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Conditions under which the performance of teams is compromised:
The role of workspace density in triggering the collapse of workgroups in commercial office settings

by
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In order to lower the operating costs of workplaces, increase flexibility and improve work performance, businesses are increasingly adopting team-working practices in open office environments, subjected to higher levels of space density.

This thesis is concerned with increasing the understanding of the adverse consequences for organizations of degraded performance when workspace density exceeds limits for viable group working.

Whilst the impact of these types of built environments on satisfaction and performance has been the subject of considerable prior research, positivist-scientific methods, favouring the use of input-output models and performance evaluation focused at the individual level, have predominated.

This thesis pays particular attention to evaluating performance effectiveness at higher organizational levels, considering the behaviour of individuals within workgroups, and studying them as work-systems, established within various embedding environments.

Critical systems thinking provided a useful overall framework to understand and connect work organization and performance outcomes to the spatial qualities of the built environment, in particular workspace density. Within this framework, interpretive research methods were employed to investigate wide-ranging differences of opinion, with a view to improving our understanding of an increasingly complex, multifaceted building-human performance problem situation.

In addition, and to maximize the practical application of any likely findings, a complementary functionalist methodology was also employed to develop solutions that lend themselves to more sophisticated mathematical modeling.
Literature from multiple strands of organization and management theory, research into the built environment, work organization and team design, and human performance in the workplace, were brought together to guide the investigation. A single case study approach was adopted, with the host organization providing access to business and organization related information and data, and employees in distinct workplace environments for the duration of the research, specifically the field data collection phase.

The research found that whilst a more comprehensive linear model could be used to describe the relationship between built environment inputs and human performance outputs, a more exciting and appropriate research alternative was available through the consideration of workgroups as complex adaptive work-systems. This approach enabled the workgroup to be described mathematical, and consistent with a set of three non-linear equations developed and used by Edward Lorenz to map the characteristics of dynamic systems.

By selecting the three sub-scale components of workgroup cohesion within the Lorenz Equations, as indicative of the system’s emergent properties, it was possible to map graphically in 3D-phase space using computer programs the impact of workspace density on work-system viability. It was found that increased workspace density resulted in more unstable system behaviour, with the likelihood of system collapse if critical workspace densities were exceeded. The nature of the work performed by the workgroup, as indicated by its primary workflow type, also appeared to have a differential impact on the “tipping point”, while the impact of work-point type (ie workstation design) was less clearly defined.

Whilst the data afforded by the single case study places limitations on the extent to which the mathematical formulae established in this research might be universally applied in the first instance, the findings indicate further research in this field is warranted.
The research successfully addressed a serious gap in the knowledge required to plan, design and manage workplaces such that they are capable of delivering commercial benefits in the form of operating cost savings, without adverse impacts on human performance effectiveness or other qualitative business performance outcomes.
Many thanks are extended to my supervisor, Dr David Leifer, Coordinator of the Facilities Management Program in the Faculty of Architecture Design and Planning at The University of Sydney for his continued encouragement, outstanding support, advice, guidance and commitment throughout the research. His ready availability to discuss research issues and questions as they arose, and his timely responsiveness to my requests along the way, is greatly appreciated.

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This thesis is dedicated to my father

Keith Ronald Purdey
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CHAPTER 1: INTRODUCTION

The Problem

In the face of global competition, sustained pressure to reduce business-operating costs, increase workplace flexibility and improve performance, organizations are increasingly turning to team working in open office environments.

The impact of these types of built environments on individual satisfaction and performance has to date been the subject of considerable research, from diverse academic perspectives. However, much of this research is based on the use of input-output models for evaluation, and at the individual level.

Insufficient attention has been paid to evaluating performance effectiveness at a higher, systemic, workgroup level, when individuals comprising these organizational and work design units are accommodated in open-plan workspaces that are subjected to increasing workspace densities. Further, in the quest to improve the environmental outcomes from buildings in use, additional demands are also being placed on the need for higher space density in order to reduce environmental footprints, with scant regard to the sustainability of organizational systems.

There is a serious gap in the knowledge required to plan, design and manage workplaces that are capable of delivering building operational cost savings without adversely affecting human and other business performance effectiveness outcomes for users of these buildings.

Aim of the Research

The aim of the research is to investigate the impact on performance effectiveness when workgroups are subjected to increasing space density. Specifically it explores the viability of the workgroup, (defined as a dynamic work system) as workspace density increases, and the possibility of work system collapse if critical thresholds of workspace density are exceeded.
Structure and Format of the Thesis

Chapter 2 provides a background literature review, which frames the research in terms of the relationship between physical environment design, occupant satisfaction and human performance. It then focuses attention on the role workspace density might play in affecting employee satisfaction and performance.

The review of the literature firstly examines the nature of modern work and the challenges associated with increasing productivity given the rising global competition facing businesses in general. The review then explores definitional issues, when the concept of measuring productivity is applied to office-based work and attempts are made to broaden measurement and evaluation to include various job satisfaction and performance indicators.

The relationship between these two important aspects (i.e. job satisfaction and job performance) is further considered as it is applied to individual jobs and then group/team work. In particular the meaning of productivity in the workplace, i.e. within the context of the built environment - the workplace itself, its physical characteristics and workspace density - is specifically examined.

The key perspectives on improving workplace performance are discussed in order to firmly establish the complexity of the cognitive, behavioural and affective “links” between built environmental conditions and occupant response to them. This discussion leads to a review of the evidence that workspace density might act as a “pre-cursor” to delivering human performance outcomes and the opportunity to explore its impact more comprehensively by using other than traditional linear cause-effect methods.

In presenting the results of this introductory review, the format used is also unorthodox, but it is in keeping with the interdisciplinary approach adopted in the research methodology presented in Chapter 4.

As the overall research thesis straddles two relatively autonomous research domains, (i.e. built and organization environments) the various knowledge streams in Chapter 2 have also been explored chronologically, enabling them to be woven together, at appropriate points in the text. These points are opportunities to pause and reflect and to summarise what might be drawn out of these interwoven streams, what findings or learnings can be revealed and what further questions might be
relevant for the overall research theme. These sections are highlighted as bold, italicized text. As the literature review unfolds, these summaries also serve to build an appropriate context for the literature review presented in chapters which follow. These sections do not necessarily provide a detailed critical review of individual referenced papers since this is not deemed necessary. The chronological review highlights a consistent weakness in almost all of the prior research, which uses linear cause-effect models. These are considered to be outmoded and inadequate for the aim of this research. Thus, all that can reasonably be expected from a review of the prior research is what is indicated above - learning carried forward into a more appropriate research model, and additional questions raised relevant to the overall research aim. Not withstanding this overarching criticism, where critical review of individual referenced papers is warranted, it is appropriately provided.

Chapter 3 employs a similar style, taking advantage of chronology to examine the literature in more detail. However, this chapter focuses attention on the team or workgroup as the predominant unit of organisation for modern work, and a range of factors considered relevant to workgroup performance effectiveness. By examining the claimed organisational benefits of teams, design considerations and criteria for effective workgroups, the emerging role of workspace attributes is confirmed. In order to understand the role workspace density might play in commercial office settings, more intense work settings incorporating high work demands or complexity, extreme co-location and computer mediation were also examined.

This leads to workgroups being considered as systems for work. These systems comprise human, technology and spatial features, embedded within wider organizational systems, being capable of exhibiting complex adaptive behaviour.

The literature review in this chapter also confirms the performance of workgroups and their potential to be sensitively dependent on space density, as a subject amenable to further research, and as such, studied from a soft systems methodological perspective as opposed to the traditional linear cause-effect perspective.
Chapter 4 provides an overview of the research methodology, and explains how a critical systems thinking framework was used to combine two research approaches - interpretive and positivist-functional. A mixed method enabled the consideration of various and significant themes, ideas and frameworks, both for the study of workgroups, and for outcome performance evaluation. This approach led to the development of a conceptual research model, and its mathematical interpretation. This framework supported the planning and conduct of the fieldwork, risk assessment, data collection and subsequent analysis. The four research hypotheses are also put forward in this chapter.

Chapter 5 provides an overview of the host organization chosen for the field research stage, presents detailed information on work group selection and classification, and the data collection methodology adopted in practice. This involved the use of accepted, but modified survey research instruments and proprietary tools. In this chapter the mathematical model is applied and used to test the hypotheses. The findings from the research are then presented using a mix of text, tables, charts and graphs. Chapter 5 also includes a risk assessment for the methodology according to AS4360: 2004.

Chapter 6 presents the conclusions drawn from the research findings. In presenting these findings, it is acknowledged that the case study was limited to a single organization in a particular industry sector. Thus it could be argued that the findings are context specific and may not be generally interpreted. However, the classification of workgroups by workflow type and the specific workstation types are generic in nature, whilst the range of workspace densities found in the host organization, are not inconsistent with current, wider Australian industry practice. Thus there are certainly some limitations placed on generalisability of the findings at this point in time, due largely to the relatively small data sets.

This limitation presents opportunities for further research in this particular subject area, or to explore the extensive array of questions raised in this research thesis, or following the research themes also developed in this thesis. Some of the more important questions are summarised in Chapter 7.
Appendices (1, 3, 4, 6, 7, 12) include supporting field data and documentation, which is further supplemented by detailed Appendices (2, 5, 8, 9, 10, 11) on a CD ROM disk. This also includes areas of literature review germane to, but not directly impinging on, the canon of this thesis, viz; substantial, but very preliminary desk research on the built environment as Appendix 13.
CHAPTER 2: BACKGROUND

The Nature of Modern Work

Globalization, technological change and environmental pressures have been changing the context in which public and private sector organizations operate over recent decades (Hirschheim, 1985; Maglen & Shah, 1999).

Jobs in offices, hospitals and schools, are being reclassified as “elite” (ibid. p 5.), compared to less-skilled occupations (A. Carnevale & Rose, 1998). Symbolic analytic services (Reich, 1992) describes a rapidly increasing new category of global work, involving problem-identifying and problem-solving activities. Modern office work is becoming more service oriented (Osterman, 1997), computer mediated (Batt, 1999), knowledge based and specialized (Janz, Colquitt & Noe, 1997; B. C. Johnson, Manyika & Yee, 2005), with jobs involving the most complex type of interactions - analyzing information and grappling with ambiguity - in the fastest-growing segment of business activity (Maglen & Shah, 1999).

Work Productivity

Increasing productivity is the key to global competitiveness (Gunderson, 2002). At a macro-economic level, productivity improvement emphasizes new capital investment, technological and organization change, and labour market reform (Cobbold & Kulya, 2003).

As labour productivity ("Productivity Primer") is traditionally measured simply as output per person, at a micro-economic level, productivity can be increased by labour intensification (i.e. having people work longer hours), although this results in increased absenteeism and turnover (Birch & Paul, 2003), increased stress (ibid. p104-106.), health problems (ibid. pps. 26, 81-88.), and “presenteeism” (i.e. people are present and visible to management, but not productive) (Levin-Epstein, 2005), which all carry increased costs for business.

In the modern economy, productivity is now increasingly viewed as an efficiency + effectiveness concept (Banks, 2001). Qualitative measures include service delivered
to customers, better value chain management, product innovation, timeliness and quality improvement (Parham, Roberts & Sun, 2001).

Job Performance

As a behavioural outcome, job performance is the result of an individual's response to a stimulus object (Herman, 1973). Hence:

"Directionality may proceed from cognition of a stimulus object, to evaluation of it and a predisposition to behave and performance. The perceived effect of that performance may act as a new attitude stimulus object and have an associated effect" (ibid. p209.).

From this perspective, job performance can be evaluated using self, peer or supervisory ratings (Bhagat, 1981; Clegg, 1983; C. N. Green, 1973a; E Sundstrom, Burt & Kamp, 1980), productivity (Bateman & Organ, 1983; Ivancevich & Smith, 1981), lateness, absence and turnover (Clegg, 1983), and other qualitative behaviours at work (Mangoine & Quinn, 1975).

Job Satisfaction

Job satisfaction has been defined as "a pleasurable or positive emotional state resulting from the appraisal of one's job or job experience" (Locke, 1976), and positive "feelings or affective responses to facets of the situation" (Smith, Kendall & Hulin, 1969).

Argyle (1989) identified more than 249 measurement scales with the Job Descriptive Index (JDI) sub scales (Smith, Kendall & Hulin, 1969), Minnesota Satisfaction Questionnaire (MSQ) (Weiss, Dawis, England & Lofquist, 1967) and Job Diagnostic Survey (JDS) (Hackman & Oldham, 1975) most widely cited for measuring job satisfaction.

The Job Satisfaction – Job Performance Relationship

One of the most controversial issues remains the job satisfaction – job performance relationship.
Vroom (1964) found correlations in the range from -0.31 to +0.86 with a median value of just +0.14, while using the standard Job Descriptive Index (JDI), (M. Petty, McGee & Cavender, 1984) measured an overall correlation of +0.23, with results higher for professional, managerial, and supervisory employees.

This research concludes that individual job satisfaction and job performance are positively correlated, but there may be a circular effect, with performance causing satisfaction, being the first link in the process. Whilst the method used by Petty et al. (1984) was more holistic, and covered a significant time period, it relied purely on data from previously published research, had an emphasis on individual satisfaction and performance measurement, and used a single statistical method of analysis.

Using other than the JDI satisfaction measures, including quality, supervisory and self-reports as performance measures, (laffaldano & Muchinsky, 1985) strengthened their statistical analysis to improve the generalisability of the findings. Despite all the methodological advances since the original work of Vroom (1964) the average correlation was still found to be only +0.15.

Since Smith et al. (1969) and Locke (1976), there has been considerable research (Isen & Baron, 1991; Rafaeli & Sutton, 1989; Staw, Bell & Clausen, 1986) to operationalize attitudes at work beyond job satisfaction, and job performance beyond quantity and quality (O'Reilly & Chatman, 1986; Staw & Boettger, 1990). Staw & Barsade (1993) suggested job attitudes could include mood, a milder more diffuse affectivity state, not necessarily directed towards any single attitudinal object, job or person, while emotions were considered to be stronger reactions to a specific object or cause (Lazarus, 1991).

The value of this research lies in a resulting proposition that affective disposition might be a more significant factor relating to satisfaction and performance in “unstructured” work compared with jobs that might be more “highly routinised”.
Happiness has also been operationalized as job satisfaction (Hertzberg, 1966; Laффaldano & Muchinsky, 1985; M. Petty, McGee & Cavender, 1984; Vroom, 1964), while R Cropanzano & Wright (2001) identified three prevailing themes commonly adopted by scholars and practitioners when considering job satisfaction. These were:
- the profile of positive and negative affectivity
- the lack of exhaustion of emotions
- psychological well-being.

With reference to a resource maintenance model, R Cropanzano & Wright (2001) argued that happy and unhappy people could find themselves in different psychological situations, which determine their perceptions of the work environment, interactions with co-workers, and attitude.

This particular model could prove useful in understanding how these expanded aspects of satisfaction can influence job performance in the workplace.

Further this research found the relationship between job satisfaction and performance depends on the actual job satisfaction measures used, with correlations higher for overall job satisfaction measures than for particular facet measures of job satisfaction.

Using a composite measure of overall job satisfaction, T. Judge, Thoresen, Bono & Patton (2001) found positive and slightly higher average correlations of +0.30 between job satisfaction and job performance, and summarized seven likely models, with their theoretical basis to describe the relationships between job satisfaction and job performance.

The value of this research lies in highlighting the need for alternate conceptualizations of the job satisfaction – job performance relationship, viz;

Re-conceptualizing Attitudes
T. Judge, Thoresen, Bono & Patton (2001) indicated affectivity and its relation to motivation and other organizational outcomes, and emotion as a predictor of job performance being fields worthy of further investigation.
R Cropanzano & Wright (2001) similarly concluded there is evidence (George, 1996; T. A. Judge, 1992) that affectivity predicts work attitudes, job satisfaction and job performance, while emotional exhaustion has been shown to be a key component of burnout (Maslach & Leiter, 1997) and could predict job performance. Wellbeing (Straw & Barsade, 1993; Straw, Sutton & Pelled, 1994) captures both positive and negative emotional states, and a causal relation might exist such that “when wellbeing is high, performance increases” (R Cropanzano & Wright, 2001, p191.).

If happiness is operationalized as wellbeing, does this approach strengthen the relationship between job satisfaction and job performance? This question could be the subject of further research.

Re-conceptualising Performance
Herman (1973) identified self, peer and supervisory ratings, objectively measured productivity, absenteeism and turnover as useful classifications of job performance measures. Both turnover and absenteeism seem to have reliable linkages to job satisfaction (Mobley, 1982; Mobley, Griffith, Hand & Meglino, 1979; Staw & Barsade, 1993), but the low levels of correlation point to other causes. Absenteeism results from dissatisfaction, while voluntary turnover is an individual decision and made in the context of prevailing job market conditions (Argyle, 1989).

Complex decision making (Isen & Baron, 1991), creative problem-solving (Isen & Daubman, 1984), and adaptation under stress, problem-focused coping and seeking social support (Scheier, Weintraub & Carver, 1986), have also been identified as potential measures for individual (job related) performance.

Measures of individual behaviour which can deliver higher organizational level performance benefits (Staw & Barsade, 1993) include helping behaviour (Cunningham, Shaffer, Barbee, Wolff & Kelley, 1980; George & Brief 1992), cooperative behaviour (e.g. in negotiation, conflict resolution, finding integrative solutions) (P. J. D. Carnevale & Isen, 1986), and persuasion of or influencing others (R. E. Petty & Cacioppo, 1986).
Peters & O'Connor (1980) reconceptualized work performance from an organization psychology perspective, considering ability, motivation and opportunity act together in a non-linear way, (see also page 20).

Re-conceptualizing Context
Considering performance more broadly can extend research into job performance beyond specific job tasks to include the psychological and social context within which the job/tasks take place. For example, equity theory (Katzell & Thompson, 1990; Pritchard, 1969) enables consideration of the psychological and social contexts within which the job/tasks take place, yielding helping others (Organ, 1988), supporting organization objectives, and organization citizenship (Borman & Motowildo, 1993) as potential job performance measures.

Ostroff (1992) suggested that employee satisfaction and attitudes (Staw & Ross, 1985) may be predictors of performance measured as effectiveness (Pulakos & Schmidt, 1983) while Ostroff & Schmitt (1993) applied a Competing Values Framework (Quinn & Rohrbaugh, 1983) to identify the most appropriate performance measures for different organizational characteristics.

These research methodologies are worthy of further investigation. The added value of this research lies in it challenging the premise of individual level of analysis, considered to be too restrictive (Ostroff, 1992; Ostroff & Schmitt, 1993) Harter & Creglow, (1998)). Individual analysis fails to take into consideration behavioural responses to wider ranging organizational measures of performance. Ostroff & Schmitt (1993) point to “reliable relations between job satisfaction and performance at the organizational level” using performance indicators that include customer satisfaction, profitability, turnover and productivity.

Ostroff (1992) concluded that failure to find strong correlations between satisfaction and performance could in part be explained by research focused at the individual level, since organizational performance is not the simple sum of individual job performance.
Noting a lack of consensus on organizational performance measures, Ostroff (1992) considered a mix of internal and external criteria as most appropriate. More importantly, Ostroff's research points to high levels of average correlation between satisfaction and organizational performance with even higher correlations demonstrable if specific facets of job satisfaction are related to organizational level performance. These facets included satisfaction with co-workers and "physical facilities".

Carlopio & Gardner (1995) however found job satisfaction related to job characteristics, which in turn can be affected by organization level (Sawyer, 1988) and workload demands (Stellman, Klitzman, Gordon & Snow, 1987). They similarly found generally higher levels of workplace satisfaction at higher organizational levels, consistent with Oldham & Rotchford (1983), who found control and influence explained most of the job satisfaction.

