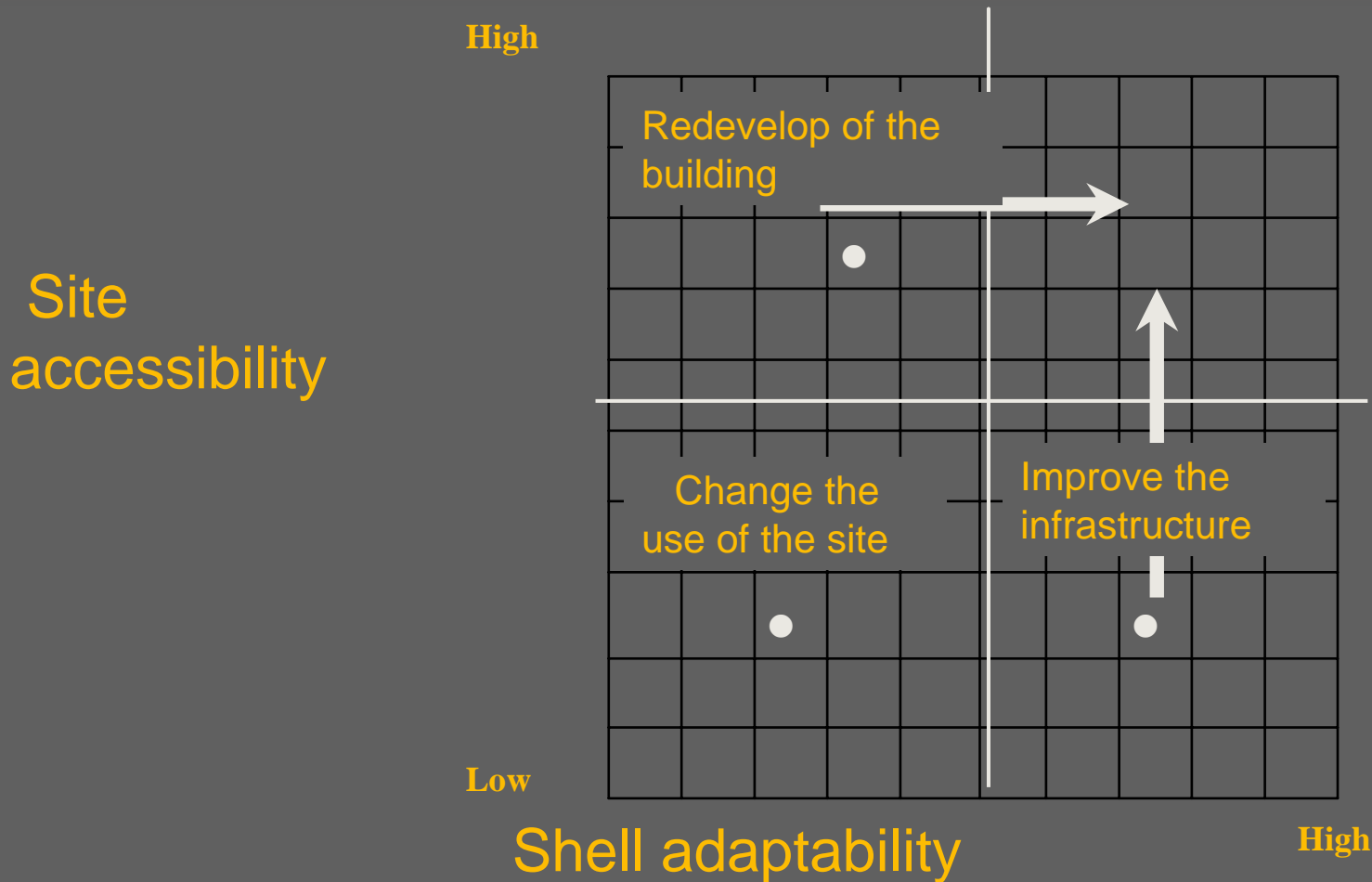
Low
 basic systems
 limited integration;
 building management focus



High
 advanced systems
 extensive integration;
 building management focus

IB Intervention Stages

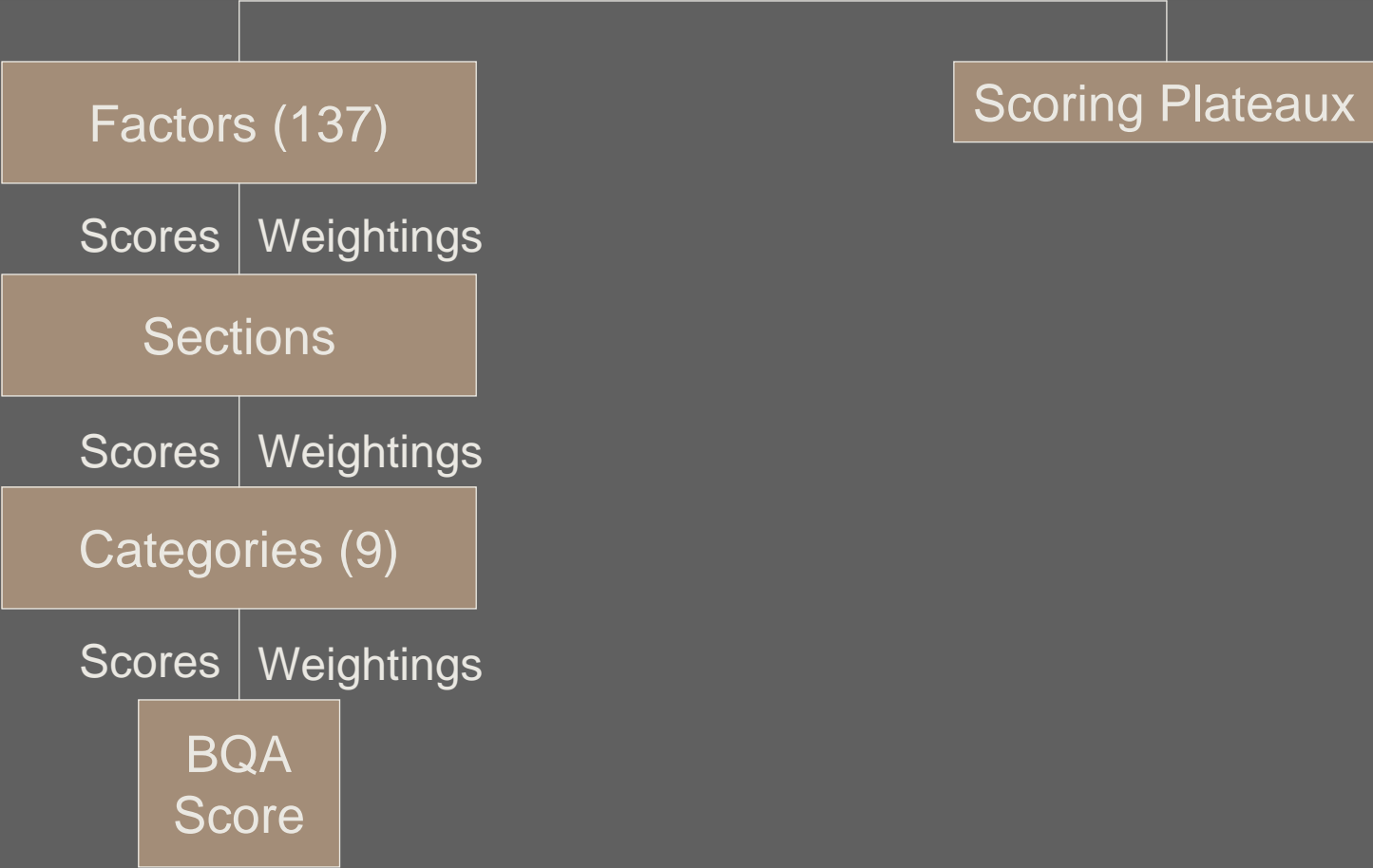
Site and shell issues



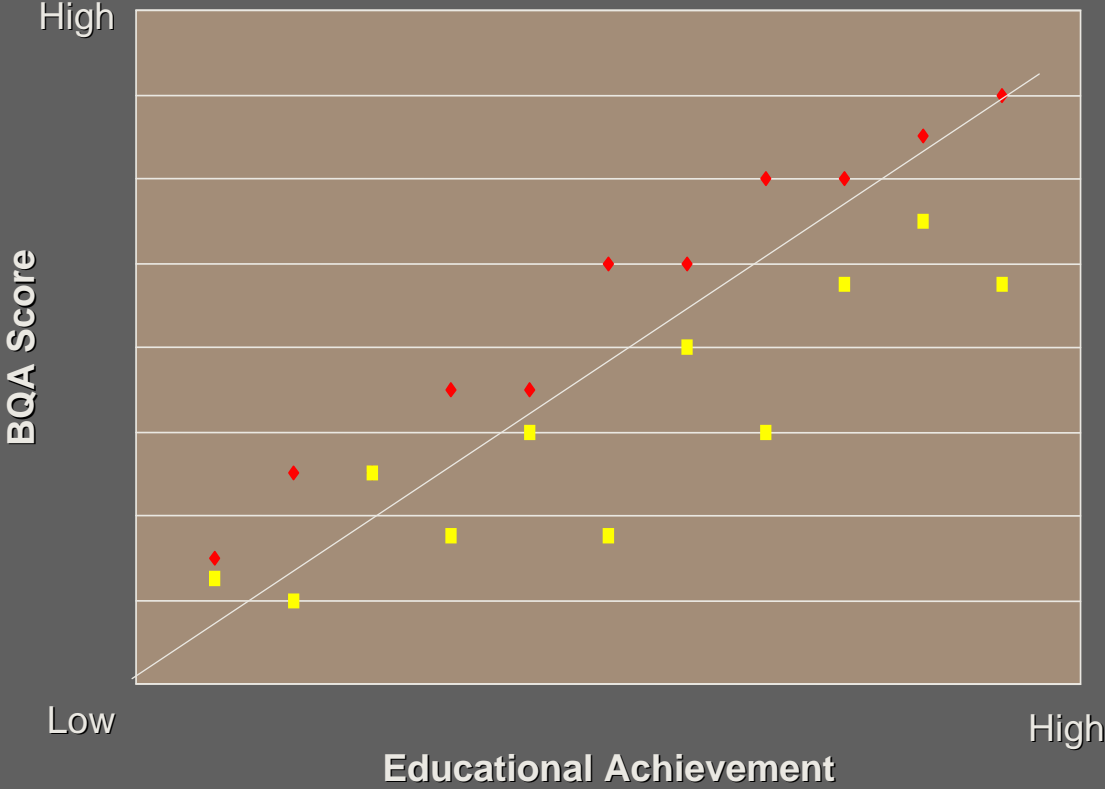
Building Quality Assessment Category Descriptors *(Williams 2000)*