Carlopio & Gardner (1995) applied a number of instruments, which are worthy of further consideration. These include;

- Perceptions of Workplace focused on perceived crowding, task privacy and communications privacy (Oldham, 1988) to measure workplace experiences
- Human Factors Satisfaction Questionnaire (Carlopio, 1986) to measure physical work environment satisfaction
- Employee Reactions were measured using a range of instruments (Minnesota Satisfaction Questionnaire (MSQ) for general satisfaction, Job Descriptive Index (JDI) for job facet satisfaction and the Organisational Commitment Questionnaire (OCQ))

Also noting that most prior job satisfaction studies focused on individual employees Harter, Schmidt & Hayes (2002) argued that evaluation at the business unit level may be more appropriate, as at this level, satisfaction – performance links are more relevant to business performance outcomes. Higher correlations were found at the business unit level - "true scores" measuring 0.2 and 0.25 respectively for overall satisfaction and employee engagement correlated to productivity.
Their composite correlations approach and the Integrated Model (Figure 1) below are worthy of further investigation.

Figure 1: Integrated Model: Job Satisfaction – Job Performance

An important outcome from the research of Harter, Schmidt & Hayes (2002) was the proposition that employees are “emotionally and cognitively engaged...when they have what they need to do their work”. This proposition begs the question as to what is actually needed to do modern work?

Equally, what constitutes “overall job performance”, what are the most appropriate performance measures, and in what context, and what is the most appropriate measure of “overall job satisfaction”?

The HR field seems has a preference for the JDI, but to what extent does this instrument capture the contribution of built environment satisfaction particularly in jobs where spatial elements are critical for employees to be
"emotionally and cognitively engaged" There may be a more appropriate instrument, or changes to the JDI can be recommended. 

Further in developing the model, research also needs to consider "job complexity" as a primary moderator, since modern work is becoming increasingly information intense and more complex.

Workplace Productivity

At the micro-economic level, productivity impacts result from either capital deepening or multifactor effects, being the combined effect of investments in labour and capital (Parham, Roberts, & Sun, 2001).

Judicious workplace investments in human, technological and workplace resources have the potential to fundamentally change the way work is designed, and deliver quantitative benefits (efficiency productivity) plus indirect qualitative benefits (effectiveness productivity).

However, while this concept might appear straightforward, measuring workplace productivity can still be difficult in practice. Measures and measurement approaches can vary across industry sectors and organization type within the same sector. They can even differ between business units within a specific organization (N Oseland & Bartlett, 1999) depending on the type of work activities. A single, straightforward measure of workplace productivity, which could be generally useful, still remains elusive.

For example, individual productivity can increase when employees perform tasks more accurately, are more creative, can sustain stress more effectively, are more able to cope with unforeseen circumstances, or are drawn toward accepting more responsibility.

At a business unit level, Glassop (2002) identified increased output, sales, revenue, profitability or fees per employee, and faster completion of projects/tasks as possible workplace productivity measures. Overall workplace performance impacts have also been identified in terms of fatigue, absenteeism, and the incidence of complaints (Birch & Paul, 2003; Lomonaco & Miller, 2005; Ose, 2005; Ostroff, 1992).
Self-assessed workplace productivity measures are widely used in practice, some correlating well with other objective measures of performance (Lynch & Riedel, 2001). Some employees have also been found to self-assess their productivity in terms of the work design elements that get in the way of effective working (Dess & Robinson, 1984; Leaman, 2000; N. Oseland, 1999; N Oseland & Bartlett, 1999).

In the early Hawthorne studies (as cited in Mayo, 1933; Roethlisberger & Dickson, 1939) an underlying assumption was that by changing the context of work - physical changes, such as lighting (E Sundstrom, 1986) - efficiency in production could improve. The outcomes however pointed more to the importance of improved social relations at work, the conclusions relating to the benefits of physical changes having since been called into question (Roethlisberger, 1941).

In a two-factor Motivation-Hygiene Theory, Herzberg (1966) then proposed physical factors (like work environments) are more likely to be a source of dissatisfaction, and with tenuous performance links. However these contentions are not widely supported in practice, (King, 1970; Wall, Stephenson & Skidmore, 1971). Almost forty years on, Hackman & Oldham (1980) found workplace amenities are unlikely to compensate for work, which is inherently poorly designed or meaningless, while Argyle (1989) noted the conclusion that physical factors become more important if they don't meet basic needs does not appear to be supported by empirical evidence.

However, with a trend towards more open working environments, there is greater sharing of physical workspace resources in work delivery (Duffy, 1974a; Duffy, 1974b; Duffy & Ellis, 1980; Duffy, 2000; Spreckelmeyer, 1993; Vos & Van Der Voordt, 2002; Zalesny & Farace, 1987), further complicating the measurement of workplace productivity.

**The Open Plan Workplace and Evaluation**

The open plan workplace is primarily characterized by workspace which has an absence of floor to ceiling separation, internal walls or partitions between co-workers (Zalesny & Farace, 1987).
The benefits of an open plan workplace are variously attributed to lower operating cost (Brennan, Chugh & Kline, 2002; J. D. Wineman, 1986), higher space density, improved productivity (Hedge, 1982), providing a more flexible work environment (Halm, 2004; Ree, 2002; Van Der Voordt, 2003), and increased communication and social cohesion (Allen & Gerstberger, 1973; Boje, 1971; Brookes & Kaplan, 1972; Duffy, 2000; Hedge, 1982; Hundert & Greenfield, 1968; Nemecek & Grandjean, 1973).

Conversely the claimed productivity and other benefits have not been consistently demonstrated in practice (De Croon, Sluiter, Kuijer & Frings-Dresen, 2005; Hedge, 1982; Maher & von Hippel, 2005; Sommer, 1974; J. Wineman, 1982).

A wide variety of factors, such as employee characteristics, individual satisfaction, status, management and job characteristics (Duffy, 1974a, 1974b; Hedge, 1982; K. E. Johnson, 1970; E Sundstrom, Burt & Kamp, 1980; E. Sundstrom, Herbert & Brown, 1982), have been found to mediate between actual office conditions and employee perceptions of them.

The significance of the research by Hedge (1982) and Duffy et al. (1974), is in qualifying which specific factors might mediate occupant concerns about built environment conditions, while differentiating between environmental and job satisfaction as outcome measures. Job related factors (e.g. type, demands, complexity) were found to mediate between objective environmental conditions and the occupants' reported experience of them (Hedge, 1982, p533.).

Marans & Spreckelmeyer (1982a) however pointed to weak construction of the conceptual links between environmental variables and occupant responses to them in prior research, but presented a useful “organizing framework” for objective and subjective evaluation of work environments.

The value in this approach is the explicit recognition of different individual bias, perception and evaluation inaccuracy of the same environmental conditions.
These assumptions hold true for differing workplace environments, outcome measures being determined by the specific behaviours attributed to the space in question.

Another key finding from this research was that “the amount of workspace available to a worker is the most important factor associated with satisfaction”, but again a weakness is the lack of exploration of the connection to job performance.

Wineman (1982) found no demonstrated causal link between worker satisfaction and job performance, but did find evidence that environmental satisfaction is “closely associated with self-related job performance”, citing also Farrenkopf & Roth (1980), L. Harris (1978) and Manning (1965).

**Significantly, Wineman (1982) also found evidence that perception of crowding in offices depends on the job tasks being carried out, while layout and adjacencies were found to be a major source of dissatisfaction in open plan environments.**

Investigating how open office environments can be configured to maintain high levels of occupant satisfaction and performance, Spreckelmeyer (1993) found workspace size (Brill, Margulis & Konar, 1985) to be a useful predictor of worker perceptions, concluding one of the most influential variables is the immediate work setting (Spreckelmeyer, 1993).

**This research raises a number of important questions that warrant further investigation. For example;**

- **Which strategies are most effective in compensating employees for the stress and environmental instability associated with constant workplace change?**

- **Is it more cost-effective to pay employees more or offer increased work flexibility than it is to provide work environments with higher levels of flexibility or aesthetic qualities?**
- **Does increasing user participation and environmental awareness throughout the design and construction process, provide a more cost-effective way to enhance employee satisfaction and performance?**
- **To what extent are built environmental factors more significant if individual/team work processes are highly dependent on such factors?**

**Physical Environment Design, Satisfaction and Performance**

Objective characteristics of physical environment design have been shown to impact upon satisfaction (Brennan, Chugh & Kline, 2002; Carlopio, 1996; E. Sundstrom, 1982; J. D. Wineman, 1986). Some physical environment design elements (e.g. noise, lighting, temperature air quality, privacy, furniture and equipment), can also affect job satisfaction but there are other contributing factors (E Sundstrom, 1986), including work tasks, autonomy, development opportunity, remuneration, supervision, job security, company policy and relations with co-workers.

In another study, Kupritz (1998) found dissatisfaction resulting from larger open work areas, larger work groups and higher spatial densities.

Brill (2001), and Brill, Margulis & Konar (1985), differentiated between individual and teams, confirming ability to work without distraction, a consequence of layout and work area, as the most important factors for both individuals and teams, or where there was a high degree of collaborative work (Brill, 1980-1985; Brill 1994-2000). Carlopio & Gardner (1992) found complex and interactive work relationships to be moderated by work type, and affecting physical environment satisfaction.

M. M. Wells (2000) however presented a case for a direct link between workspace satisfaction and job satisfaction, with “self-schema” as an important activator. Fischer, Tarquinio & Vischer (2004) building on this theme, proposed three major categories of mediating influences on workspace satisfaction (Refer Figure 2), identifying the nature of work being performed, task complexity and expectations about spatial allocation as key variables.
These studies point to a lack of clarity in the definition of satisfaction as an outcome measure, and a need to differentiate between individual employee satisfaction as a psychological construct, team/workgroup satisfaction as a psychosocial construct (work colleagues, reward systems, organization culture etc), environmental satisfaction as a psychosocial or affective response to the built environment (workspace layout, lighting, noise, views etc) and job satisfaction at the individual or team/workgroup level (job content, complexity, autonomy, etc).

Job Performance in the Workplace

The human resources literature has focused on individual job satisfaction and job performance, the research generally pointing to a positive, but weak relationship between the two variables, and certainly no consensus on the “happy-productive worker” thesis (Laffaldano & Muchinsky, 1985),

Elsewhere, there have been extensive studies (O'Neill, 1994; Oldham & Rotchford, 1983; E Sundstrom, Burt & Kamp, 1980; J. Wineman, 1982; Zalesny & Farace, 1987) into the impact of various aspects of the physical environment design on performance.

Brill (1980-1985, 1994-2000) identified positive performance benefits from a range of workspace design elements, (e.g. enclosure, layout), with individual work-style determining the prioritization of these factors. Haynes (2007) also suggested work area layout is a key variable affecting perception of individual work performance.
A great deal of the early built environment research has been based on the assumption that increased occupant satisfaction results in improved performance, this improvement flowing through to higher levels of business organization performance. The findings from these studies have been challenged by questioning the definition of what constitutes “performance”, and the choice of measures that might allow for replication across diverse organizational situations.

Research into the physical work environment can now be broadly clustered as having its focus on environmental satisfaction (Hedge, 1982; Brennan, Chugh & Kline, 2002; Carlopio, 1996; Marans & Spreckelmeyer, 1982b), environmental psychology (Vischer & Fischer, 2005; Leather, Beale & Sullivan, 2003; Russell & Laniouss, 1984; Russell, Ward & Pratt, 1981; Fischer, Tarquinio & Vischer, 2004; Wohlwill, 1974) or indoor environment quality (Gonzales, Fernandez & Cameselle, 1997; Vischer & Fischer, 2005).

Workspace, as a concept, has its origins in the study and analysis of these built environments, having both functional and psychological meaning, capable of delivering work-related value (e.g. support or “tool” integral to the design and conduct of work), whilst providing a context for social relationships at different organizational levels. Hence, more recent interdisciplinary approaches to the study of workspaces (Burgess, Lane, & Stevens, 2000; De Croon, Sluiter, Kuijer, & Frings-Dresen, 2005; Vischer, 2006; R. Cropanzano & Wright, 1999) are bridging the gaps in our theoretical understanding of their impact on human performance.

Organisational psychology also provides a useful, three-factor, non-linear framework (Peters & O’Connor, 1980) for potentially measuring workplace performance, viz;

\[ \text{Performance} = \text{Ability} \times \text{Motivation} \times \text{Opportunity} \]

These aspects are integral to good work design (Parker, Wall & Cordery, 2001), itself a significant factor in delivering work performance outcomes.

Opportunity relates to accessibility, and a person cannot perform if s/he is denied access to needed resources or amenities. Opportunity potentially includes access to workplace physical features such as desks, chairs, or the workspace itself, which
creates conditions that increase health and safety risks, affecting performance (Butterworth, 2000; E Sundstrom, Burt & Kamp, 1980).

Ability to work is primary capacity, but can be extended to include the effects of extreme postures, awkward motions, highly repetitive movement, (Spector, Dwyer & Jex, 1988) exposure to extreme heat or cold, inadequate lighting, glare, or noisy conditions (Evans & Johnson, 2000; Knez & Enmarker, 1998; Leather, Beale & Sullivan, 2003).

Workplaces can also affect motivation by promoting positive affective functioning and psychological engagement, or conversely contributing to negative affect (Evans & Stecker, 2004; Russell & Lanious, 1984; Russell & Pratt, 1980; Russell, Ward & Pratt, 1981). Physical discomfort can also generate psychosocial and psychological reactions (O' Neill, 1994), increased stress (Carlopio & Gardner, 1992; Spector, Dwyer & Jex, 1988; Witterseh, Wyon & Clausen, 2004), and workplace conflicts (Anderson, 1989; Ayoko & Hartel, 2003), which worsen working relationships and decrease motivation. Mood has also been directly tied to motivation and cognitive performance (Rothbard, 2006; Russell & Pratt, 1980).

A more integrated framework (Vischer J., 2002) comprising physical, psychological and functional dimensions is considered more appropriate for performance measurement in the built environment context (refer to Table 1).
This framework suggests user evaluation of workspace is a process combining cognitive and affective responses (Fischer, Tarquinio & Vischer, 2004; Gonzales, Fernandez & Cameselle, 1997) occurring at many different levels and an expression of satisfaction or dissatisfaction with it (Preiser, Rabinowitz & White, 1988; Stokols, 1978).

Using a three-dimensional theory of attitudes developed by Osgood et al. (Osgood, Suci & Tannenbaum, 1957), emotion was identified as a central component in environmental perception, (Gonzales, Fernandez & Cameselle, 1997) particularly for buildings. However, studies of perceptual-cognitive response aspects of building physical characteristics, indicate the basic dimensions of user awareness are objective properties such as space (Gifford, 1987), along with indoor environment quality (Vischer, 1989).

Self-schema (Markus & Kitayama, 1991; Markus & Wurf, 1987), defined as “a cognitive structure containing the generic knowledge that one has about oneself, and
uses to organize, summarize and explain one’s behaviour”, may function as a “cognitive filter” (Fischer, Tarquinio & Vischer, 2004), influencing people’s perceptions of their work situation and consequently how they evaluate their work and work environment. Overall assessment is considered a function of cognitive schema, (Stokols, 1978) where personal expectations and prior experience establish pre-existing standards as a basis for such assessments (Becker, 1981).

The researchers noted that affective and perceptual - cognitive aspects of environmental rating are rarely studied together, providing opportunities for more holistic approaches to performance improvement and evaluation research.

Primary underlying processes of psychological arousal (i.e. activation theory (Katzell & Thompson, 1990)), stress, distraction and fatigue can also account for short-term individual performance impacts in the built environment.

Activation can either help or hinder performance, since it affects the state of alertness, but people generally perform better with moderate levels of activation. Performance on more complex work tasks benefits from lower levels of activation, which facilitates stress reduction (Gardner, 1986; E. Sundstrom, 1986; E. Sundstrom, Town, Rice, Osborn & Brill, 1994).

Environmental stress occurs when individuals perceive the environmental conditions as threatening to their wellbeing or challenge their ability to cope. However, the consequences of environmental stress in the form of distraction depend on the nature of the work tasks being performed. For less demanding work, distraction can increase activation and performance, while these extra demands added by the workplace can lead to degraded performance for more challenging tasks or complex work. When demands in the workplace persist, employees can experience fatigue, physically or psychologically. Table 2 summarizes these various themes in performance evaluation.
<table>
<thead>
<tr>
<th>Level of Evaluation</th>
<th>Facets of Physical Environment</th>
<th>Key Processes</th>
<th>Outcomes</th>
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<tr>
<td>Individual Workers</td>
<td>Indoor Environment Quality</td>
<td>Adaption</td>
<td>Individual Satisfaction</td>
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<td></td>
<td>- temperature</td>
<td>Arousal</td>
<td>Individual Performance</td>
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<td></td>
<td>- air quality</td>
<td>Over Stimulation</td>
<td>Individual Productivity</td>
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<td>- lighting</td>
<td>Stress</td>
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<td>- noise</td>
<td>Fatigue</td>
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<td>Workstations</td>
<td>- floor area</td>
<td>Attitudes</td>
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<td>- furniture/chair</td>
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<td>- colour/aesthetics</td>
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<td>Supporting Facilities</td>
<td>- work areas</td>
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<td>- circulation</td>
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<td>Interpersonal</td>
<td>Differentiation of Workspaces</td>
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<td>Relationships</td>
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<td></td>
<td>- seating location</td>
<td>Regulation of Access</td>
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<td></td>
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<td></td>
<td>Building Layouts</td>
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<td>- proximity</td>
<td>Choices</td>
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<td>- enclosure</td>
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<td>- social and meeting spaces</td>
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<tr>
<td>Organization</td>
<td>Buildings and Layout</td>
<td>Alignment of organization structures and business processes with physical environment</td>
<td>Organization Effectiveness</td>
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<td>- separation/integration of work groups</td>
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<td>- differentiation of work groups</td>
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While this approach goes a long way towards viewing workplace performance evaluation from a business perspective, a criticism of the Balanced Score Card is that it is not sufficiently outcomes-oriented and also not easily scalable from the organizational level down to the individual performance level.
A framework comprising four primary performance outcome categories, based upon Jung's Thinking Style Grid (Jung, 1976), is considered to provide a superior evaluation model. Thinking style underpins behavioural (and learning) style and is considered to be more relevant as an underlying principle for studying the performance of knowledge-based work. Jung's framework also has the benefit of being scalable up and down the different organizational levels at which performance might need to be measured without need for modification or loss of integrity. It is equally applicable at the individual, workgroup, business unit or overall organization level.

Nonetheless, the entanglement of business organizational, socio-technical and other systems creates a context within which the allocation of spatial resources takes place, and shapes the ways these resources directly or indirectly affect the satisfaction and performance of those who use them. This complex setting continues to provide a rich context for further research.

Perspectives on Improving Job Performance in the Workplace

Activation and Inhibition

Social facilitation or social contact and communication (R. G. Green & Grange, 1977), provides stimulation that results in performance improvement (R. G. Green & Grange, 1977) particularly for less complex tasks. Schwab & Cummings (1976) suggest the number of sensory modalities stimulated, the magnitude of the stimulation and the variation in the stimulation combined, contribute to the activation.

Social contact in the workplace can have an optimal level (E. Sundstrom, 1978), beyond which occupants feel the effects of crowding (Altman, 1975) while inability to exercise control over interaction with others has associations with architectural privacy, psychological privacy and performance (E Sundstrom, Burt & Kamp, 1980; J. Wineman, 1982).

Workspaces designed to increase social contact, do not necessarily facilitate increased communication (Brennan, Chugh, & Kline, 2002), can result in over-stimulation (Oldham, 1988; Oldham & Rotchford, 1983; E Sundstrom, Burt & Kamp, 1980; E. Sundstrom, Town, Rice, Osborn & Brill, 1994), and there is evidence this
approach has no positive effect on work outcomes (Allen & Gerstberger, 1973; Brookes & Kaplan, 1972; Nemecek & Grandjean, 1973).