- ⇒ *Presentation*: Appearance of the building & impression created
- ⇒ *Space Functionality*: Factors that determine operation of spaces
- ⇒ *Access & Circulation*: Matters Concerned with access's of people & goods
- ⇒ *Amenities*: Facilities or spaces for people
- ⇒ *Business Services*: Electrical services & information technology.
- ⇒ *Working Environment*: Working conditions of people in their work spaces
- ⇒ *Health & Safety*: Mandatory & other health or safety requirements
- ⇒ *Structural Considerations*: Building structure, construction & condition
- ⇒ *Building Operations*: Short & long term management of the building

Overall BQA Structure



Benchmarking Quality of Buildings and Educational Achievements – Primary Schools Study in Kent



Clients Views of Their Buildings

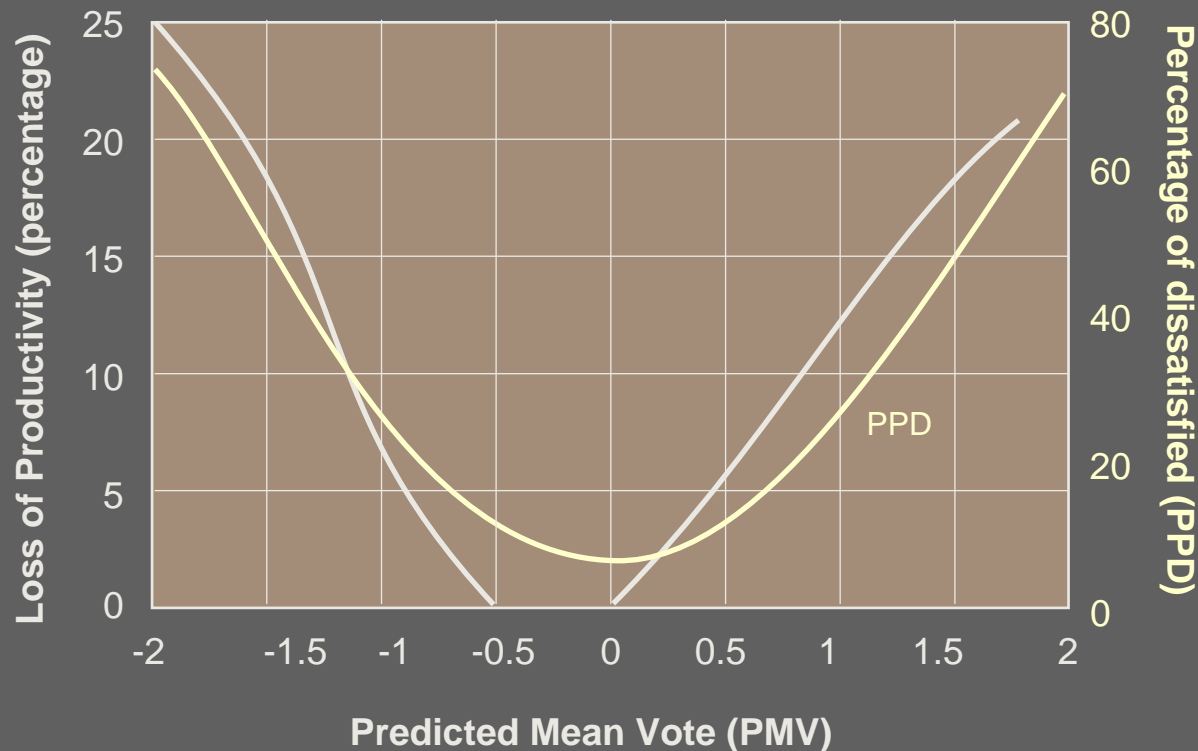
- ⇒ *Containers* built for a cheap price with no respect for the impact of the built environment on performance
- ⇒ *Prestige Symbols* in which the exterior is the key status factor than internal working conditions.
- ⇒ *Vehicles for Industrial Relations* in which a healthy work environment is viewed as important for the workforce
- ⇒ *Instruments of Efficiency* in which work investment expenditure is related to the rate of return of money not staff welfare
- ⇒ *Operational Force* for which the function and the symbolic roles are reflected in the management and design.

Comparison of energy and staff costs for North American offices

Costs	Rosenfeld (1989)	Abdou & Lorsch (1994)	EPA (1989)	Woods (1989)	BOMA (1988)
Staff costs (\$/ft ² /year)	300	218	200	237	130
HVAC running costs (\$/ft ² /year)	–	2-10	6	12	2.9
Energy costs (\$/ft ² /year)	1.5	1-2	2	2	1.5
Ration of staff to energy costs	200	114-218	100	118	87
Energy as proportion of productivity costs (%)	0.5	0.5-0.9	1.0	0.9	1.2
Equivalent productivity costs (min/day per person)	2.25	2-3.75	4.33	–	5

Relationship between the loss of productivity, PPD and the PMV

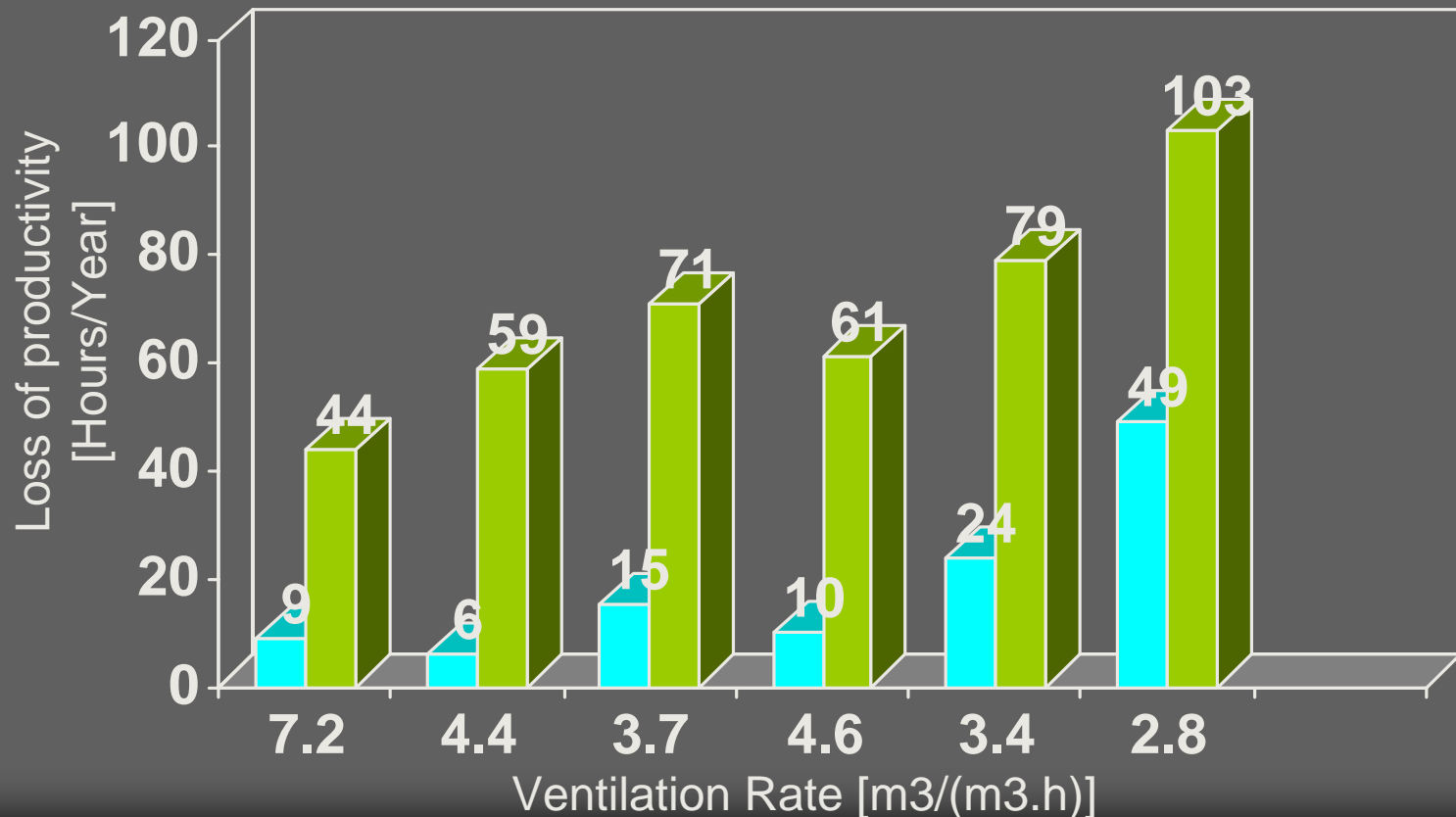
Loss of Productivity and PPD
as a function of the PMV