Stimulus screening and inhibitor ability (Mehrabian, 1976, 1977a, 1977b) are identified as important determinants of individual employee reactions to open plan (Maher & von Hippel, 2005; Oldham, 1988), while individual ability to attend to relevant information and inhibit (or suppress) irrelevant information (Lavie, 1995) can be crucial to capacity to concentrate and perform (Lavie, 2005; Mehrabian, 1995) in a distracting environment.

Distraction and overstimulation are “intrinsically linked” to open office design (Oldham, 1988) - another reason why occupants have a preference for lower workspace densities (E Sundstrom, Burt & Kamp, 1980; E. Sundstrom, Town, Rice, Osborn & Brill, 1994).

However, also using activation theory (Scott, 1966), Brennan, Chugh & Kline (2002) argue that the real key to improving work performance is to focus on changing the work itself.

**Overstimulation and Distraction**

While it is often necessary to focus on a single distracting agent, like noise, it may be only one of a combination of environmental stressors. Mental or motor performance, can be adversely affected by workplace background noise, the effect likely to be more severe as work tasks become more complex (Block & Stokes, 1989; Brookes & Kaplan, 1972; Hackman & Oldham, 1975; Hedge, 1982; Oldham, 1988; Oldham, Kulik & Stepina, 1991; Stone, 2001; E Sundstrom, Burt & Kamp, 1980; J. D. Wineman, 1986), or the duration of the noise exposure increases (Glass & Singer, 1972; G. R. Hockey, 1970; G. R. J. Hockey & Hamilton, 1970; Witterseh, Wyon & Clausen, 2004; Wargocki, Wyon, Sundell, Clausen & Fanger, 2000; A. Kjellberg, 1990; Anders Kjellberg & Landstrom, 1994a, 1994b).

It is excessive, unpredictable noise (Kupritz, 1998) more common in crowded settings that causes distraction and hampers performance (Brennan, Chugh & Kline, 2002; D. A. Harris, 1987; L. Harris, 1978), while uncontrolled noise can lead to post
stressor deficits in task performance (Evans & Johnson, 2000; E. Sundstrom, Town, Rice, Osborn & Brill, 1994).

The percentage of occupants, who complain about noise increases with workgroup size and space density (E. Sundstrom, 1986; Sutton & Rafaeli, 1987), the latter dimension also correlates with higher noise ratings (E Sundstrom, Burt & Kamp, 1980).

Environmental Adaption

As people endeavour to adapt to a working environment there are a number of recurring performance management themes and modes of adaption.

Theme 1: Comfort and Efficiency
The idea that a comfortable worker is more efficient, grew out of the notion of the worker as a “human machine” (Meakin, 1905).

Theme 2: Communication and Interpersonal Relationships
Interpersonal relationships have an association with supervision, ability to communicate, visual and auditory accessibility and physical proximity.

Theme 3: Organisational Effectiveness
The workspace may improve organizational effectiveness if it contributes to improved workflow, work practices or coordination.

Mode 1: Behavioural Adaption
People take action to modify their environments or to alleviate the stress conditions that occur. This may include modifying work practices.

Mode 2: Perceptual Adaption
Individuals tend to they set their own psychological benchmarks, but perceptions shift after continued exposure to the environment, usually to the positive. Acclimatization occurs, and negative responses have less amplitude, unless there are environmental extremes or highly variable conditions.

Mode 3: Detachment
Employees doing highly demanding work may “detach” (Csikszentmihalyi, 1988) become more focused and less affected by general environmental conditions.
Workspace Density Satisfaction and Performance

There is some evidence that crowding has negative psychological effects on humans (Evans, 1979; Freedman, Levy, Buchanan & Price, 1971; Griffitt & Veitch, 1971; Saegert, 1978), and depends on work tasks (J. Wineman, 1982). In studies of 5 – 9 person workgroups, in experimental situations Paulis, Annis, Seta, Schkade & Matthews (1976) citing also Freedman, Klevansky & Ehrlich (1971), Kutner (1973) and Sherrod (1974), failed to find any effects of crowding on the “quality of task performance”.

Conversely, both Epstein & Karlin (1975) and Martens & Landers (1972) found crowding in specifically designed experiments using small 2 – 4 person groups, does affect task performance.

Noting that the experimental situations varied greatly in social density (group size), spatial density (amount of space) and proximity (interpersonal distance), Paulis, Annis, Seta, Schkade & Matthews (1976) concluded that task performance could be affected by spatial density, at least in the short term.

One weakness with this research lies in the choice of a “maze learning” task. As this task had previously been shown as one “sensitive to variations in socially induced stress”, individuals performing the task, could reasonably, be expected to be affected, by stress resulting from crowding. A further weakness relates to what constitutes a “large room” (from approx. 9.4m² to 18.0m²) and a “small room” (from approx 0.6 m² to 9.7m²). In a modern open plan workspace, the concept of room is antiquated, while the spatial densities based on actual m² per person would be considered low.

Higher spatial density has been associated with lower job satisfaction (Oldham & Rotchford, 1983; Sutton & Rafaeli, 1987; and Oldham, 1988), while lower interpersonal distance and higher density has been associated with lower job performance (Paulis, Annis et al., 1976; Sundstrom et al, 1980; Worchel & Teddlie, 1976).
Oldham, Kulik & Stepina (1991) also found stimulus screening ability and job demands/complexity moderate the relationship between space density and individual satisfaction and performance outcomes. Additionally, there was some support for the hypothesis that individuals with weak stimulus screening ability in unshielded environments had lower levels of satisfaction and performance (Mehrabian, 1977a, 1977b) compared with other environments, but higher dissatisfaction and lowered performance in high density workplaces (Mehrabian, 1995).

Screeners may adapt more effectively to higher density environments (Baum, Calesnick, Davis & Gatchel, 1982), while non-screeners reported less perceptions of crowding when moved from open working environment to those with more enclosure (Oldham, 1988).

_The weakness in the research here is the emphasis on individual satisfaction and performance, not workgroups that are currently considered the fundamental building blocks of business organization. While the Mehrabian (1977) study did normalize for pay levels associated with job complexity, the satisfaction and performance measures used left a lot to be desired. Equally, there was no clear definition of “low” or “high” spatial density. Job complexity was based on a simple assigned score. Job performance was based on supervisors’ immediate ratings of individual performance. Job satisfaction was measured using the Job Diagnostic Survey (JDS). Hackman & Oldham (1975) Job Characteristics Theory underpinning the JDS is within the Behavioural Approach, which proposes that it is the attributes built into jobs that create the conditions for work motivation and performance (Hackman & Oldham, 1980). Whether any of the satisfaction or performance outcomes found here bear any relation to modern group oriented work is still open to question._

Preliminary Findings and Questions

_It is entirely possible that one of the reasons why previous studies have produced mixed or contradictory findings is that the research paradigm has been too mechanistic, linear cause-effect, microscopic, or too fine-grained._
Overall, these research findings point to the need for longitudinal studies and for further research to be carried out from a more holistic or systems perspective. This research should investigate the effects of space density on the satisfaction and performance of different workgroup types, work processes or task complexity, in different organizational settings. A practical outcome would be to ascertain if there are workspace density “tipping points” beyond which the overall viability of a workgroup could be called into question.

Specific research questions worthy of further scholarly examination include;

- Are there variable impacts of space density dependent on workgroup type?
- Is there is a critical space density at which the work group “tips” from having positive to negative performance outcomes?
- Is there a different tipping point for space density affecting environmental satisfaction or job satisfaction?
- Further, if stimulus screening is a skill, is it possible to learn how to moderate the effects of higher space density?
- To what extent can individual employees adapt to increasing organizational pressure to higher space densities, enabling the “tipping points” to be more effectively managed?
- Is it possible to maintain workgroup at the “edge of chaos” to be able to deliver both optimal space density and workgroup performance outcomes?
CHAPTER 3: LITERATURE REVIEW

The Organizational Benefits of Teams

An Introduction to Teams and Teamwork

It is a global phenomenon that organizations are changing the design of work (Hakken, 1993; Howell, 1993), shifting from individuals doing standalone jobs in highly structured, functional organizations to teams and workgroups embedded in more complex organizational systems (Cooke, 1992), workflows and work practices (Cordery, 2005; Devine, Clayton, Philips, Dunford & Melner, 1999; Gunderson, 2002; Maglen & Shah, 1999; Parker, Wall & Cordery, 2001; Ware & Grantham, 2003).

In the last two decades, the application of high-performance work practices such as teams in organizations has increased dramatically in order to improve workplace performance and employee satisfaction (Campion, Medsker & Higgs, 1993; S. Cohen & Ledford, 1994; Devine, Clayton, Philips, Dunford & Melner, 1999; Glassop, 2002; Kozlowski & Ilgen, 2006).

In an organizational setting, there are many different team definitions, (e.g. Guzzo & Dickson, 1996; Hackman, 1987; E. Sundstrom, De Meuse & Futrell, 1990; Zaiger Roberts, 1994), but a team has been usefully defined as “a collection of individuals who are interdependent in their tasks and outcomes, who see themselves and are seen by others as a distinct social entity embedded within one or more larger social systems” (S.G. Cohen & Bailey, 1997, p241.).

However, when “new” work designs like teams are implemented, they may also have adverse effects on employees (Esser, 1998; Hackman, 1998b; Shepperd & Taylor, 1999), by altering work practices in unintended ways (Zuboff, 1988), or by diffusing temporal and spatial working arrangements (Nicolini, 2007). Work practices comprise actions, reactions, routines and other aspects that acquire overall meaning (ibid. p892), and can be broadly described as a set of techniques or technologically-based tasks that directly shape the labour process (Cordery, 2005).

Technique-based tasks involve the practical application of a particular method, procedure or skill, whereas technologically-based tasks involve using technological
hardware such as machinery or computers.

Team work-practices primarily involve technique-based tasks, whereas knowledge work (Blackler, 1995; Devine, 2002) involves the use of particularly information-based technologies, community and network-based practices, to collect, create and centralize knowledge. Thus teamwork, in an office situation, would appear to be a combination of technique-based tasks and knowledge work, and if organized around the convention of physical co-presence, or spatial co-location, can be affected (Blackler, 1995; Erngestrom, 2000) when changes (e.g. space density) redistribute the work practices, spatially or temporally.

Team working refers to interactions amongst individuals that are necessary for information exchange, developing and maintaining communication patterns, coordinating actions, maintaining social order and the like (Campion, Medsker, & Higgs, 1993; Campion, Papper & Medsker, 1996; Guzzo & Dickson, 1996; Tesluk, Mathieu, Zaccaro & Marks, 1997).

Teams can also be considered as complex, dynamic networks that exist in a particular organization context (Losada & Heaphy, 2004; E. Sundstrom, De Meuse & Futrell, 1990). They develop as team members interact over time, adapting and evolving contingent upon the particular demands of the work situation (Kozlowski & Ilgen, 2006). The dynamic, changing environment in which the team is embedded creates team task demands that team members need to resolve through “coordinated processes that combines their cognitive, motivational/affective and behavioural resources” (ibid. p78.).

**Typologies of Team Types**

A number of differing but overlapping typologies have been presented to identify different team types (Katzenbach & Smith, 1993; E. Sundstrom, De Meuse & Futrell, 1990), but S.G. Cohen & Bailey (1997) identified four prominent and different team types occurring in organizations; work teams, parallel teams, project teams and management teams.
E. Sundstrom (1999) further proposed six team types: production, service, project, action/performance, advisory (parallel) and management, reflecting the trend towards information-based work.

*The weakness in these classifications is a view towards hierarchical organization structure, rather than seeing the team as a specific organization resource directed to achieving effectiveness – that is, adopting a performance outcomes approach. Work and project teams are within and at the bottom of the hierarchy, while managerial teams operate towards the strategic apex of an organization.*

Devine (2002) suggested a general lack of acceptance of the previously mentioned team classification schemes is due to their focus on function and purpose, not the relationship between team type and effectiveness. An “integrated taxonomy” of 14 different team types, clustered according to intellectual or physical work tasks (ibid. p299.) was presented, along with identification of underlying contextual attributes that imply team effectiveness.

*Of potential relevance to the proposed research was the identification of hardware dependence as a key team performance attribute. While not specifically mentioning workspace, hardware referred to tools and other technological resources upon which work groups are highly dependent.*

Despite the uptake of teams, their importance in organizations is changing. In the 1950’s the emphasis was on work redesign (Trist & Bamforth, 1951), worker participation (1960’s), (Likert, 1961; McGregor, 1960) overcoming worker alienation (1970’s) (D. Katz & Kahn, 1978), improving productivity (1980’s) (Shea, 1986), supporting flexible, leaner, more effective organizations in the 1990’s and beyond (Church, 1996; Guzzo & Dickson, 1996; Kozlowski & Ilgen, 2006; Price, 2007; Staw & Epstein, 2000).

Team composition is now defined more broadly in terms of individual characteristics, resources at individual, team and organizational levels, team processes and outputs, viz; performance, meeting team member needs and viability. For example;
“A team can be defined as (a) two or more individuals who (b) socially interact (face-to-face or, increasingly, virtually); (c) who possess one or more common goals; (d) are brought together to perform organizationally relevant tasks; (e) exhibit interdependencies with respect to workflow, goals and outcomes; (f) have different roles and responsibilities; and (g) are together embedded in an encompassing organizational system, with boundaries and linkages to the broader system context and task environment” (Kozlowski & Ilgen, 2006).

Team Performance Effectiveness

Introduction to Team Performance Effectiveness

Team performance effectiveness is emerging as an important area of academic research (Guzzo & Dickson, 1996; Ilgen, 1999; Kozlowski & Ilgen, 2006; Osterman, 2000; Stewart, 2006).

There is no single, uniformly accepted measure of performance effectiveness for teams, but it can be indicated by group-produced outputs, consequences for members of the group and capability to perform effectively in the future (Guzzo & Dickson, 1996).

However, despite the continuing uptake of teams, empirical evidence demonstrating their consistent positive impact on organizational outcomes is rare. While Osterman (1994) estimated 40% of companies in the US had more than 50% of their employees working in teams, Buzaglo & Wheelan (1999) considered 80-90% of teams have performance difficulties.

There is now considerable evidence that the anticipated employee and organizational benefits from implementing teams may not necessarily eventuate (Holman, Wood, Wall, & Howard, 2005) citing also Clegg et al. (1997), Parker & Wall (1998), Patterson, West & Wall (2004), Waterson et al. (1999), Staw & Epstein (2000) and Trent (2003).

Hackman (1998a) found teams in practice tend to “clump” at the extremes of the effectiveness scale, and there are simple reasons why teams fail to perform, most
often related to team structure and support. Hackman (1998b) and Vallas (2003) offer other possible reasons for team performance failure, including:
- the social and technical context is unsuited to teams
- the design of the team structure is deficient
- teams may be poorly supported by other aspects of the organizational resource context including equipment, tools and space

With regards context, it might not be feasible to establish teams where “operating system” predictability is high (Hackman, 1998b), or operational uncertainty is low (Wall, Cordery & Clegg, 2002).

**Teamworking may be more appropriate where there is higher work variability and work complexity, greater requirement for adaptability and interdependence in decision-making, or where there is higher operational uncertainty.**

Team members must also time-share the requirements for socialization, interaction and coordination with the demands of the task(s), resulting in group-process losses (Hackman, 1987; Steiner, 1972), reducing the theoretically expected levels of team productivity or performance.

Team effectiveness is now seen as a dynamic process, creating emergent organizational states (Holland, 1995) that influence team performance outcomes (H. Arrow, McGrath & Berdahl, 2000; Kozlowski & Ilgen, 2006).

**Clearly with the increasing uptake of teams in organizations, team performance effectiveness is a critical management issue.**

**The Dimensions of Team Performance Effectiveness**

There have been numerous studies into what makes teams work and the dimensions that drive team performance.

Hackman & Oldham (1976) identified autonomy and self-management as among the most powerful predictors of team effectiveness, along with conflict resolution, collaborative problem solving, communication, goal setting, performance management and planning and task coordination.
Hackman & Oldham (1980) similarly identified a lack of clarity regarding at what level there is “autonomy”, either group or individual, and which tasks should reasonably be allocated to workgroups as key aspects affecting performance.

Campion et al, (1993) identified five common themes in work characteristics and their relationships with team performance effectiveness, with one characteristic - work task demands - considered to account for a significant percentage of all variance in team behaviour affecting performance (Hackman, 1990; Tesluk, Mathieu, Zaccaro & Marks, 1997).

Stevens & Campion (1994) identified individual member knowledge, skill and ability required for effective team functioning, as key factors underpinning team behaviour.

Cordery (2005) proposed three “team design variables” for high performance, similarly including the characteristics of team task(s), plus team composition and interdependence.

*Cordery (2005) makes a significant contribution to the proposed research, by drawing together many of the threads relevant to the consideration of team performance effectiveness from a more traditional cause-effect perspective. The impact of space density on one or more of the variables identified by Cordery represents a potentially rich vein for future research.*

Further in relation to team tasks, Bowers, Salas, & Jentsch (2006b), citing also Fleishman & Zaccaro (1992) developed a “taxonomic classification of the primary task-related activities or functions that teams perform”, identifying common or “major” team functions that were considered to underlie team performance, viz:

- orientation (exchanging information)
- coordination (and sequencing of activities)
- monitoring (performance monitoring)
- motivation (conflict resolution, maintaining norms)
Meanwhile Cannon-Bowers, Tannenbaum, Salas, & Volpe (1995) proposed a comprehensive list of teamwork dimensions, considered “prerequisites for effective team performance across a variety of types of tasks and teams”.

McIntyre & Salas (1995) used a critical incident approach to interdependence within team structures, similar to that of Fleishman & Zaccaro (1992), to identify critical team behaviours for performance effectiveness. Baker & Salas (1992) had previously included adaptability as a key behavioural dimension affecting team performance.

In developing a classification of team types Devine (2002), also identified team task as having a significant impact on team interaction affecting performance effectiveness.

*These dimensions have relevance for this research in that they offer the possibility of a different approach to team performance effectiveness measurement using a common set of criteria across a diversity of organizational types and team constructs.*

Table 3 summarizes the findings from these various research themes.
Table 3: Dimensions of Team Performance Effectiveness

<table>
<thead>
<tr>
<th>Effectiveness Dimension</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptable</td>
<td>Team members use information from the task environment to adjust strategies through the use of flexibility, compensatory behaviour and reallocation of resources</td>
</tr>
<tr>
<td>Shared Situational Awareness</td>
<td>Team members develop shared knowledge of the team’s internal and external environment</td>
</tr>
<tr>
<td>Performance Monitoring and Feedback</td>
<td>Team members give, seek and receive task-clarifying feedback</td>
</tr>
<tr>
<td>Team Management</td>
<td>Team members direct and coordinate task activities, assign tasks, plan and organize and motivate other team members</td>
</tr>
<tr>
<td>Interpersonal Relations</td>
<td>Team members optimize interpersonal interactions by resolving conflicts, use of cooperation and building morale</td>
</tr>
<tr>
<td>Coordination</td>
<td>Team members organize team resources, activities and responses to ensure complete and timely completion of tasks</td>
</tr>
<tr>
<td>Communication</td>
<td>Team members exchange information efficiently</td>
</tr>
<tr>
<td>Decision Making</td>
<td>Team members integrate or pool information, identify alternatives, select solutions and evaluate consequences</td>
</tr>
</tbody>
</table>


Performance Effectiveness of High Demand Teams

Hackman (1998b) suggested that it might not be feasible to establish teams where the predictability of the “operating system” is high, or conversely team demands are not high. Team workload demand is driven by the supply and demand of resources available to the team (M. Endsley, 1995).

*Teamworking may be more appropriate where there is higher work variability and work complexity, greater requirement for adaptability and interdependence in decision-making, or where there is higher operational uncertainty.*
Team or workgroup tasks can also be classified according to relative task difficulty, being the degree of cognitive load, or mental effort required for problem solution (Bowers, Salas & Jentsch, 2006b).

High demand teams are subjected to greater stress, which has consequences for team interaction, notably a reduction in tendency to assist others, increased interpersonal conflict, lower levels of cooperation and neglect of social cues, plus a narrowing of attention. Peripheral or less relevant task cues are ignored first followed by restriction of central or task relevant cues (Bowers, Salas & Jentsch, 2006b; Broadbent, Cooper, Fitzgerald & Parkes, 1982).
To the extent that these task-relevant cues are neglected, performance suffers.

Stress also results in a narrowing of group awareness. Team members are less likely to maintain broader team perspective under stress and more likely to shift to individual focus, resulting in poorer overall performance as interdependent behaviour is lost (Bowers, Salas & Jentsch, 2006b).

Design Criteria for Performance Effectiveness

Team or Workgroup?
S.G. Cohen & Bailey (1997) reviewed research on “groups” and “teams” noting that these two terms have often been used interchangeably, with the latter term being used more frequently in the management literature and groups being referred to more frequently in the academic literature. Performance effectiveness focus also differs, with group effectiveness measures favouring cohesion and group dynamics among others. A “team” has also been labeled as a group that has developed a “high degree of groupness”, although this convention has yet to be widely accepted (Katzenbach & Smith, 1993).

E. Sundstrom, McIntyre, Halfhill & Richards (2000) provide a very useful historical review of the application of workgroups from their limited, directive use under “scientific management” (Taylor, 1911) to widespread application in the 1990’s organization and workplace transformation (Kanter, 1983; T. J. Peters, 1988). Workplace transformation is broadly defined to include teamwork, multi-skilling and a focus on quality or continuous improvement (Fairris, 2002).
Guzzo & Dickson (1996) maintained that “team” has largely replaced “group” in organizational psychology, but defined a workgroup as being “made up of individuals who see themselves and who are seen by others as a social entity, who are interdependent because of the tasks they perform as members of a group, who are embedded in one or more larger social systems (e.g. community, organization), and who perform tasks that affect others (such as customers or coworkers)”.

Whilst the literature might use the terms team and group interchangeably, there is a general acceptance that “team” connotes more than group, which is its fundamental basis. This subtle degree of difference is significant for this research, as the workgroup and its performance effectiveness can be considered from the perspective as a work-system embedded within one or more larger socio-technical systems in an organizational context.

Design Criteria for Workgroup Performance Effectiveness
However, relating to the design criteria for performance effectiveness of work groups, Campion, Medsker, & Higgs (1993) identified five common themes in the literature. These were job design, interdependence, composition, process and context.

These themes or “clusters” comprised a set of 19 characteristics, derived from different fields of study: social psychology, (McGrath, 1984; Steiner, 1972), socio-technical theory, (Cummings, 1978; Passmore, Francis & Haldeman, 1982), industrial engineering, (Majchrzak, 1988) and organizational psychology, (Guzzo & Shea, 1992; E. Sundstrom, De Meuse & Futrell, 1990). These themes also incorporated the factors previously identified (Hackman & Oldham, 1980) for effective teams.

Figure 3 summarizes the model clustering these workgroup performance effectiveness design characteristics.
Key points to note from these descriptors relevant to the proposed research are:

- **Whilst useful in terms of identifying a diverse range of (input) design criteria for teams/workgroups the performance effectiveness criteria used (productivity, employee satisfaction, manager judgments) were very broad, reflecting the general view at the time that there was no single, uniformly accepted measure of performance effectiveness for teams. A further weakness is the reliance on individual measures of satisfaction, simply aggregated for all employees in each workgroup.**

- **Organizational and resources, could be taken to include the physical environment and included in the context theme as an additional "situational characteristic"** (Tannenbaum, Beard & Salas, 1992), and E. Sundstrom, De
Meuse & Futrell, (1990) present a list of “features of the organizational context” that in their view fostered team effectiveness, including among others, the physical environment.

- A preference for group work may affect workgroup cohesion, individual member attraction to the group and desire to remain within a particular work group.

- Training could be broadly interpreted to include workspace situational awareness and specific knowledge about the physical workplace. Group member familiarity with the work and environment has been shown to be related to productivity (P. S. Goodman & Leyden, 1991).

- Group identity can be shaped by spatial elements or factors, such as the creation of workspace boundaries (E. Sundstrom & Altman, 1989) that serve to increase control over resources or sources of disturbance and distraction.

- Workgroup size could be important for the proposed research because larger groups can become dysfunctional, due to the increased need for coordination. The point is made elsewhere that to be effective, workgroups should comprise “the smallest number needed to do the work” (Campion, Medsker & Higgs, 1993) citing also (P. S. Goodman, 1986; Hackman, 1987; E. Sundstrom, De Meuse & Futrell, 1990).

- All of the process characteristics could be affected by space density as a variable resource. Process in this context was not considered simply from an input-process-output perspective, but in terms of things that occur within the group that are considered to impact upon effectiveness (i.e. from a group internal perspective).

Further value can be found in the thoroughness of the sampling method used (Campion, Medsker & Higgs, 1993) and the recommendations for studying work groups, (P. S. Goodman, 1986).

In addition, the workgroups studied involved at least two different classifications of group work; either involving sequentially interdependent workflows (i.e. flowing from some employees to others) or reciprocally interdependent workflows (i.e. flowing back and forth between employees) for the sharing of resources, knowledge and responsibilities.
The most important conclusions from this research and implications for the proposed research are:

- Context characteristics related mostly to satisfaction, and while more directly controllable as an input characteristic (than process), the importance of context and resources had only recently been recognized. Training, in terms of group member familiarity with work environment is related to productivity (P. S. Goodman & Leyden, 1991). Clearly there are opportunities to investigate the impact of workspace resources, particularly where such resource might be a critical work task tool.

- Process characteristics related mostly to productivity, highlighting the importance of this theme to the effective functioning of work groups. Opportunities exist to take a broader view of process characteristics to include factors such as cohesion, although the authors referred to this characteristic as being associated with composition via a preference for group work.

- Job design characteristics were related to all three workgroup performance effectiveness criteria although the focus here is on work task design. There are opportunities to expand these characteristics given changes in the nature of work since the 1990’s, particularly with regard to the increased use of IT, increased information intensity and resultant job complexity.

Aiming to establish the generalizability of their previous findings, Campion, Papper & Medsker (1996) extended their research to knowledge work, which was considered to be more complex (Campion & Berger, 1990), finding the effects of the 19 team characteristics on performance effectiveness to be similar. Effectiveness measures however included the dimension of time, which was a significant research development.

A key difference in the findings compared with the previous study was the apparent reduced significance of the composition characteristics, which might influence the value of further research on cohesion. Context characteristics were also found to have slightly stronger relations with effectiveness than the previous study, while process characteristics had the most criterion relationships. Importantly the need for further research into team performance effectiveness measurement is warranted given workgroup satisfaction and productivity have been
shown to be “inherently conflicting outcomes” (Campion, 1988; Campion & McClelland, 1991).

E. Sundstrom, McIntyre, Halfhill & Richards (2000) summarized research into workgroups from the time of the original Hawthorne studies (Roethlisberger & Dickson, 1939). They focused on the following important questions, relevant to the proposed research;

- what identifying features have been used to operationally define workgroups?
- which criteria have been used to measure the performance effectiveness of workgroups?
- which variables have linkages with measures of work group effectiveness?

In relation to the first question; operationalizing workgroups, the key identifying features were confirmed as shared responsibility and interdependence, in addition to those defined by Hackman (1990), viz; intact social systems, having boundaries, interdependence amongst members, differentiated member roles, shared purpose, identified tasks to perform, shared responsibility for producing identifiable outcomes, operation in an organization context and with manageable relationships with other parts of a larger social system (ibid. p52.).

Noting the resurgence of field studies of workgroups since the1980’s, the analysis focused on studies that measured broader facets of performance effectiveness. Performance (Pelld, Eisenhardt & Xin, 1999) and effectiveness (Campion, Medsker, & Higgs, 1993; S. G. Cohen, Chang & Ledford, 1997) have been considered as global criteria, although some studies have equated performance with effectiveness (Tziner, 1988), or defined performance as an aspect of effectiveness (Gladstein, 1984).

Productivity, as a criterion, because of its input-output emphasis, was most associated with performance evaluation for production and service groups. (E. Sundstrom, McIntyre, Halfhill & Richards, 2000).

Importantly, (ibid. pps47, 48, 54.) other less frequently used global performance criteria, including viability (E. Sundstrom, De Meuse & Futrell, 1990) and cohesion (Harrison, Price & Bell, 1998a) were also identified.
The importance of this research also lies in the identification of effectiveness criterion, which are more internal to the group (cohesion, integration, member satisfaction, attitudes and behaviour) as alternatives to external measures of productivity or outcome performance.

The research also makes reference to workgroups as sharing a physical location, a relatively recent observation, suggesting an area ripe for further workgroup research. (E. Sundstrom, McIntyre, Halfhill & Richards, 2000), citing also Buller (1988), Fry & Slocum (1984) and George & Bettenhausen (1990).

E. Sundstrom, McIntyre, Halfhill & Richards (2000) concluded many of the prior models of workgroup effectiveness (Argote & McGrath, 1993; Campion, Medsker & Higgs, 1993; Campion, Papper & Medsker, 1996; S.G. Cohen & Bailey, 1997) tend to overlap and converge to the category frameworks, with those factors relevant to the proposed research identified as follows, viz;

Organizational Context
Systems or features of the overall organization, including training, measurement and information systems

Group Composition
Workgroup size, member traits and attributes, demographics and competence

Group Work Design
Including equipment, task characteristics, group autonomy, degree of self-management

Intragroup Processes
Interactions and relationships among members, communication, coordination, conflict, collaboration, status, roles, and group characteristics such as cohesion, perceived potency and group norms

External Group Processes
Interactions of work group members directed outside of the group

In relation to work design, Cascio (1995) identified a shift away from task-based work to more process-based work, accompanied by an increasing emphasis on the cognitive demands of tasks (ibid. p932.). Cognitive demands imply a shift from “doing” activities to thinking, trouble-shooting and multiple tasks that may change over time. Workers increasingly participate as members of multiple teams, sharing
information, communicating and collaborating to deliver shared or workgroup outcomes (ibid. p933.).

Cognitive work task analysis seeks to uncover the cognitive demands of modern work, the processes that underlie performance and the subtle cues that may depend on employee experience and work context, including those obtained or received from the physical environment (Brenner, Sheehan, Arthur & Bennett, 1998).

*This kind of analysis suggests a more holistic or systems-oriented approach to workgroup performance effectiveness evaluation is appropriate.*

Parker, Wall & Cordery (2001) identified four major theories underpinning thinking in work design practice: Herzberg’s “Two-factor Theory” (Herzberg, Mausner & Snyderman, 1959), since refuted (King, 1970), the Job Characteristics Model (JCM) (Hackman & Oldham, 1976), socio-technical systems thinking (STS) (Trist & Bamforth, 1951) and more recently team effectiveness models (Campion, Medsker & Higgs, 1993; Parker & Wall, 1998).

Whilst JCM and STS are still popular in work design research today, both approaches have proven more effective in determining employee affective responses (satisfaction and motivation) than work performance behaviour or outcomes (Parker, Wall & Cordery, 2001).

*This finding serves to confirm that much of the work – performance – effectiveness research effort is still focused on the nature and content of the work itself and how this content affects satisfaction and behavioural outcomes (including performance), potentially ignoring antecedents of work/workgroup design (such as existing workspace design) and characteristics of increasing importance (such as increased workspace density), thus presenting opportunities for extension with this research.*

The context for work today is very different from the time when the major work design theories were developed. Organisations face greater uncertainty than they did in the past and need to cope with increased complexity. Flexibility is a key business factor. Work design needs to accommodate this more dynamic perspective and recognize that it is more tightly intertwined with organizational
initiatives and practices, such that performance effectiveness outcomes are now co-created.

Parker, Wall & Cordery (2001, p240.) proposed an elaborated model of work design, but still failed to recognize the interaction of human, technological and spatial systems for modern work at the individual, workgroup and organizational level, establishes a more appropriate context for an expanded list of work characteristics, their antecedents and effectiveness outcomes.

Stewart (2006) cited a heuristic model of group effectiveness (S.G. Cohen & Bailey, 1997) as representing a deviation from the more traditional input-output models (Hackman, 1987; Hackman & Oldham, 1976; McGrath, 1984) directed towards the team/group performance measures. Importantly, composition as a key design characteristic was considered in terms of how individual attributes (disposition, skills, ability) aggregate to the group level, and predict collective performance. An underlying assumption was that the emergent group response was a linear aggregation of individual characteristics (Chan, 1998; Stewart, 2003), although it was concluded that “very little is known about the relative value of different characteristics when they are aggregated to predict collective performance” (Stewart, 2006. p32.).
Stewart (2006) further contended that the performance effectiveness framework is a function of environment (industry characteristics, turbulence), design factors (composition, task features), internal and external processes (communication, conflict) and psychosocial traits (norms, shared mental models). “Design factors” were defined as “those features of the task, group and organization that can be directly manipulated by managers to create the conditions for effective performance” (S.G. Cohen & Bailey, 1997).

This could include workspace through the manipulation of workspace density.

While this framework may still not capture all of the constructs related to teams and their performance, it draws attention to the major design factors, which leverage team effectiveness, whilst within the input-process-output model for team/workgroup effectiveness (Gladstein, 1984; Hackman, 1987; McGrath, 1984), design features merely comprise inputs.

The value of this research lies in the inclusion of physical surroundings (ecology) (Levine & Moreland, 1990a) and other design features impacting on work-task information intensity or complexity (Guzzo & Dickson, 1996; Levine & Moreland, 1990a).
Important questions have been raised regarding the dispositions of individual team members and how they might aggregate to collective performance. Stewart’s conclusion that little is known about the relative value of different (individual) characteristics when they are aggregated to predict collective performance suggests a more holistic, systems-oriented approach to team performance effectiveness research may be worthwhile.

Campion, Medsker & Higgs (1993) reviewing work familiarity and its links to performance effectiveness, citing (P. S. Goodman & Leyden, 1991), considered work complexity, to be based on three criteria:
- the programmability of the task activities - the more programmable, the lower the complexity.
- difficulty of task activities - the greater the effort or number of skills required, the more complex.
- diffusion of task information - the more diffuse is knowledge, or the less it is centralized, the more complex is the task.

Performance Effectiveness of Self-managing Workgroups
Glassop (2002) identified three basic types of teams; problem-solving, cross-functional and self-managing work groups (SMWGs). A SMWG is a formal team structure defined as “a group of interdependent individuals that have accepted responsibility for a group task and share this responsibility by monitoring and controlling the contributions of its members” (ibid. p227.) also citing (S. Cohen & Ledford, 1994; F. Emery & Emery, 1974, 1993).

A brief, specific consideration of self-managing workgroups is relevant to this research. Their wide application would enable cross-organizational research in order to replicate specific research findings.

The adoption of semi-autonomous, self-managing workgroups by organizations has been driven by the need for more flexible and adaptive work structures (F. Emery & Emery, 1993). The purported performance benefits include improved service quality, lower cost in management structure, lower levels of absenteeism and employee turnover and higher levels of workplace productivity (Glassop, 2002).
A lack of clarity regarding workgroup autonomy, has previously been identified as a key aspect affecting studies of team performance (Hackman & Oldham, 1980). Most of the evidence for performance benefits has been limited, organization-specific, case-based or anecdotal (Bowers, Salas & Jentsch, 2006a; S. Cohen & Ledford, 1994).

Despite these deficiencies, studies seem to suggest there are no clear team benefits from SMWGs, but there are individual benefits in job satisfaction, motivation and work performance. There have been even fewer studies of the organizational benefits, resulting in a lack of empirical evidence to support the case for the continued widespread adoption of this type of team.

The analysis of Australian Workplace Industrial Relations Survey data from 1995 at the “firm” (organizational) level (Glassop, 2002), found firms that only have SMWGs reported improved labour productivity, defined simply as labour utilization (i.e. labour input to unit output).

*Despite the deficiency of the data used in this research, and the lack of evidence to support any labour productivity gain from SMWGs being sustained over time, the value of this research lies in its support for the theoretical premise of redundancy of parts of the team or workgroup considered as a “work system” (E. Davis & Lansbury, 1996; F. E. Emery, 1972, 1993).*

“These elements are inherent to the notion of productivity, inasmuch as productivity is generally viewed as a measure of output per unit of composite input (that is capital plus labour), (Horngren, Foster & Datar, 1997). Given the same level of inputs, if errors and problems are eliminated and work continues undeterred then the resultant output would be expected to be above that of a work system that had not been designed to attend to these issues; hence the notion that Quality Circles and SMWGs improve productivity” (Glassop, 2002).

**Performance Effectiveness of Autonomous Workgroups**

Similar to the findings for SMWGs above, Harris (1994) found satisfaction in autonomous workgroups to be higher than in traditional workgroups, although this
difference abated over time, and that improvements in team performance did not necessarily yield gains for the whole organization.

This finding reinforces the need for performance effectiveness measurement to be made at the workgroup level, rather than using higher organizational level performance effectiveness measures.

Performance Effectiveness of Computer-Mediated Workgroups

Much can be learnt about workgroup performance effectiveness from the study of more information intensive, computer-mediated workgroups.

Computer-mediated workgroups (Mandviwalla & Olfman, 1994) tend to be characterized by interaction that is heavily mediated by computers, have group tasks that require higher levels of coordination, and are less “productive” in terms of quantity, not quality. High computer use might also imply higher levels of information intensity and increased work complexity (Bartel, Ichniowski & Shaw, 2004; Gonzales & Mark, 2004; Hakken, 1993; Howell, 1993).

Conversely, Hakken (1993), maintained that despite the “computer revolution”, there is considerable empirical evidence (Hakken, 1991) that work has not changed much at all.

Computer-mediated groups however do appear to be superior at innovating, in generating ideas, and enhance group processes where tasks are more structured. Face to face groups seem to be better on problem solving tasks and those requiring conflict resolution (Gibson & Gibbs, 2006).

If there is a tendency for individuals to become self-focused, or perhaps withdraw into “the computer screen”, what might be the consequence of higher spatial density on team performance effectiveness for this more complex type of work?
Longitudinal Effects in Workgroups and Performance Effectiveness
In a relocation of people from traditional to open offices, Brennan, Chugh & Kline (2002) examined performance effectiveness over time, in particular satisfaction with the physical environment, team member relations and perceived job performance.

In relation to physical environment changes over time and employee reactions (satisfaction, performance, effectiveness) it was noted there had only been one previous study, suggesting a field of research worthy of further attention. (ibid, p 283.), citing also Stokols, Churchman, Scharf & Wright (1990). The value of this research lies in the particular approach taken to measure performance of employees over an extended time period, the opportunity to extend the research to cover workgroups and make the study more dynamic.

A context specific instrument was created, addressing four performance outcome variables, and incorporating the functionality and design of the physical environment, physical stressors, team characteristics (member relations), and organizational context (use of protocols) (Brennan, Chugh & Kline, 2002).

The general findings from the research can be interpreted in the light of previous research that suggest the degree to which open offices are successful depends on "specific space considerations", and small-scale environmental features (individual work surface area, privacy, and noise) account for "incremental variance in employees' satisfaction with their work environment, above and beyond the office design alone". Those in most demanding jobs appeared to be more negatively affected, (ibid. p293-295.), citing also (Marans & Yan, 1989; Spreckelmeyer, 1993; E Sundstrom, Burt, & Kamp, 1980; E. Sundstrom, Town, Rice, Osborn & Brill, 1994).