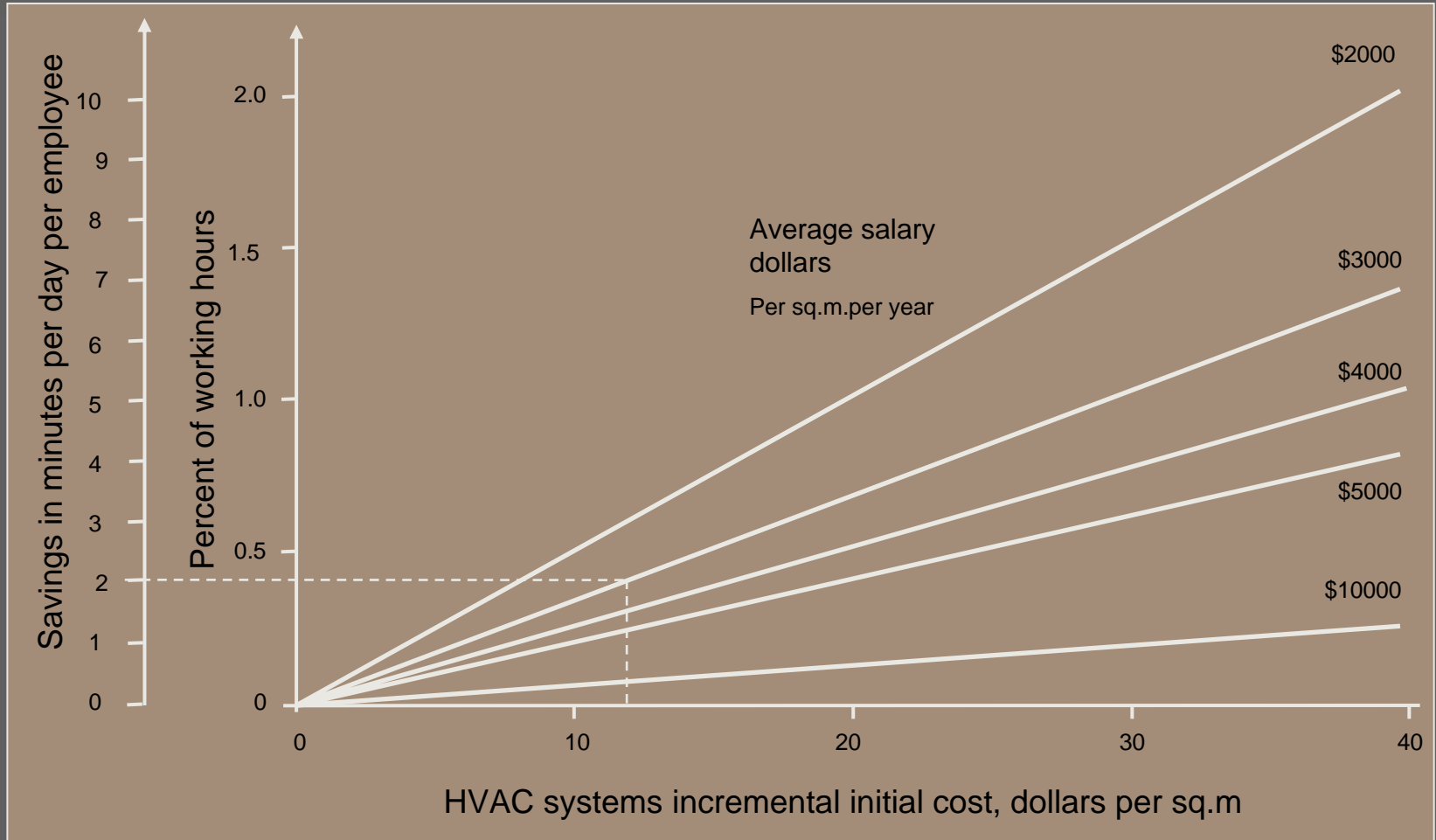
Loss of productivity per employee Standard Office South Facing

■ Cooling (Comfort categories in accordance with NPR-CR 1752)

■ No Mechanical Cooling



The relationship of incremental initial cost to potential user time saving (Rosenfeld, 1989)

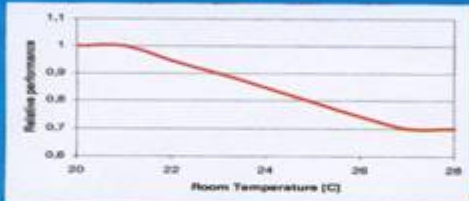


SUMMARY

A sensitivity analysis methodology for life-cycle costs (LCC) and non-productivity costs comparison is presented. The methodology is suitable tool for system evaluation during practical building design. It is also demonstrated that an investment to a better HVAC system is profitable already with modest profitability improvements of only a few minutes per day.

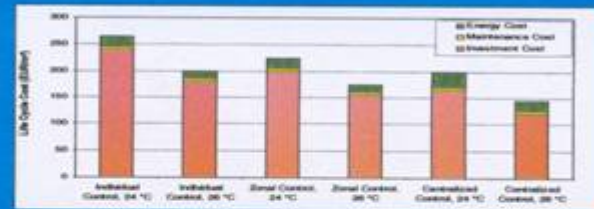
PRODUCTIVITY LOSS

The existing literature contains some significant evidence of the Indoor Environment parameters' influence on workers health and productivity. The air conditioning system affects on thermal environment and indoor air quality. The influence of the room temperature on thinking is reproduced in Figure 1/Wyear/.