Member Longevity, Group Stability and Performance Effectiveness
One of the major problems in the study of workgroups is taking into account the effects of time. R. Katz (1982) looked at the performance differences in different project groups, with different member longevity. As project success depends on the collection, processing and communication of information from a variety of sources, a tendency towards more predictable levels of certainty with increasing group longevity, the effects of behavioural stability, and group homogeneity might combine
to reduce workgroup performance effectiveness particularly if it is more knowledge based. The results here show a non-linear relationship between group member longevity and performance and significantly lower performance outcomes for projects with group longevities of less than 1.5 years or more (ibid. p92.).

This finding could have implications for the selection of workgroups for this research based on group member longevity.

Carley (1991) also looked at interaction probabilities and other determinants of group stability, to investigate the effects on effectiveness as new members enter the workgroup in the short term, and what types of groups are least affected by the addition of new members? A group was considered to be “perfectly stable only when no new information enters the group and everyone in the group knows everything that any-one else in the group knows” (ibid. p332.). In the process of group members interacting, exchanging information, learning, adapting their behaviour, interacting, and so on, individual and group behaviour is simultaneously and cyclically determined. Formalization of this process is considered necessary if group behaviour is to be predicted and consistent performance outcomes delivered (ibid. p333.), citing also (Turner, 1988).

The proposed “dynamic-model”, was considered more applicable to small groups over short periods of time, in less formal organizational structures and where interactions were primarily concerned with the exchange of information.

Smaller groups were found to be more stable in the short term, (ibid. p351.), with further implications for the selection of workgroups based on size characteristics, in the proposed research.

Further relevance of this research lies in the potential impact changes in spatial conditions (e.g. space density) over time, higher levels of job information intensity, and work complexity have on interaction probabilities, potentially causing the group to become less stable.
Workgroup Process and Performance Effectiveness

Within the commonly accepted input-process-output framework for team performance effectiveness, design features are considered as inputs (Campion, Medsker & Higgs, 1993; Campion, Papper & Medsker, 1996; Gladstein, 1984; Guzzo & Dickson, 1996; Guzzo & Shea, 1992; Hackman, 1987; McGrath, 1984; Tannenbaum, Beard & Salas, 1992). Mediator and moderator variables act on these inputs to determine outputs. This approach is summarized in the model depicted in Figure 5.

Figure 5: Input-Process-Output Model for Workgroup Effectiveness

![Input-Process-Output Model](image)

Source: Adapted from Hackman & Oldham (1980)

In this model, information and communication technology (ICT) and workspace as a physical space technology are explicitly included as moderator variables.

The heuristic framework (S.G. Cohen & Bailey, 1997) suggested team effectiveness is less input-process-output in nature and more a "function of" environment context, both internal and external to the organization, work design factors, workgroup processes and individual psychosocial traits (shared mental models).

Group composition research (Kozlowski & Klein, 2000) developed the theme of individual characteristics aggregating to emerge as a team level construct. A linear
model was initially proposed by Chan (1998) and Stewart (2003). Stewart (2006) subsequently confirmed aggregations of personality and cognitive ability "correspond with team performance", whilst conceding that further research is warranted to determine which aggregated traits are most strongly connected with performance.

Kozlowski & Ilgen (2006) further proposed a cyclical and reciprocal process model to review team effectiveness as a dynamic process, and emergent states that contribute to team effectiveness similarly resulting from a dynamic process that "coordinates" the cognitive, affective and behavioural resources of individual team members. In this model, team processes and emergent states are shaped by team mental-models among other things. Team mental models (Klimoski & Mohammed, 1994) refers to information or knowledge structures shared by the team or workgroup that might help improve performance. The primary content domains of team mental models initially proposed included the "equipment model" (Cannon-Bowers & Salas, 1993) - knowledge about equipment and tools used by the team.

*With reference to Figure 5, the equipment model in a modern workplace would most likely include ICT and workspace tools.*

Similarly, team behaviour and affective processes and emergent states focuses attention on (workgroup) cohesion as a construct that has consistently been linked to performance (C. R. Evans & Dion, 1991; Katzenbach & Smith, 1993; Mullen & Copper, 1994; K. G. Smith et al., 1994).

Team cognition therefore requires communication about the work environment in which the team task is embedded. Physical environment cues therefore can help establish these shared mental-models, the phenomenon referred to as distributed cognition, whereby team members exploit features of the social and physical environment as resources for accomplishing tasks (Hutchins, 1997).

MacMillan, Entin & Serfaty (2005) refer to the time taken to develop this cognitive resource as communication “overhead”, which increases as task interdependence increases - that is, as team workflow demands or complexity increases.
This points to the need to account for work demands or workflow complexity for the teams/workgroups selected in this research. Task Load Index used by Hart & Staveland (1988) might also hold promise for workload rating.

**Cohesion and Workgroup Performance Effectiveness**

Multiple definitions of cohesion have been put forward by team researchers (Carron, 1982; C. R. Evans & Jarvis, 1980; Festinger, 1950).

A broad definition of cohesion, being “a general orientation or motivation towards developing and maintaining social relationships within the group”, has been proposed by (Widmeyer, Brawley & Carron, 1985).

Cohesion has since been variously conceptualized as group level input (Hackman, 1987), as a group psychosocial trait (S.G. Cohen & Bailey, 1997), as part of the category of group structure and process (E. Sundstrom, De Meuse & Futrell, 1990), and as part of group process (Bettenhausen, 1991).

A meta-analysis focused on group level cohesion and performance found cohesive groups on average were more productive than non-cohesive groups, despite measurable performance criteria for groups being “extremely difficult” to define (C. R. Evans & Dion, 1991). Gully, Devine & Whitney (1995) while noting methodological problems with the Evans & Dion (1991) study, confirmed high cohesion-performance relations at the group level, as did Beal, Cohen, Burke & McLendon (2003), who reconceptualized performance as behaviour (ibid. p996.).

An even more significant finding was that the strength of the relationship between workgroup cohesion and performance depended on the team workflow pattern type (Tesluk, Mathieu, Zaccaro & Marks, 1997).

A simple measure for “unification” or cohesion within groups (Polley, 1985; Polley & Jessup, 1988) proposed an optimal level of cohesion for workgroup performance. Kelly & Duran (1985) also found very high levels of cohesion were associated with poor team performance.
This research points to team performance being low at both low and high levels of cohesion, suggesting a non-linear relationship might exist between cohesion and performance.

What then are the critical team constructs that might “optimize” cohesion and thus performance? What role does space density have to play?

Further research is needed using a measure of group cohesion that can be applied to work groups in an organizational context, and consistently across a range of different organization types.

None of the moderating variables used to explain variance in the cohesion-performance relationship (C. R. Evans & Dion, 1991) were “spatial” in nature. However, E. Sundstrom, De Meuse & Futrell (1990), citing also E Sundstrom (1986), identified “physical proximity of workspaces” as one of the conditions likely to be favourable to cohesion.

There has been a general lack of agreement on how to operationalize and measure cohesion, but increasing agreement that cohesion is a multi-dimensional construct. Carless & De Paola (2000) differentiated between task cohesion and social cohesion, examining further whether the latter is antecedent to the former. Evidence indicates task cohesion is more related to work performance than social cohesion (Mullen & Copper, 1994; Zaccaro, 1991; Zaccaro & Lowe, 1988).

To shed more light on how cohesion for work groups could best be operationalized, Carless & De Paola (2000) investigated a range of measurement tools, viz:

- **Team Cohesion**, an adapted 18 item Group Environment Questionnaire (GEQ) (Carron & Brawley, 2000)
- **Work Group Characteristics**, using seven sub scales (Campion, Medsker & Higgs, 1993)
- **Team Effectiveness**, a five item scale (Careless, 1995)
- **Job Satisfaction**, using the Minnesota Satisfaction Questionnaire (MSQ) (Weiss, Dawis, England & Lofquist, 1967)
- **Work Group Performance**, using managerial ratings on a 7-point Likert Scale (Carless & De Paola, 2000)
The GEQ (Carron & Brawley, 2000), was developed specifically for sports teams and based on the definition provided by Widmeyer (1985). In this regard, a group was defined as “two or more individuals who possess a common identity, have common goals and objectives, share a common fate, exhibit structured patterns of interaction and modes of communication, hold common perceptions about group structure, are personally and instrumentally interdependent, reciprocate interpersonal attraction and consider themselves to be a group” (Carron & Hausenblas, 1998).

The GEQ treats cohesion as a dynamic process, not a trait, and thus changeable over time, having an instrumental basis and an affective dimension (Carron, Brawley & Widmeyer, 2002).

In using the GEQ, the assertion is that cohesion, a group property, can be assessed through the perceptions of individuals in the group. In relation to the unit of analysis (individuals, aggregated group measures, the group as a whole), the authors indicated it depends on the nature of the specific research. Individual questions might be used on their own, or the four scales may be presented as aggregated or averaged scores, but not as an overall single measure of cohesion from the combined scales.

Carless & De Paola (2000) selected 18 items from the GEQ in the four categories that reflected both task and social cohesion components. Group integration and Individual Attraction to Group aspects were further divided into Task and Social components. In relation to workgroup effectiveness, some of the sub-scales developed by (Campion, Medsker & Higgs, 1993) to assess work group characteristics that related to cohesion were extracted.

For team effectiveness, Carless & De Paola (2000) developed their own 5 point scale, but these were based on individual perceptions of how the team overall was considered to be functioning. The MSQ provided input to how individuals judged their satisfaction with the group. Performance outcomes related to the specific organizational context, in this case measured by customer service, efficiency, work completion and service innovation.
While the study did not identify specific workflow type for the teams, the value of the research lies in its detailed assessment of aspects of the overall cohesion construct, which are more or less relevant to performance, and through factor analysis the finding that task cohesion, social cohesion and individual attraction to group all have different impacts on performance. This research led to the construction of a ten-factor, Team Cohesion Scale, more generally applicable to organizations, and comprising only three underlying constructs (Carless & De Paola, 2000), viz:

- Task Cohesion (4 factors)
- Social Cohesion (4 factors)
- Individual Attraction to Group (2 factors)

The findings summarized below point to the need for further research in this area.

- Task Cohesion most strongly relates to team effectiveness, and results from both individual and group level processes. Individuals do not appear to distinguish between individual and group level task cohesion (ibid. p82.).
- Commitment to task relates to work group performance but social aspects of cohesion may be unrelated to work group performance. Also citing Mullen & Copper (1994) and Zaccaro (1991).
- As cohesion can be either task or social, social cohesion could be impacted before task cohesion, particularly where overall cohesion is important for workgroup performance. A change in social cohesion might then affect task performance either directly or via changes in task cohesion.

The relationship between cohesion and performance also needs to be explored for different workgroup types, under different work environment conditions. The value of the research in differentiating between task and social cohesion, is that social cohesion was considered to be an antecedent to task cohesion, also citing Zaccaro & Lowe (1988).

Carron & Brawley (2000) in response to the findings of Carless & De Paola (2000), further defined cohesion as “a dynamic process that is reflected in the tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member affective needs” citing also (Carron & Hausenblas, 1998).
Defining cohesion as a “process” raises research questions concerned with the changing nature of the cohesion-performance relationship, not only for different team types, but also over the lifecycle of the team itself. These issues have implications for this research in terms of team selection and its life cycle stage.

With respect to space as a resource (reflected through space density) its relation to cohesion remains to be proven. Flowing from this is the possibility that continued research might indicate for different workgroup types, or different workflow types, there is an optimal space density, or “range” where cohesion and performance are both optimized.

Physical Space and Workgroup Performance Effectiveness

Proximity, Propinquity and Performance Effectiveness

Sommer (1967) observed that the systematic study of spatial arrangements, in small, face-to-face groups was a comparatively recent development, but noted that for individuals in such groups, it is a function of, among other things, group task and the amount and kind of available space.

Whilst not specifically studying space density and crowding, “conversational distance” (Hall, 1959) was identified as influencing avoidance and other adverse behaviours, contingent upon gender type (Garfinkel, 1964), personality (Williams, 1963) and ethnic attitudes (Campbell, Kruskall & Wallace, 1966).

To the extent individual employees find themselves in increasingly impersonal environments, knowledge of how groups arrange themselves in space can assist in fostering or discouraging group relationships important for performance effectiveness (communication, social arrangements and productivity), particularly where the occupants have little control over their surroundings (Sommer, 1967).

These findings potentially have relevance for workgroup selection and description in this research.

Proximity, an aspect of physical structure, being “the architectural design and
physical placement of furnishings in a building that influence or regulate social interaction" (T. R. V. Davis, 1984), has been identified as an antecedent of cross-functional cooperation, influencing the type of interactions, exchanges and communications within and among groups in organizations, and thus group performance effectiveness (Pinto, Pinto & Prescott, 1993; Souder, 1981).

Interaction and communication are affected by physical characteristics of workplace settings, with frequent interactions shown to produce interpersonal attraction, which “creates the conditions for high task performance” (Moenart & Souder, 1990; G. R. Oldham & Brass, 1979; T. Peters, 1990).

However, in relation to the specific effects of physical nearness among team members, in place (propinquity), the direct linkages to project outcomes were considered to be inconclusive, it being suggested an indirect link exists between psychosocial traits such as member relationships and communication flows (Pinto, Pinto, & Prescott, 1993), citing also Allen (1977), Keller (1986) and Keller & Holland (1983).

Proximity was found to have a significant impact on cooperation suggesting the physical layout of a workplace can affect the frequency and nature of interactions among team members, factors that impact on workgroup cohesion (ibid. p1294.).

A weakness of the research lies in the use of a single item seven-point scale to determine team member perceptions of physical proximity. Conversely, whilst psychosocial outcomes as indicators of performance effectiveness for work teams was considered a field worthy of further attention, this preliminary finding lends further weight to the importance of group cohesiveness as a predictor of team outcomes (Pinto et al., 1993).

Trent (2003) whilst again noting the lack of consistent empirical evidence supporting the relationship between “teaming” and improved performance outcomes, switched his attention to creating an environment that increases the likelihood that teams will be successful.

In presenting a generic, “work team planning guide” (ibid. p55.), team resources (L. H. Peters & O'Connor, 1980; Trent & Monczka, 1994), were identified as an
important factor, more specifically the work environment, being “the physical aspects of the team's work environment” (Trent, 2003, p55.).

It was also concluded that the allocation of resources could be different for every team, dependent on its “assignment” (ibid. p55.).

*This general finding prompts a question as to whether the allocation of workspace density, as a work environment resource, might need to be different for different team types, and/or other workgroup characteristics shown to have a relationship with performance effectiveness.*

**Extreme Colocation and Performance Effectiveness**

A “war-room”, where people work closely, collaborating together in a face-to-face situation using a variety of technologies is an example of an extreme physical environment used by specific types of project teams (Mark, 2001). Examining these kinds of workspaces is considered instructive given the current research aim.

War-room environments have been shown to substantially increase productivity by encouraging extreme collaboration (Teasley, Covi, Krishnan & Olson, 2000; Covi, Olson & Rocco, 1998). Extreme collaboration was defined as “working within an electronic and social environment that maximizes communication and information flow” (Mark, 2002, p1.).

Despite the high level of background noise, team success was found to depend in part upon the ability of individuals to develop clear mental “maps” (internal models) of their particular team interdependencies, which provided a focus for effort. Combined with a high situational awareness, this helped limit overload in the work environment (ibid. p91.). In physical space, the colocation of team members makes the human “networking” system visible.

“Activity among team members is always related to physical location, and each one's activity is visible to everyone else in the room. Thus, the physical arrangement of the entire group provides indication to everyone else as to the state of the human network, which in turn conveys information about a particular mission proposal’s overall design status” (ibid. p92.), also citing Kendon (1990).
Hutchins (1997) refers to the phenomenon of workgroup members exploiting social and physical system elements as resources for task accomplishment as distributed cognition.

Whilst the researchers studied design project teams in enclosed spaces, the findings highlight the importance of team member situation awareness and cognitive ability in order to function effectively in higher space densities.

Teasley, Covi, Krishnan & Olson (2000) also found significant productivity enhancements when teams were radically colocated and “time-boxed” in a project space for the duration of the task, but the improvements were not attributable to the colocation and time-boxing individually. This type of physical work environment best supported continuous, interactive communication, movement within the space and use of other shared “artifacts” that helped make visible project status and responsibilities, i.e. performance effectiveness (ibid. p 34.).

The findings parallel those from studies of open plan working where noise, distraction, visual disturbance and lack of privacy affect satisfaction and performance, but also highlight potential issues to be considered in this research where work may be in open plan, more sedentary in nature, with higher space density (Hutchins, 1997).

Situation Awareness and Performance Effectiveness
Adams, Tenney & Pew (1995, p85.) refer to situation awareness as “the up-to-the-minute cognizance required to operate or maintain a system”. Whilst research into situation awareness from a human factors perspective has focused on the domain of aviation (M. Endsley, 1990; M. R. Endsley, 1988; Fracker, 1988), the issues in situation awareness are also considered applicable to any complex system (Adams, Tenney & Pew, 1995), and other complex work environments (E. Salas, Prince, Baker & Shrestha, 1995).

Adams et al. (1995) maintain that situation awareness is not the same as “performance”, but in critical situations and potentially in the context of complex, demanding work which has a high mental workload (Hancock & Meshkati, 1988), the consequences of not having a high situation awareness can be a problem for team

Studies of situation awareness focused on cognitive processes and temporal components (E. Salas, Prince, Baker & Shrestha, 1995) have addressed definitional difficulties to present two alternatives of interest to the proposed research. Fracker (1988) identified attention to knowledge allocated to a zone of interest, being the "volumes of space that surround the agent", while M. R. Endsley (1988) defined situation awareness in terms of perception of elements in the environment, within a volume of space and time.

Accordingly, the process of situation awareness can also be described as a type of mental workload (Pew, 1994), involving the observing, exploring and perceiving critical information in the environment, based on pre-existing knowledge (E. Salas, Prince, Baker & Shrestha, 1995) and expectations (Becker, 1981), integrating bits of information (Checkland & Holwell, 1998; Fauconnier & Turner, 2002), the "schema" selected (M. Endsley, 1995) guiding comprehension, the formation and development of mental models (Klimoski & Mohammed, 1994). The temporal aspect of situation awareness (Sarter & Woods, 1991) lends further support to the concept being viewed as a dynamic, open system, influenced by a variety of interacting variables (E. Salas, Prince, Baker & Shrestha, 1995).

Situation awareness is an important issue in human activity involving complex cognitive tasks (M. Endsley, 1995), and applies more widely, other than in aircraft (Sarter & Woods, 1995) and air traffic control situations (K. Smith & Hancock, 1995), with acquiring and maintaining situation awareness made more difficult with increasing workload, stress and system complexity.

Whilst situation awareness research has focused on complex systems created by technology, it has applicability to the study of workgroups embedded within complex integrated human/organizational, technological and workspace systems, particularly if there is a high level of performance dependence on spatial system allocation.
Because these design features can be impacted by workspace density, situation awareness has relevance for the study of workgroups undertaking more complex work.

Increased work complexity (M. Endsley, 1995) implies an increase in the number of system components, the degree of interaction between these components and their rate of change, plus the number of goals, tasks and decisions to be made in regard to the work system.

The point is that the complexity of office work might be considered low with respect to the complexity of the work of an aircraft pilot, but the interdependence of spatial, technological and human systems means the overall complexity of the work could still be quite high. This is of particular concern in the case of work design, which has a high spatial dependence. Any attempt to increase space density independently in order to save cost could have unintended consequences for the performance effectiveness and viability of the overall workgroup. An increase in space density could be such that given other small changes to the system of work, overall complexity increases greatly, and in non-linear ways. The overall Complex Adaptive System of work (CAS) exhibits emergent and adaptive behaviour, which cannot simply be described in terms of a linear relationship between space density and performance. If the work system is at, or near the edge of chaos, then a small change in space density might be sufficient to tip the system into unstable behaviour. It would not be clear where there was insufficient system redundancy for viable behaviour, only that the change in space density was sufficient to trigger system collapse.