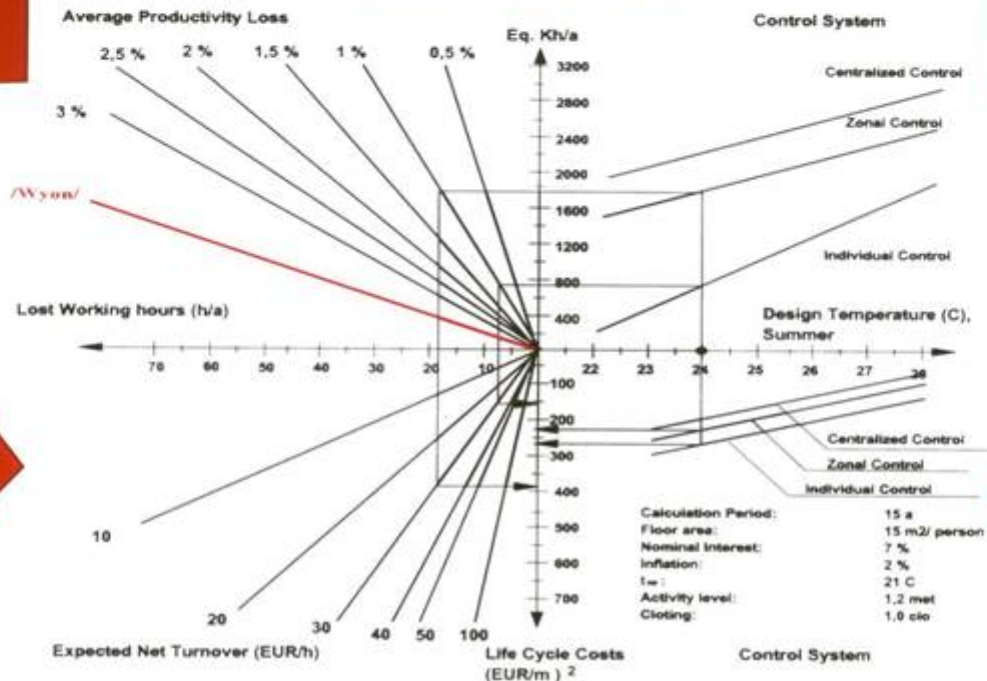


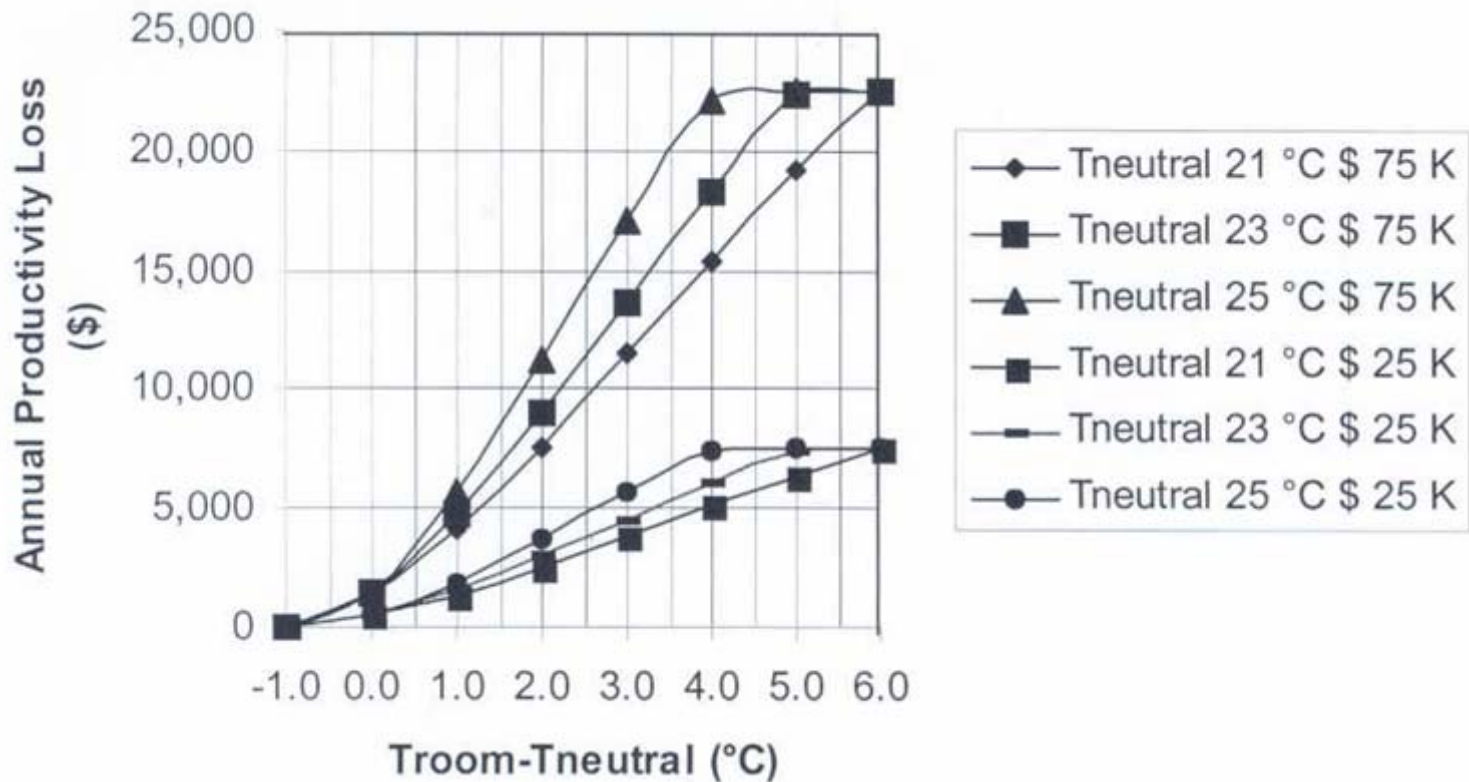
LCC ANALYSIS

The Life Cycle Costs (LCC) of different ventilation and control systems defined with dimensioning temperatures are presented in figure:



JOINT ANALYSIS

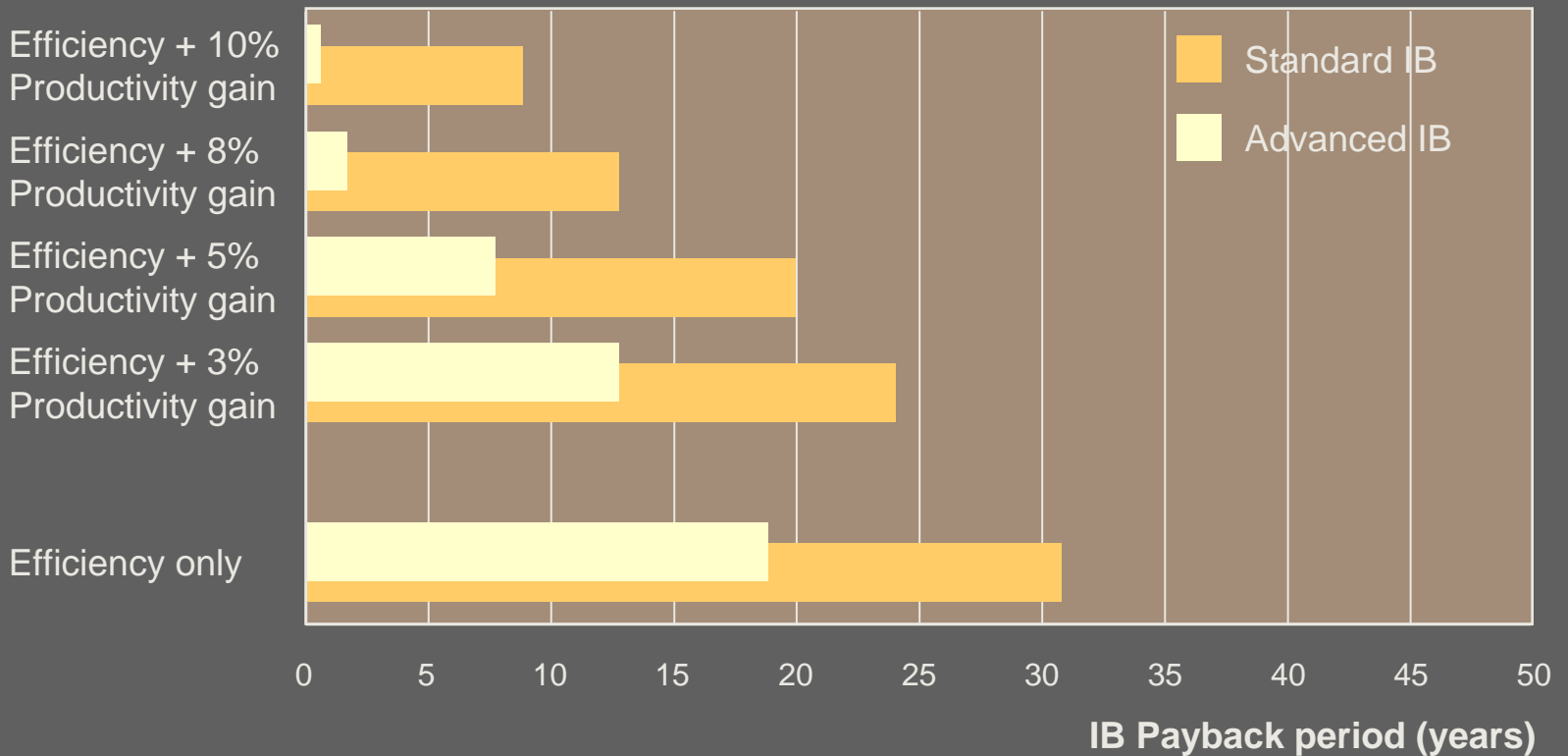




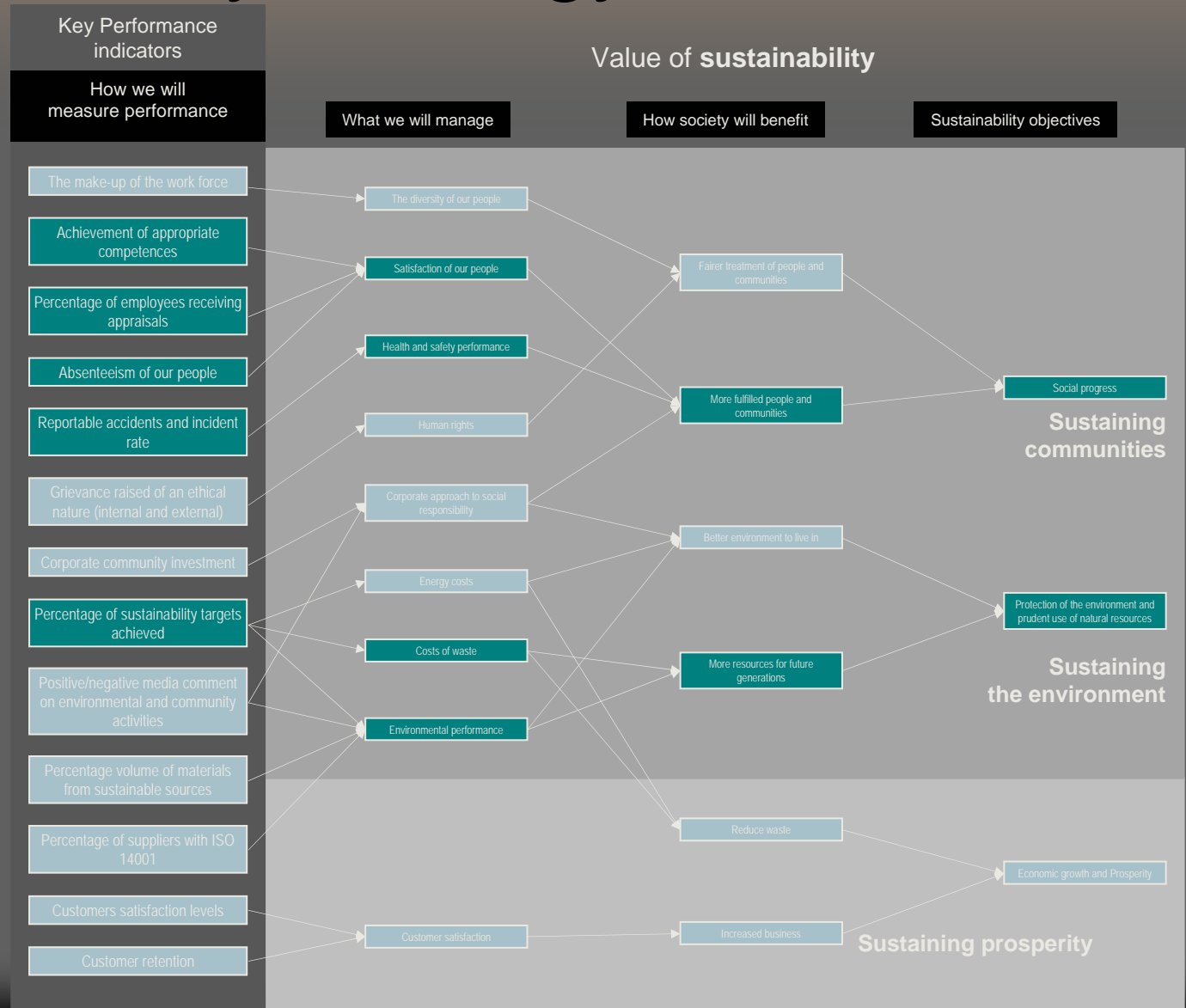
Cost implications of productivity loss at different neutral temperatures (Kosonen and Tan 2003)