Workspace Awareness and Performance Effectiveness

Workspace awareness (Gutwin & Greenberg, 2002) develops the concept of situation awareness to take into consideration person interaction in a shared workspace. They maintain that collaborative work in shared workspaces shares the same characteristics as those for pilots and air traffic controllers (dynamism, high information load, complexity, variable work and risk), but while most shared
workspaces do not have the same high dynamism and information load, these qualities "could easily be part of collaborative work" (ibid. pps418, 441.). Whilst the focus for their research was on better design for real time, distributed groupware for Computer Supported Collaborative Work (CSCW), it is instructive for this research since it provides a glimpse into one possible future for the evolution of office work. Many aspects of modern knowledge based office work could already be considered to be CSCW, e.g. through shared databases, project management tools, spreadsheets and the like.

Their descriptions of shared workspaces as bounded environments, task types/activities and small groups with a "mixed-focus" collaboration (ibid. p414.) can equally be applied to the study of the performance effectiveness of workgroups in more conventional commercial office situations.

Team situation awareness has been identified as a critical factor in complex work situations, specifically in military aviation where pilots interact with information rich, highly dynamic environments (E. Salas, Prince, Baker & Shrestha, 1995). Team situation awareness represents an even higher level of complexity beyond simply additive individual situation assessment (ibid, p125.), also citing Schwartz (1990), as it involves information sharing and coordination. However E Salas, Dickinson, Converse & Tannenbaum (1992) and E. Salas, Prince, Baker & Shrestha (1995) believed this field of research might prove beneficial to improving any team working.

This has relevance for this research since a critical behaviour for team situation awareness concerns individual monitoring environmental conditions and orientation in space (ibid. p128.), communicating this information to other team members, two not well understood team processes that contain highly interactive, dynamic system elements that facilitate team performance (ibid. p129.)

Of further relevance for this research is the contention that if team performance outcomes are poorly defined, this affects communication of knowledge, how the environment is perceived and team situation awareness, thus adding further complexity in terms of our understanding of the relationship between workspace density and team performance effectiveness.
Workspace awareness as a special kind of situation awareness, has received considerable attention in the study of computer-supported collaborative work (CSCW). Workspace awareness is defined as “an up to date understanding of other team/workgroup members and their interaction with the shared workspace” (Gutwin & Greenberg, 2002, p416), citing also Gutwin and Greenberg (1996).

Gutwin & Greenberg (2002) investigated how small groups performing a mix of individual and shared tasks in “medium-sized” shared workspaces to understand the ways that people use and maintain workspace awareness in collaborative work. They stated that it is generally not difficult to maintain high workspace awareness in most shared workspaces because the work does not involve “high information load or extreme dynamism” (ibid. p418.).

*With the changing nature of modern work and the increasing application of ICT, this contention might now be questioned.*

Gutwin & Greenberg (2002) maintain workspace awareness is critical in *dynamic environments*, and the physical workspace can affect team cognition (Clark, 1996; Hutchins, 1990; Norman, 1993). They developed a model for workspace awareness based on a cognitive framework (Neisser, 1976), which importantly includes individual team member knowledge of the workspace. Critical workspace knowledge elements identified include proximity, person location, visual and auditory indicators, which can all be influenced by workspace density.

Complex work in a physical office setting (Gaba, Howard & Small, 1995) may share the same characteristics of dynamism, complexity, high information load, variable workload and risk.

**Workspace Density and Workgroup Performance Effectiveness**

**Introduction**

Early studies of the impact of crowding (J. L. Freeman, Klevansky & Ehrlich, 1971; Kutner, 1973), failed to find any effects on task performance, due to the fact that the levels of space density employed were not sufficiently adverse (Paulus, Annis, Seta, Schkade & Matthews, 1976).
Worchel & Teddlie (1976) claimed there was little evidence to suggest high spatial density might be arousing, suggesting a two step process might explain experience of crowding and that the reaction is first due to a violation of individual personal space and then an attribution of the arousal to other persons in the environment, not to space density itself.

There is now a body of evidence that space density is one of the most important characteristics likely to influence employee reactions about the physical environment (G. R. Oldham, 1988; Sutton & Rafaeli, 1987). Higher spatial density has been associated with lower job satisfaction, while lower interpersonal distance and higher space density are associated with lower job performance (G. R. Oldham, 1988; G. R. Oldham, Kulik & Stepina, 1991; G. R. Oldham & Rotchford, 1983; Paulus, Annis, Seta, Schkade & Matthews, 1976; E Sundstrom, Burt & Kamp, 1980; Sutton & Rafaeli, 1987; Worchel & Teddlie, 1976).

Higher workspace density is likely to result in more uncontrolled interruptions (Ornstein, 1990), decreasing ability to concentrate (G. R. Oldham, Cummings & Zhou, 1995), generating adverse behavioural and affective responses from employees (Douglas. R. May, Oldham & Rathert, 2005; E Sundstrom, 1986). Over-stimulation theory (Desor, 1972; Paulus, 1980) postulates that intrusions result in stimulus overload, a psychological state that induces these behavioural and other affective responses. Mehrabian (1976; 1977) has presented a rationale for a questionnaire to measure individual differences in stimulus screening ability, arguing that this skill enables employees to moderate inputs and stimuli from the work environment.

**Workspace Density, Work Complexity and Performance Effectiveness**

Sutton & Rafaeli (1987) and Douglas. R. May & Oldham (1990) found employee reactions to environmental stimuli depend on individual workload or job demands, whereas previously E Sundstrom, Burt & Kamp (1980) found job complexity had little impact on employee responses to a range of environmental characteristics associated with architectural privacy.
It should be noted that three, simple self evaluation criteria (complicated-simple; exciting-dull; requires little concentration-requires great concentration) were used to construct the “complex job” composite score, suggesting the jobs evaluated were not complex or even demanding by today’s standards. The research identifies the need to operationalize jobs accordingly, that are complex or demanding. A further weakness in the research is the focus on individual jobs as opposed to team/group work.

G. R. Oldham, Kulik & Stepina (1991), applying the input-output model, researched the moderating effects of stimulus screening ability and job complexity on the relationship between space density (and closeness, enclosure) and work performance. The research focus was again on individual jobs, satisfaction and performance, not teams. A complexity rating was “assigned” to jobs by the researchers based on those developed by Roos & Treiman (1980) for job classifications in the US Department of Labor Dictionary, (1977).

The study results indicate stimulus-screening ability can moderate the relationship between space density and individual job performance (ibid. p. 936), but highlights the need for further research, particularly for complex work involving higher levels of interaction in open working environments. Elsewhere, employees with high screening ability have been shown to be more effective in adapting to higher density environments (Baum, Calesnick, Davis & Gatchel, 1982), but this ability has not featured prominently in research into the design and effectiveness of teams or workgroups.

G. R. Oldham, Kulik & Stepina (1991) expressed concerns about generalizing the effects of job complexity. Block & Stokes (1989) for example suggest that more complex work benefits from more isolation. Other studies have found individuals with higher job demands can divert their attention from external to internal environments, suggesting that jobs with higher demands create a focus that helps block out disruption (ibid. p31.), citing Douglas. R. May & Oldham (1990) and Sutton & Rafaeli (1987).
However, job demands and job complexity are different aspects of work. Highly complex work can have few demands (e.g. of time) while the converse is also true.

Increased work complexity implies an increase in the number of system components, the degree of interaction between these components and the rate of change of these components, the number of goals, tasks and decisions to be made in regard to the work system (M. Endsley, 1995).

Bowers, Salas, & Jentsch (2006b) indicate complex team or workgroup tasks can be classified according to task uncertainty (the extent of objectivity or judgment required in the task), or relative task difficulty (the degree of cognitive load, or mental effort required for problem solution).

To what extent can the consequences of organisational demands for space saving resulting in higher density be adapted to or be learned thus giving individuals the ability to manage the tipping points at much higher levels of space density before a work system catastrophically fails?

Some studies (Carlopio & Gardner, 1992; Zalesny & Farace, 1987), have supported the view that workspace density affects employees adversely when jobs are more complex, while the converse has also been demonstrated (G. R. Oldham, Kulik & Stepina, 1991). Higher workspace density has been shown to have a positive effect on job satisfaction and information exchange, while reducing role conflict and ambiguity for professional employees (Szilagyi & Holland, 1980).

Citing inconsistent evidence (G. R. Oldham, Cummings & Zhou, 1995) for adverse effects of space density, Fried, Slowik, Ben-David & Tiegs (2001) examined the relationship between workspace density and individual employee attitudinal outcomes, considering job complexity as having a moderating effect on job satisfaction and co-worker satisfaction outcomes.

In this instance, workspace density was defined as “the number of people within a certain distance of a target employee”, a variant on social density, which may have some relation to the more commonly accepted definition of m²/person.
Job complexity however referred to “the degree to which an employee’s job is demanding, challenging and stimulating”, citing Hackman & Oldham (1980). They further maintain that the inconsistent evidence results from methodological shortcomings in classifying job complexity.

While the research described the job complexity for every individual employee surveyed, Fried, Slowik, Ben-David & Tiegs (2001) contend that the past inconsistencies might be also explained by a lack of recognition of important moderator variables such as organizational tenure (length of service), a variable considered to indicate individual knowledge of the organization.

Negative reactions to workspace density may be moderated by tenure since longer serving individuals might have an improved ability to manage interactions, this learning being particularly useful when job complexity is higher. However it is also conceivable that longer tenure may have either an ameliorating or aggravating effect on reactions as it interacts with workspace density and job complexity (ibid. p361.).

Their study found a clear negative association between workspace density and attitudinal variables measured (job satisfaction, co-worker satisfaction and organizational commitment) when both job complexity and tenure were high.

A weakness in the research (Oldham et al., 1991) is the difference between low and high workspace density was not clearly articulated, the factor measured in terms of radius from a “target employee” (ibid. p364.). Further the research again focused on individual job complexity and reactions, not the performance effectiveness at the workgroup level. Job Complexity was measured using an average of 10 items from the Job Diagnostic Survey (JDS) (Hackman & Oldham, 1980) which may have potential application for this research.

Both job complexity and tenure are considered relevant to this research, with the implication that there should be focus on more established as opposed to start up or newly formed teams.

However the finding that the relation between job complexity and employee reactions was considered to be more complex, depending on workspace
characteristics, poses a particular research challenge in terms of isolating cause-effect relations when the complex array of possible human cognitive, affective and behavioural reactions to both complex (group) work and workspace characteristics are simultaneously considered.

Workspace Density Job Complexity and other Employee Reactions
Kozlowski & Ilgen (2006), commenting on the changing nature of work in organizations, concluded that the design of work was shifting from individual jobs to “teams embedded in more complex workflow systems”. Their view was that the research focus had similarly shifted from small interpersonal groups in social psychology to the study of work teams in organizational psychology (Levine & Moreland, 1990b; Moreland, Hogg & Hains, 1994).

Their literature review similarly identified significant studies of work teams and their effectiveness, (S.G. Cohen & Bailey, 1997; Keller & Holland, 1983; E. Sundstrom, McIntyre, Halfhill & Richards, 2000), but more recent research reflected a view of work teams as emergent, complex and adaptive, dynamic systems evolving over time as situational demands or constraints unfold (Kozlowski & Ilgen, 2006).

Work Demands, Workplace Control and Performance Effectiveness
When workplace conditions increase work demands, exceeding the worker’s belief in their capacity to cope, the result is workplace stress. Hart & Staveland (1988) proposed the most significant job stressors are organizational (including major changes to working conditions) or job specific (including high work loads or demands).

When work design is meaningful, it signals organizational respect for the individual, (Sutton & Rafaeli, 1987) resulting in happiness and health outcomes.

Sargent & Terry (1998), hypothesized that high levels of work task control would moderate the stress effects of high job demands, with reference to a Demands-Control Model (Karasek, 1979) based on a Stress-Buffering Hypothesis, describing the effects of a wide range of variables that may help protect people from the effects of stress.
The value of this research is likely parallels being drawn into work demands, work stress, work control and work performance resulting from the physical environment, in particular work space density. The weakness is job demands are defined in terms of extent of time pressure and level of conflicting job demands, whereas in the modern working environment demanding work would be characterized more by information intensity and work complexity.

Inconsistent support was found for the Demands-Control Model, (Landsbergis, 1988; Wall, Jackson, Mullarkey & Parker, 1996), but an Action Sequence Model (Frese, 1989) in which control dimensions that are closely proximal to daily work activities have a greater impact on employee adjustment received wider support in the literature.

This hypothesis raises a question as to the possible linkages between workspace density, ability to control and performance effectiveness, particularly if space is a work design element central to individual or group work performance. What ability does an individual in a work group have to "stress buffer" the impact of increased spatial density?

Aspects of physical control and socio-psychological control may differ in their "central importance" or priority for individuals and groups, and/or individual or group work/performance (Sargent & Terry, 1998), again citing Frese (1989).

Sargent & Terry (1998) claimed too little research had been undertaken on the multiple dimensions of work control, (ibid. p224., Table 1), with the exception of McLaney & Hurrell (1988), who found physical environment control exerted a positive effect on job satisfaction for employees in a retail situation, or the moderating effects of control on the demand-work performance relationship.

This research also highlights the difficulties in conceptualizing and operationalizing work control, including aspects of the physical work environment.
Most people in organizations have a generalized desire for more control and will engage in activities to increase their perception of control. Perceived control is a cognitive construct but may also be a function of actual control, beliefs, personality, observations and biases (Greenberger, Strasser, Cummings & Dunham, 1989). They found, for clerical workers, that a lack of control could have long-term deleterious effects on performance, while unpredictable stressors make individuals believe they have inadequate control over their environment, which leads them to feeling helpless. A helpless person does not expect that an action will lead to an anticipated outcome, thus setting up a reduced incentive to perform well on subsequent tasks (Bazerman, 1982; Glass & Singer, 1972; Glass, Singer & Friedman, 1969).

However, the precise way in which a person increases their control may have little effect upon performance (Greenberger, Strasser, Cummings & Dunham, 1989).

To what extent do various aspects of the physical environment have a role to play in “stress-buffering” to improve employee performance outcomes? If employees have some level of job control, but little environmental control, when space density is increased for the overall work group, do perceptions of control decline and is performance and satisfaction adversely impacted accordingly? What are the implications for stress buffering and workgroup performance effectiveness?

According to Csikszentmihalyi (1988; 1996), job complexity can affect job-related stimuli, competing with other environmental stimuli (or interference) for the limited attention capacity of individuals, resulting in stress and other negative attitudinal reactions.

Conversely, Wells & Matthews (1994) suggested that one of the few consistent effects of arousal stressors is a narrowing of attention, which may cause individuals to detach from their surroundings and focus more on the task, excluding other environmental stimuli when work demands are high.

These findings suggest the study of established work teams, engaged in more complex group work, most likely will exhibit negative psychological (stress,
satisfaction) and behavioural (performance) reactions as workspace density increases. It remains to be proven that under extreme spatial conditions the reactions are such that they lead to the collapse of the workgroup as a viable work system.

Vischer (2007) cites a lack of control over, or understanding of, the physical workspace provided to employees as a key determinant of stress for people in modern office environments carrying out increasingly complex work. Stress related to the work environment has elsewhere been shown to have a relation with work complexity, and affects performance adversely (McCoy & Evans, 2005).

The impact of noise induced stress, a consequence of open plan design, has been identified as a key, uncontrollable aspect of the modern, physical workspace, and a determinant of lower performance effectiveness (Banbury & Berry, 1998; G. W. Evans & Johnson, 2000; Leather, Beale & Sullivan, 2003; Stokols, Churchman, Scharf & Wright, 1990; E. Sundstrom, Town, Rice, Osborn & Brill, 1994). Yet, despite the compelling evidence, attempts to control office noise have been “undermined by increasing office densities and collaborative work in modern workspace”, Vischer (2007, p178.).

Theories of and thinking about workplace stress appear to have parallels in a range of disciplines (psychology, engineering, human factors, physiology) used to approach the design of work and its corresponding outcomes (Campion, 1988), viz:

- motivation approaches and satisfaction outcomes
- biological approaches and comfort outcomes
- perceptual/motor approaches and reliability outcomes
- engineering approaches and efficiency outcomes

Campion (1988, p477.) concluded that different approaches to job design influence different outcomes, calling for an interdisciplinary perspective.

From the work design perspective, stressors can be classified as psychosocial, while from a physical workspace perspective, psychological stress equates to motivational
consequences and fatigue affecting job performance (Cropanzano & Wright, 1999; G. W. Evans & Stecker, 2004).

The physiological data points to environmental stress, particularly from noise, resulting in depression, elevated blood pressure, lowered autonomic arousal and impaired cognitive performance (R. Gatchel, Mc Kinney & Koebernick, 1977; R. Gatchel, Paulus & Maples, 1975).

The demand-control model at the task level of job characteristics has been widely studied and establishes the connection between the study of stress and job design theory, albeit adopting the mechanistic input-output model approach (Karasek & Theorell, 1990; Karasek, 1979). Low control-high demand environments produce job strain, one approach to modeling and measuring stress (LaMontagne, Louie, Keegel, Ostry & Shaw, 2006). This type of job strain, coupled with low supervisory and co-worker support creates a work environment condition called “iso-strain” (Johnson & Hall, 1988).

**Could these effects be gauged by task and social cohesion measures?**

Vischer (2007) identified that environmental psychology-based research has until recently focused on a stimulus-response logic that posits user satisfaction (either job or environment) as a “measurable behavioural response to features of the physical environment” (p179.), and that “the inexact concept of satisfaction does not address the complexities of the transactional nature of the person-environment relationship”. There is inconclusive evidence regarding the satisfaction-performance relationship at the individual job level, and multiple aspects of the physical work environment likely to impact job satisfaction or performance, dependent on other situational contingencies. The uptake of teams and workgroups as a primary organizational unit, and the increasingly complex nature of knowledge-work, calls for a more systems-oriented approach to the study of workplace performance. Reference is made to a “cybernetic model” which might be worthy of further investigation to support this research (p177.), citing Cooper & Dewe (2004).
In a study of acute care settings, Chaudhury, Mahmood & Valente (2009) conceptualized performance impacts resulting from stress in the physical environment at two levels, identifying “latent conditions” (Reason, 2000). Latent conditions refer to performance failures resulting from decisions made by the management and architects, including physical environment variables (noise, design, layout, access to space) that produce psychological or physiological outcomes. These variables have been shown elsewhere to be affected by workspace density.

**Work Demands, Workplace Control and Other Reactions**

Douglas. R. May, Oldham & Rathert (2005) found specific reactions of tardiness, *transfer intentions* perceived crowding and *work area satisfaction*, identifying also the specific conditions under which spatial density has its strongest/weakest relations to these reactions. Dean, Pugh & Gunderson (1975) and G. R. Oldham & Rotchford (1983) similarly found higher space density to be associated with *turnover intentions*, *lower levels of job satisfaction* and *withdrawal* from work areas if discretion is available.

Duval, Charles & Veitch (2002) reviewed 19 separate studies into the effects of open plan office space density on *environmental satisfaction*, concluding higher space density in open-plan offices tends to lead to higher *environmental dissatisfaction*.

**Important findings from this research with relevance to the proposed research are;**

- **inconsistent use of quantifiable density measures (also drawing a distinction between social and space density)**
- **variability in the measures used for environmental satisfaction, and**
- **the moderating effect of job type on environmental satisfaction**

*It is recommended that space density be measured as area per person as this measure has more validity than social density (i.e. number of persons per “office”).* 
*Duval et al. (2002) were unable to determine “density points above and below which occupant satisfaction is unacceptable”, but recommended, given the*
trend to smaller open-plan office workstations, “future work needs to focus on the effects of these higher density settings” (ibid. p21.). This research will address some of the questions posed by the above work with particular emphasis on performance effectiveness of workgroups, not environmental satisfaction. As discussed in the Introduction the correlation between satisfaction and performance is low for individual jobs.