Summary of IB break-even periods

Business Benefit



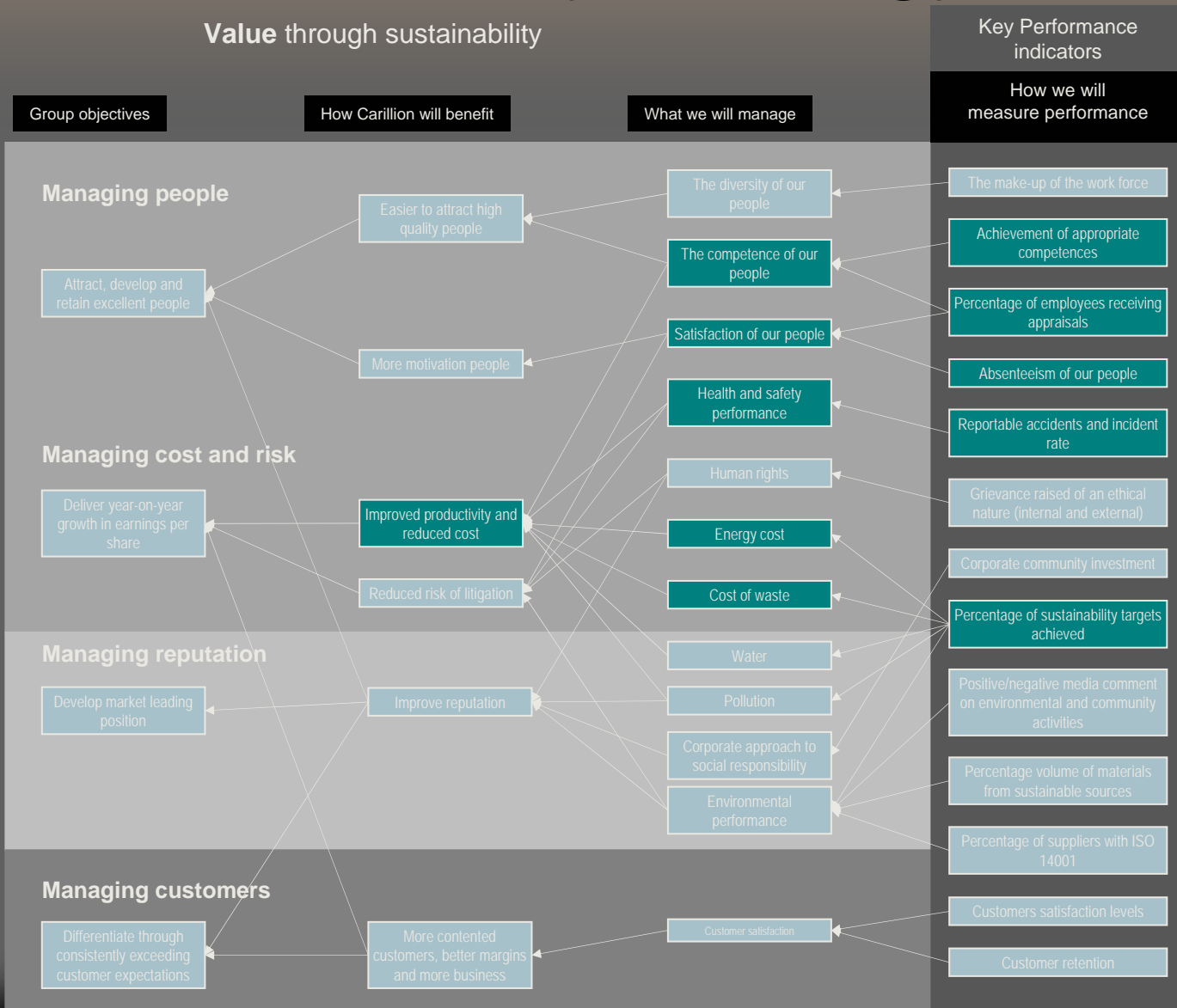
Sustainability Strategy Model



Sustainability strategy model (adapted from Leiper et al, 2003, Proceedings ICE, 156 ES1, 59-66 (ISSN 147 4637))

Sustainability Strategy Model

Value through sustainability



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Value of sustainability