Ayoko & Hartel (2003) also suggest different cultural norms in heterogeneous workgroups (i.e. comprising members from different racial, ethnic, cultural or national backgrounds) might contribute to different viewpoints regarding the use of space, interpersonal space and privacy invasion, which could potentially impact upon the type, frequency and duration of conflict. Conflict events could lower the performance of the workgroup. Their study found workspace, and the design of space as critical factors underpinning conflict in culturally heterogeneous workgroups, with performance impacts including reduced efficiency, ill-health, higher turnover and withdrawal tendencies, feelings of mistrust, victimization and anger. Social cohesion was also affected, the environment being described as “tense”, “unwelcoming”, lacking in support from others and with lower levels of work socialization (ibid. p401.).

Expanding on this proposition, Harrison, Price & Bell (1998b) differentiated between surface-level diversity in groups; and deep-level diversity (values, beliefs and attitudes), and their impact on group cohesiveness, conflict, interaction and performance effectiveness (ibid. p98.).

A Systems Perspective on Workgroup Performance Effectiveness

Workgroups as Work Systems

One of the earliest definitions of a work system was provided by Trist & Bamforth (1951) who referred to the long-wall method for mining coal as a “technological system expressive of the prevailing outlook of mass production engineering and as a social structure consisting of the occupational roles that have been institutionalized in its use”. This work system was introduced in response to advances in mechanical technological complexity (ibid. p9.), allowing a differentiated organization structure to replace the smaller work groups that had previously been used in coal-getting.
The concept of work as a socio-technical system arises from a reconsideration of work from that which relates workers to only limited parts of the technical production process, to a production “system”, that requires both a technology and a work structure, the latter tying people to the former (Cummings, 1978).

P. S. Goodman (1986) proposed a broader definition of the technological system to include the “physical technology” with “physical environment” defined as one of the four classes of components in the technological system.

However, within this field of research there has generally been a lack of clarity in the definition of a work system, inconsistency in the use of this term and the inclusion of specific aspects of either the physical technology or environment.

In the research and analysis of information systems, the concept of a “work system” as the focal point in the methodology for understanding and improving systems in organizations, whether or not IT is involved, is widely accepted. Within this domain, a work system is described as “a view of work as occurring through a purposeful system” (Alter, 2002, p91.), and further refined to be defined as follows. “A work system is a system in which human participants and/or machines perform business processes using information, technologies, and other resources to produce products and/or services for internal or external customers” (Alter, 1999).

In this framework, technologies include tools (e.g. phones, spreadsheet software) and management techniques (such as remote tracking) that work system participants use while doing their work, while infrastructure includes human, informational, and technical resources, there being no reference to workspace as a either a technology or technical resource. People who perform at least some of the work in the business process are considered the work system participants, while the primary purpose of the work system is the processing of information (ibid. p93.).

The emphasis here is clearly on information and individuals, not knowledge work, teams or workgroups.

Whilst these concepts are useful for clarifying the definition of work systems, the
authors note that they are more prescriptive than those applicable in soft systems methodology (Checkland, 1981).

Recent research into teams generally reflects the perspective that these entities are dynamic systems exhibiting emergent and adaptive characteristics whilst embedded in a multi-level systems context at the individual, team and organizational levels. These interdependent systems adapt and evolve as situational demands unfold over time (H. Arrow, McGrath & Berdahl, 2000; Kozlowski & Ilgen, 2006; Marks, Mathieu & Zaccaro, 2001).

However, the definition of a work system as “the purposeful and intentional combination of people, processes, technologies, resources, place and intellectual capital to achieve a planned business outcome” (Bruce-Smith, 2003), more closely fits the conceptualization of a workgroup as a work system, including the spatial dimension (place), and thus has greater relevance for this research.

*The combination of physical space, other elements/artefacts and shared activities in a work system, is now made manifest by the workgroup as a representation of the “shared workspace”.*

**Workgroups Embedded in Higher Order Systems**

Groups responding to physical features of the environment have been shown to become less flexible (Staw, Sandelands & Dutton, 1981; Gladstein, 1984; Gladstein & Reilly, 1985).

Staw, Sandelands & Dutton (1981) further suggested that such responses could result from major changes in the environment, with major threats (stress, anxiety and psychological arousal) affecting group cohesiveness and potentially causing increasingly dysfunctional groups to break up.

Gladstein & Reilly (1985) gave a broader definition of threat, being an event with either a high probability of loss, or involving a significant amount of loss. This definition of a threat could potentially apply to a reduction in work area, particularly if work is highly spatially dependent or a small change in space density has a
significant impact on the group due to overall, low levels of requisite variety in the work system (Beer, 1979).

Gladstein & Reilly (1985) noted that there had been no direct group research into this issue. The systems approach has the potential to demonstrate how a workgroup under threat of reduced workspace density may respond.

W. R. Evans & Davis (2005) examined the relationship between high performance work systems (HPWS) and organizational performance. However, whilst they defined a work system at a higher order system level as “an integrated system of HR practices” (ibid p759.), and adopted a linear model in their performance framework. They identified self-managing teams as a key category of HPWS. Further, “shared mental-models” were identified as a key variable in the social structure mediating organizational performance – specifically flexibility, citing also Cannon-Bowers & Salas (2001) and Mathieu, Goodwin, Heffner, Salas & Cannon-Bowers (2000).

Elsewhere linkages between environmental psychology and organizational behaviour have been explored from a systems perspective, particularly for the “group-in-organization” system, enabling various aspects of the “external physico-sociocultural environment” and interactions between group members to be taken into consideration (Mayo, Pastor & Wapner, 1995).

The category system linking the group into the organization system, which includes physical attributes, could prove useful for further research (ibid. p79.).

Haynes & Price (2004) maintained that most workplace research has confined itself to the positivist-reductionist paradigm, and that a different underlying paradigm is called for if there is to be any understanding of the complex interrelations in the modern workplace.

Adopting an agent-based modeling approach, they hypothesized there may be a “critical density of connectivity between agents in a network” which could explain why some workplaces support organization or business performance better than others. Too much distraction in an open plan layout for example and the benefits may not be
seen. They also suggested the tipping point at the edge of chaos might vary with work type.

Unfortunately the research appears to have fallen well short of their own call for a new paradigm, the researchers reverting to a “perceptionist approach”, devising a research instrument which asked respondents to assess their perceptions of 27 variables on their individual productivity.

A further weakness of the research relates to the continuing evaluation of individual productivity when there is clear evidence that the primary organizational design unit is now a team or workgroup, and the description of work types using the simple interaction-autonomy matrix (Laing, Duffy, Jaunzens & Willis, 1998).

Nonetheless, having found some confirmatory evidence to support the hypothesis Haynes & Price (2004) recommended future research explore differences between individual and group evaluations of workplaces, using tools from complexity theory. This challenge is to be taken up in this research.

A Dynamic Complex Adaptive Systems View of Workgroup Effectiveness
Introduction
The study of workgroups as a Complex Adaptive System (CAS), is based on concepts drawn from the fields of social science, general systems theory, dynamical systems theory (mathematics), complexity and chaos theory (H. Arrow, McGrath & Berdahl, 2000).

In the study of workgroups as complex and adaptive work systems, the challenge is to understand how the workgroup maintains coherence and continues to be viable in the face of change. Coherence and viability depends on the extensive interactions within the group, aggregation of diverse work system elements and adaptive capability. Holland (1995), identified seven general principles that govern the behaviour of all complex adaptive systems as follows:
Aggregation

Aggregation is the property that relates to the emergence of higher-order system behaviour, from the aggregated reactions of component parts of the system (agents). A CAS comprises active elements, agents or people in the “network” constituting the workgroup, who exhibit reactions (cognitive, behavioural, affective) to other elements of the work system based on stimulus-response “rules”. Aggregates of individual agent reaction turn into agents at a higher level (workgroup), thus revealing how the complexities of individual stimulus-response are made manifest or exhibit emergent behaviour.

Non-linearity

Non-linearity is a property of the system. Linear rules do not describe emergent behaviour. Therefore mediator, moderator and linear input-process-output models are not applicable. In a non-linear system, simple cause and effect relationships do not hold in that a change in one variable may cause a proportionate change in another variable, up to a point beyond which disproportionate outcomes can be observed (McClure, 1998).

Flows

Flows through a CAS vary over time, whilst the nodes and connections in the network appear and disappear over time as agents adapt or fail to adapt. If individuals are connected and communicating in some way, with information flowing across a connected network, then the non-linear dynamics perspective could be applied to workgroups (Arrow, 2005). In the workgroup, the flow of work (workflow) is described as a dynamic mix of the four primary types (Beal, Cohen, Burke & McLendon, 2003) depending on the adaptability of the individuals to work collaboratively, to interact, be autonomous or work in isolation.

Diversity

The property that describes the persistence of an agent depending on the context provided by other agents. For the workgroup as a work system, context includes workspace and situation awareness, interactions and aspects of cohesion.

Internal Models

Internal models covers the mechanism of anticipation, and is similar to “schema”, (Gell-Mann, 1994), which may be more appropriate for the study of “genetic algorithms”. In the study of physically located workgroups, internal-models may be
analogous to mental-models (see above), while self-schema (Fischer, Tarquinio & Vischer, 2004) has been proposed as a frame for built environment evaluation.

**Building Blocks**

This mechanism results from the ability of individual agents to decompose complex situations into their component parts.

**Tagging**

Tagging is a visible sign that provides a pervasive mechanism for aggregation and boundary formation. Tagging is analogous with the formation of physical boundaries for workgroups or teams and other visual cues embedded in the work system that may have social or functional meaning relevant to group cohesion. Tags enable groups to perceive and model their everyday world, thus establishing a connection with workspace awareness.

From this perspective a workgroup as a work system can be defined as "a complex, adaptive, dynamic, coordinated and bounded set of patterned relations among members, tasks and tools" (H. Arrow, McGrath & Berdahl, 2000, p34.).

In their review of work teams from a systems perspective (Kozlowski & Ilgen, 2006), the authors argued that team effectiveness could be viewed as a dynamic process, then identified the minimum requirements for the "resources" pool available to the team necessary to resolve the team task as a critical team effectiveness issue.

According to this model, team tasks define workflow structures and coordination demands, which are critical enablers of team effectiveness. Kozlowski & Ilgen (2006) also concluded that the static input-process-output models of team performance were limited in terms of their application for determining team effectiveness, given team processes develop and unfold over time.

**Workflow Structures, Connectivity and Performance Effectiveness**

The "degree of connectivity" in a team (Losada, 1999) has been identified as an excellent predictor of team performance. By considering a team as a complex adaptive system (Kauffman, 1993; 1995), Losada suggested that the optimal environment for adaption, and thus performance, might be the region between order
and disorder, or chaos, the latter state being defined by highly interconnected teams exhibiting complex patterns of interaction.

Losada prior evaluated the performance of teams he studied using three traditional indicators - profitability, customer satisfaction and assessment by superiors, peers and subordinates, rating them either high performing, medium or low performing. Other qualitative assessments of team performance were also made.

Connectivity was measured by cross correlating coded speech acts observed between individuals in the differently rated teams, in a “laboratory” setting. Low performance teams were characterized as being “stuck in a viscous atmosphere, highly resistant to flow”, whereas high performance teams might operate in a more “buoyant atmosphere”, drawing an analogy with fluid dynamics. The research indicated the classified high performance teams exhibited a “sophisticated pattern of interaction, typical of non-linear systems”, with trajectories plotted in “phase space” showing chaotic dynamics. Low performing teams became locked in self-orientation, as opposed to member orientation towards others in the team.

Losada (1999) concluded that “chaotic dynamics” are associated with high performance, citing also Freeman (1991), who similarly concluded that “chaos underlies the ability to respond flexibly to the outside world and to generate novel activity patterns”.

Whilst the methodology employed by Losada demonstrated a step change away from using traditional linear cause-effect models, its weakness lies in the artificiality of the laboratory setting and limitations with performance measurement of the teams in action, viz; short time frame and performance criteria used. As indicated above, Losada chose to measure connectivity within each of the various teams, this variable being chosen as a “predictor” of performance. It was subsequently argued that “chaotic dynamics”, portrayed by the butterfly attractor pattern, could be associated with the teams, prior evaluated as delivering high performance outcomes. The converse was apparently shown to be true.

The high levels of connectivity observed, may well have been associated with sophisticated patterns of interaction, although no differentiation was made between
interaction which might be either task or social performance outcome oriented. The weakness in this research lies with the assumption that interaction overall is equated with task performance outcomes only. This is not necessarily the case. Interaction (comprising adaptability, interpersonal relations, communication and coordination) is a team/workgroup effectiveness dimension, as identified in Table 3. Therefore, while the research purports to demonstrate the butterfly pattern associated with chaotic system dynamics, and also high performance, it may simply reflect the artificial reality of a “time-boxed” workgroup with a very short term “performance focus”, as opposed to indicating any longer term viability of the workgroup as such.

Further, the research makes no mention of workspace density, or questions the extent to which this factor could have influenced observed patterns of interaction and measured degree of connectivity. Certainly if space density is higher in the laboratory situation than normal experienced by the teams in question, these conditions might be more palatable to team members since they could be viewed as short-term constraints, accepted as “givens”. The analysis of computer supported collaborative workgroups and workspace awareness provided above would support this contention.

This research can however build on the methodology used by Losada, whilst addressing the ongoing challenges associated with measuring the performance of teams or workgroups. Rather than connectivity, cohesion, which comprises both task and social aspects, is considered a more relevant determinant of team/work group effectiveness. Whether this construct is affected by workspace density is therefore an important question for this research.

Despite the weaknesses in Losada’s research, it does make another important contribution, in that it differentiates between individual and group level data and its subsequent analysis.

Within this wider frame of reference, understanding if there are conceptual and practical distinctions between “cohesion as an individual perception and cohesion as a shared perception among members”, is also an important consideration, since both are likely to moderate the cohesion-performance relationship. In addressing this question it is noted that Kozlowski & Ilgen (2006) identified cohesion as an important contributing factor in affective processes and emergent states of teams, although no
specific distinction between individual or shared perception was made. However, in examining task interdependence (defining workflow complexity) as a moderator in the cohesion-performance relationship, they found (ibid. p89.) as workflow complexity increased, so to does the cohesion-performance relationship, citing also Beal, Cohen, Burke & McLendon (2003) and Gully, Devine & Whitney (1995).

The conclusion that cohesion is an emergent state (that is a mix of individual and shared perceptions) that relates to performance through the complexity of team workflow is thus a more significant finding for this research, rather than attempting to make practical distinctions between individual or group perceptions. Further, if the cohesion-performance relationship is moderated by work complexity, different types of workgroups with different workflow types might require different levels of cohesion to remain viable.

Could a change in space density have a non-linear change effect on the cohesion of a workgroup described as a work-system?

Is it possible to describe the viability of a workgroup as a work-system, by mathematically mapping its underlying dynamics?

Could there be a space density for a particular workgroup, described as a “bifurcation point” at which the work-system transits from a functioning state, into a dysfunctional or unstable state?

Modern computational capabilities now enable better descriptions of these complex adaptive socio-technical systems. As changes in the essential nature of the system take place when a control parameter passes a critical threshold (Dooley, 1997) the exhibited behaviour can now be discovered by topological mapping in mathematical phase space.

Mobach (2007) confirms the relevance of the critical systems thinking perspective in the built environment, having also applied its principles to the design of distinct organizational spaces.
CHAPTER 4: RESEARCH METHODOLOGY

Introduction to Methodological Perspectives

There have been numerous studies into the relationship between organization design and architectural design, specifically for offices (Becker, 1981; Bhagat, 1982; Boje, 1971; Broadbent, Cooper, Fitzgerald & Parkes, 1982; Cairns & Beech, 1999; Carlopio & Gardner, 1995; Davis, 1984; Duffy, 1974a, 1974b; Ree, 2002; Romero, 2004; Sundstrom & Altman, 1989; Sundstrom & Sundstrom, 1981; Ward, 2004; Zalesny & Farace, 1987; Marans & Spreckelmeyer, 1982; Mayo, Pastor & Wapner, 1995; Ree, 2002; Selinger, 2004).

Since about 1990, given the increased use of teams as a basic unit of organization, there has been renewed interest in their study (Guzzo & Dickson, 1996; Hackman, 1998; Sundstrom, De Meuse & Futrell, 1990). This research generally confirms that the technologies and resources available to groups affect how members decide what to do, how to proceed and how effective the group is in delivering outcomes.

However, until most recently, the positivist-scientific method (Easterby-Smith, 1991; Remenyi, Williams, Money & Swartz, 1998) cited in Amaratunga, Baldry, Sarshar & Newton (2002) has dominated research into the impact of the physical environment on human performance in organizations (Pacheco & Lucca-Irizarry, 1995).

Yet, in workgroups, people, work tasks and work tools are interconnected in complex ways, with performance deficits depending on the situational context in which they are embedded.

The positivist paradigm pays less attention to the behaviour of groups within their embedding environments, potentially creating problems in the study of social phenomena (Amaratunga, Baldry, Sarshar & Newton, 2002; Foster, 1972; Vickers, 1995), such as the performance of workgroups in the workplace.
On the other hand, small group research has always incorporated wide ranging theoretical and research perspectives, potentially providing a better basis for the study of workgroups (McGrath, 1997), considered as work systems. What seems to be missing from small group research is any explicit reference to workspace as a group resource, tool or spatial technology in any of the various embedding environments.

**Critical systems** thinking can provide a useful overall framework to understand and connect organization and building (Mobach, 2007), and **systems science** (e.g. system dynamics, organizational cybernetics, complexity theory, and soft-systems methodologies) can function extremely well in an interdisciplinary context where other more traditional approaches may not be so successful (Arrow, McGrath & Berdahl, 2000; Holland, 1995).

Systems-thinking has already been applied to the study of teams (Fredrickson & Losada, 2005; Losada, 1999; Losada & Heaphy, 2004; Stacey, 1996). Losada’s short term laboratory study (Losada, 1999), however lacked contextual realism, tended to be very academic and highly mathematical. But for practical and methodological reasons, shorter span studies (e.g. like Losada (1999)) have been more popular than longitudinal field studies for small group research. The study of group-in-environment (Mayo, Pastor, & Wapner, 1995; Minami & Tanaka, 1995; Wapner, 1987) however allows for multiple research strategies to be employed and thus an interdisciplinary approach across sub-specializations.

**Critical Systems Thinking**

Within the critical systems thinking framework, two methodological approaches – **interpretive** (Bruce-Smith, 2003; Checkland & Holwell, 1998; Gubrium, 1988; Walsham, 1993) within paradigm **A: realism and qualitative**, and **B: positivist-functional** (Remenyi, Williams, Money & Swartz, 1998; Schwaninger, 2006) enable such a mixed approach to be considered. Both aspects are outlined here under.
The interpretive method within this paradigm allows for different world-views or differences of opinion, with a view to improve understanding of the complex problem situation.

This aspect of the research aims to find a way to deal holistically with a messy real-world problem using systems thinking. The intention here is to develop and explore alternate ways of thinking about a challenging workplace situation in order to recommend pathways for purposeful, practical action.

By linking various aspects of the problem situation that have been extensively studied elsewhere, using predominantly input-output models, enables this research into the workgroup as being a new kind of human activity system (Checkland, 1979, 1981; Smyth & Checkland, 1976) - the work system. Establishing a work system in an organizational context is essentially to construct a social system (team or workgroup) that interacts with spatial and information systems, either technology enabled or facilitated by human communication, with a purpose to deliver performance outcomes.

Researching this “social reality” equates more to the discovery of attributes of the overall system as it continuously deconstructs and reconstructs, a consequence of individual cognitive, affective and behavioural reactions to selected data (“capta”) (Checkland & Holwell, 1998) to which meaning is attributed, either cognitively, spatially (viz; space density) or temporally (Cairns, 2002).

Soft Systems Methodology
Soft Systems Methodology (SSM) is a most useful systems methodology within this paradigm, as it is positioned in relation to the interpretive research stream (Bulow, 1989; Walsham, 1993) as well as the positivist approach (Schwaninger, 2006) outlined later.

The fundamentals of the Soft Systems Methodology may be summarized as follows:
- It is concerned with "ill-structured" problem situations
- The reality of the social system is continuously created and changing over time, demanding a more dynamic model
- The performance of the system cannot be measured to "optimize" its effectiveness, the situation being more fluid and learning-oriented
- The research requires taking a more radical position, not necessarily based in a positivist epistemology

The general interpretive methodological framework including the SSM is outlined diagramatically in Figure 6.

**Figure 6: General Interpretive Methodological Framework**

Source: Adapted from Checkland (1985) and Checkland & Holwell (1998)

The qualitative research process using SSM involves four distinct process steps, which are broadly summarized as follows:

**Step 1: Exploration of the multiple facets of the problem situation**

Chapters 2 and 3 explored in great detail a diversity of ideas, themes and frameworks, which may characterize the multitude of facets likely to affect the performance of teams or workgroups. The frameworks considered to be more important, with respect to the research question, are briefly restated hereunder.
According to Hackman (1998), many teams do not work effectively because the organization skimps on resources necessary to meet required objectives, viz; reward systems, information systems, education and training systems and material resources (including equipment, tools and workspace).

Some relevant questions raised in this framework include:

- Is workspace (or space density) currently used as part of the reward system or is it independent of the reward system?
- Do all employees will have equal access to information resources within the work system?
- What is the status of education and training in relation to the work performed, or more specifically to increase workspace awareness?
- Is there a requirement to describe the work being performed by workgroups in of its information intensity or “complexity”?

Also, can material resources be described in terms of:

- workgroup spatial allocation in the overall workspace layout?
- individual spatial allocation in terms of space density within the workgroup?
- individual and workgroup spatial allocation in terms of workstation standard type?

Framework 2: Campion, Medsker and Higgs (1993)
This is a hybrid framework based on social psychology (McGrath, 1984; Steiner, 1972), socio-technical theory (Cummings, 1978; Passmore, Francis & Haldeman, 1982), industrial engineering (Guzzo & Shea, 1992; Hackman, 1987; Majchrzak, 1988; Sundstrom, De Meuse & Futrell, 1990), organizational psychology (Guzzo & Shea, 1992; Hackman, 1987; Sundstrom, De Meuse & Futrell, 1990) and models of work group effectiveness (Gladstein, 1984; Guzzo & Shea, 1992; Hackman, 1987; Tannenbaum, Beard & Salas, 1992).

In this framework, general workgroup descriptors relevant to this research include:

Job design features, including autonomy, task variety, task significance and task identity.
Team or workgroup composition characteristics, including heterogeneity, flexibility, workgroup size, individual preference for group-working

Interdependence

Context, including training and managerial support

Work group processes

Work complexity, including degree of routine or programmable tasks, degree of difficulty of tasks, extent of diffusion of information required to complete tasks, level of information intensity

Alternately, standard instruments (e.g. Task Load Index Workload Rating (Hancock & Meshkati, 1988) or the Job Descriptive Index (JDI) (Smith, Kendall & Hulin, 1969) could be considered.

Learnings from Framework 2

- Workgroup performance could include a mix of qualitative and quantitative measures, as performance = efficiency + effectiveness
- Quantitative measures will relate more specifically to team functionality from a business/economic perspective.
- Qualitative measure may also relate to team performance but could include the psychosocial aspects of team effectiveness.
- Efficiency or productivity could be measured by the amount of unfinished work as a percentage of total new work received.


An extension to Framework 2, including professional knowledge workers carrying out more complex work, analyzed at the group level.

Learnings from Framework 3

- Different data sources and time frames might be employed.
- Different constructs were used to “operationalize the team characteristics and measurement criteria”, but a deficiency is in the use of a linear cause-effect model.
- Did not include productivity as a team effectiveness measure, it being argued that “team productivity” could not be measured due to job complexity.
- Outcome measures didn’t translate particularly well across diverse job types.

General workgroup descriptors relevant to this research include:

*Task design*, including organisation context and internal processes
*Environmental factors* such as client organization, industry factors, turbulence and rate of change
*External processes and communication*, including conflict with peers, workgroup boundaries
*Group psychosocial traits*
*Group norms and shared mental models*

**Learnings from Framework 4**
- Team performance output measures were clarified as effectiveness measures comprising three component parts (performance, attitudinal, behavioural).

**Step 2: Modeling the situation based on an explicit perspective, outlook or world view**

The *world view* adopted is that individuals in workgroups can be described as comprising embedded, spatial, informational and human-social subsystems, that interact in complex, dynamic ways to create emergent states, the viability of which may be influenced by increasing workspace density, such that overall system redundancy is compromised, potentially resulting in system collapse.

The research conceptual model is presented in Figure 7.
The model is clearly a simplification of the real-world situation, representing a concept of what is perceived, in this instance the workgroup in its own right but part of larger wholes (Checkland & Holwell, 1998).
Step 3: Exploration of the situation using the model
The exploration of the real world situation is covered in Chapter 5.

Step 4: Building knowledge to enable increased understanding of the problem situation to provide a basis for action
Please refer to Chapter 6.

Step 5: Taking action to better design and manage the problem situation
Please refer to Chapter 7.

B: Positivist Paradigm – Quantitative Research

The functionalist methodology emphasizes a concentration on objectivity, solutions lending themselves to mathematical sophistication.

Conceptualizing groups as “holistic and dynamic systems” is not new (Altman & Rogoff, 1987; Lewin, 1948), but applying the mathematics used in dynamical systems theory to social sciences is considered by Arrow, McGrath & Berdahl (2000) to be “more novel”.

One of the challenges posed by the study of social phenomena using a systems approach is the definition of mathematical models that provide sufficient analytical rigour that enables replicability. Agent-based modeling (ABM) (Elliott & Kiel, 2004; Epstein, 1999) represents a middle ground between the study of complexity in systems and remote mathematical studies (Stacey, 2003), enabling the interactions and behaviours of complex adaptive systems to be structured and patterned as “micro-worlds” created in a computer.

In the case of this research, the interactions among individual (workgroup) members (“agents”) resulting from cognitive, affective and behavioural reactions to meaning attributed spatially (viz; workspace density), create larger social structures and patterns of behaviour at the work system level, which may influence workgroup performance effectiveness.
Supporting the relevance of this approach, “explicit space” as a “defined landscape, or n-dimensional lattice” for evolution of the “model” (Elliott & Kiel, 2004) citing Epstein (1999), is identified as a key aspect in the ABM approach.

The ABM approach confirms a functional requirement to establish (simple) mathematical models that can demonstrate replicability of the research outcomes in the wider business context. To this end, Guastello (2005) maintains concise analytic tools and flexible software are now available to connect systems theory with group dynamics.

With reference to Figure 6, a number of the performance effectiveness measurement frameworks identified in the literature review, which are considered most appropriate for this research, are now briefly reconsidered and summarized hereunder.

**Framework 1: Traditional Group Performance Measures**

Sundstrom, McIntyre, Halfhill & Richards (2000) summarized workgroup research from the original Hawthorne experiments into the 1990’s, identifying likely data sources for group performance measures that have relevance for the research. These include:

*Customer ratings*, although value chains within service level agreements may be more appropriate for internal teams. This approach is likely to add unnecessary complexity to the research.

*Organizational records*, a prevalent source of information, specifically where team output can be measured.

*Manager ratings*, plus multi-item ratings for high internal consistency (Fry & Slocum, 1984).

**Learnings from Framework 1**

- Individual group member ratings, but aggregated data based on traditional measures can be misleading. More acceptable if prior agreement of group members is obtained citing also (Roberts, Hulin & Rousseau, 1978). Possibly use a “statistical index of intra-group agreement”, citing also James, Demaree & Wolf, (1984) and Moritz & Watson (1998).
- Mitigating against this approach, aggregated individual member assessments of overall group performance do not correlate well with objective indicators of performance (James, Demaree & Wolf, 1984).

Framework 2: Group Characteristics as Outcome Effectiveness Measures

Group characteristics worth considering include:
- Collaboration
- Interactions and relationships among members
- Cohesion (workgroup cohesiveness)
- Group norms (e.g. shared views about the role and relevance of space density to individual satisfaction and group satisfaction/performance)
- Team cognition (required for coordination in a workspace for teams to be able to perform)
- Team environment (important for team cognition). Environment could include the physical environment

Predominant instruments used for measuring group effectiveness could also be considered, e.g.:
- Minnesota Satisfaction Questionnaire (MSQ) (Weiss, Dawis, England & Lofquist, 1967)
- Group Environment Questionnaire (Carron & Hausenblas, 1998; Carron & Brawley, 2000; Carron, Brawley & Widmeyer, 2002)
- Team Cohesion (Carless & De Paola, 2000; Weiss, Dawis, England & Lofquist, 1967)
- Team Effectiveness (Carless & De Paola, 2000)
- Group Level Job Satisfaction (Mason & Griffin, 2002)

Learnings from Framework 2
- Differentiating between individual and group measures in the selection of any instrument is an important research consideration.
Tesluk, Mathieu, Zaccaro & Marks (1997) recommended using several sources of information in combination (e.g. surveys, questionnaires, observation, interviews, archival data) to provide a more holistic view of team/workgroup functioning and effectiveness.

Learnings from Framework 3
- For individual satisfaction, the Minnesota Satisfaction Questionnaire (MSQ) is considered appropriate (Polley, 1985; Polley & Jessup, 1988).
- Individual team members can legitimately provide information on team/workgroup processes (e.g. cohesion), member satisfaction and team viability, not obvious to others outside the team.
- Reactions from individuals (either cognitive, affective or behavioural) have a complex interplay, since individuals not only respond to external environmental stimuli (e.g. jobs, organizational and spatial contexts); they also reflect interactions with others in the workgroup. Identifying an appropriate performance effectiveness measure and its particular causes presents significant challenges, necessitating an interdisciplinary perspective. This enables the effectiveness or the workgroup to be considered in terms of its viability as a work system. For a workgroup to be viable, it should be cohesive enough to perform its allocated task(s), meet individual social needs and be attractive enough for individuals to want to stay engaged with the group.

Framework 4: Aggregation Issues
Tesluk, Mathieu, Zaccaro & Marks (1997) indicated that data on measures such as cohesion collected through individual’s ratings are typically aggregated at the group level. Carron & Brawley (2000) and Carless & De Paola (2000) aggregated individual data, confirming the Carless Cohesion Survey can be used as a legitimate instrument at the workgroup level for this research.

Learnings from Framework 4
- Further research, may consider the application of more rigorous statistical criteria to aggregate the individual data, such as calculating an Index of Interrater Agreement ($r_{wg}$) to assess the homogeneity of member perceptions (Tesluk et al.,
1997) citing James, Demaree & Wolf (1984; 1993) and Kenny & La Voie (1985),
or to conduct multi-trait, multi-source analysis, citing Thomas, Shankster &
Mathieu (1994). However this level of analysis is not considered warranted for this
research.

**Framework 5: The Laboratory Study**

Losada (1999) chose profitability, customer satisfaction and assessment by
superiors, peers and subordinates as performance measures. However he pre-
classified the teams’ performance (either high, medium or low performing) prior to
“mapping” their connectivity, considered to be indicative of the same performance in
a different, controlled working situation.

The “degree of connectivity” of a team (Losada, 1999) was identified as an excellent
predictor of team performance, and chosen as a “critical control parameter” in this
research. Connectivity was mathematically calculated based on observations of
“coded speech acts” (a qualitative measure) in a laboratory situation.

**Learnings from Framework 5**

- The value of this research is in the use of mix of qualitative and quantitative
  performance measures, some quite context specific.
- The research is heavily mathematical, the laboratory study “based on expedience
  and comfort” (Cohen & Bailey, 1997) does not represent a real world group
  working situation.
- Losada (1999) (ibid. p188.) beneficially concluded that “chaos underlies the ability
to respond flexibly to the outside world”, citing also Freeman (1991), but most
likely incorrectly, in the generalization that complex dynamics are associated with
high team performance. Certainly in the “time-boxed” laboratory study of the
teams in question here, higher short-term performance outcomes may have been
achieved (although these were not indicated). A performance rating was prior
allocated to each team in a completely different spatial context. Whether these
teams could be seen as effective in the longer term, or viable as ongoing work-
systems, in the “time-boxed” context, was not questioned. Thus, the butterfly
patterns may indicate chaotic behaviour associated with unstable work-system
dynamics, despite short term “performance” potentially being demonstrated.
Losada may therefore have not necessarily made the more significant advance
from measuring team performance effectiveness using variables that are context specific, to using an overarching measure (e.g. viability), which can be utilized generally across a diversity of spatial contexts.

**Framework 6: The Workflow - Cohesion - Performance Relationship**

Beal, Cohen, Burke & McLendon (2003) proposed that as team workflow increases, the cohesion – performance relationship becomes stronger.

**Learnings from Framework 6**

- Cohesion has generally been narrowly operationalized as “attraction to a group”, but task cohesion is more closely related to work performance than interpersonal cohesion (Carless et al., 1995), citing also Mullen & Copper (1994), Zaccaro (1991) and Zaccaro & Lowe (1988).

- As exploring the relationship between workgroup and workflow type, cohesion and performance is central to this research, workflow type becomes a critical workgroup selection criterion.

- Behavioural indicators such as cohesion are preferable, being antecedents of actual performance outcomes.

- While space density affects overall cohesion, social and task cohesion may be impacted differently, and for different workgroup types.

- Carless & De Paola (2000) seeking a broader conceptualization of cohesion adapted the Group Environment Questionnaire (GEQ) (Widmeyer, Brawley, & Carron, 1985), validating it for naturally occurring work teams, thus providing a measure of cohesion that has applicability in this research.

**Constructing the Mathematical Model**

Holland (1995) noted that while complex systems might differ in detail, they share a commonality with regards coherence and viability in the face of change. The study of these diverse systems comes under the heading of Complex Adaptive Systems (CAS), which exhibit general characteristics of involving agents, properties of aggregation, non-linearity, flows, diversity, and mechanisms - internal models, building blocks, and tagging, a visible sign of aggregation or boundary formation.
Complex adaptive systems, associated with chaotic behaviour, also have processes that appear to proceed according to chance, even though their behaviour is determined by precise laws (e.g. Rossler, Lorenz).

**Thus H1: Workgroups, as work-systems exhibiting complex adaptive behaviour, can be described using a mathematical model comprising a set of non-linear equations, when the interdependent variables are the three subscale components of Workgroup Cohesion.**

**Confirming the First Hypothesis**
The findings from the literature review of cohesion can be summarized to indicate interrelationships between the subscale components, $C_s$, $C_t$, and $C_a$ as follows.

- Social Cohesion ($C_s$) and Task Cohesion ($C_t$) interact non-linearly, with lead-lag relationships, $C_s$ preceding $C_t$.
- The interaction of $C_s$ and $C_t$ drives a third variable, Individual Attraction to the Group ($C_a$). Some individuals may be more or less attracted to the group by either variable or in combination.
- Space density has a critical incidence on $C_s$.
- Change in $C_s$ is also a function of $C_t$, discounted by a scaling factor
- Change in $C_t$ is also a function of space density, which influences $C_s$ in a non-linear way.
- $C_s$ precedes $C_t$ and the combined effects of $C_a$ and $C_s$ can be discounted.
- Change in $C_a$ is a function of both $C_s$ and $C_t$ and the existing state of $C_a$.
- $C_s$ is considered to be a precursor to $C_t$ the latter having stronger links to performance.

Based on these interrelationships, the subscale components of cohesion, lend themselves to mathematical modeling according to a set of non-linear differential equations.

Thus, the non-linear differential equations, with the capability to indicate the viability of the workgroup as a system, using the three aspects of cohesion, are constructed as follows:
\[
d C_s /dt = S \times (C_t - C_s) \quad \text{(Eqn 1)}
\]

\[
d C_t /dt = (R \times C_s) - C_t - (C_s \times C_a) \quad \text{(Eqn 2)}
\]

\[
d C_a /dt = (C_s \times C_t) - (B \times C_a) \quad \text{(Eqn 3)}
\]

S, R and B are variables used to complete the non-linear equations based on the relationships between the various aspects of cohesion as described above.

H1 being confirmed, these equations can then become the mathematical tools for handling work “flows” (Sparrow, 1982), when all the internal variables in the work system are constantly changing, and the basis for testing the subsequent research hypotheses.

**Application of the Lorenz Equations**

One set of differential equations, the Lorenz Equations (Lorenz, 1993), seem to display for different parameter values, most of the kinds of chaotic behaviour observed in other three-dimensional systems of chaotic differential equations (Sparrow, 1982). See also APPENDIX 1.

It is possible to map in as many dimensions as the number of variables in the system. Hence for 3 variables it is possible to map in 3-Dimensional Phase Space (i.e. the micro-world of the computer) by observing the “flow” of the work system in response to perturbations caused by different levels of workspace density in 2-Dimensional physical space (Lorenz, 1993).

The challenge is to determine the three variables such that they adequately describe the complexity of the system or move to map in higher n-Dimensional Phase Space using more complicated equations and mathematics.

**Thus H2**: That the state of a workgroup as a work-system can be described by a set of non-linear differential equations developed by Edward Lorenz, and mapped mathematically in “3D Phase Space”.
The three aspects of cohesion have been selected to describe the complexity of the work system and to indicate its viability in response to different levels of space density.

The non-linear differential equations in the model bear a remarkable resemblance to the Lorenz Equations, a not unsurprising fact given that workgroups can be described as a CAS. However the applicability of the Lorenz Equations will be determined by varying the value of $\rho$ (to reflect space density), to solve them mathematically. By comparing the computer-generated time series for the three variables ($x$, $y$ and $z$) with the actual time series generated for the three aspects of cohesion, based on longitudinal workgroup data collected from respondents in the field (Carless & De Paola, 2000) their correspondence can be established.

If H2 is confirmed, then for each workgroup, the first measured values (i.e. field data) for $C_s$, $C_t$, and $C_a$, can then be used subsequently as "start data" in the Lorenz Equations for different values of $\rho$, the Critical Control Parameter, to mathematically generate the 3D Phase Space plots

**Sensitive Dependence on Initial Conditions**

Chaos can be described as *when the present state completely or almost completely determines the future state, but does not appear to do so*. In other words, deterministic behaviour appears random.

A chaotic system has a sensitive dependence on initial conditions, but this sensitivity does not necessarily imply chaotic behaviour. The initial conditions for the workgroup at the time of the research need not be the same as those that existed when the work system was originally created. Hence, space density as an external condition can establish in the workgroup, the internal conditions that are subject to change and investigation.

Thus H3: The viability of the workgroup as a work system has a sensitive dependence on workspace density, with a likelihood of system collapse if increased beyond a certain critical point.
It is expected the following 3D Phase Space plots (maps, graphs) can be generated when the equations are solved for different values of $p$ corresponding to different levels of workspace density.

<table>
<thead>
<tr>
<th>Unstable State</th>
<th>Transition State</th>
<th>Stable State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

Increasing Workspace Density

The Importance of Workflow Type

Beal, Cohen, Burke & McLendon (2003) presented a useful taxonomy of primary work process types to describe how work flows between members of a team or workgroup.

Thus H4: The impact of workspace density on work-system collapse is different for different workgroups depending on their predominant workflow type.
CHAPTER 5: FIELD RESEARCH AND CASE STUDY

Introduction to the Host Organization

The host organization (HO) was a large local government authority. A research champion (RC) was identified in the HO. This senior manager (HO Branch organization level head) had direct responsibility for employee accommodation and thus a strong interest in the expected practical application of the research findings.

The RC was fully briefed on the research proposal by way of a Research Project Plan, face-to-face meetings, telephone conversations and email communication. This enabled an internal proposal to the Chief Executive Officer to be circulated at directorate level for review and preliminary research project approval. Additional cost-benefit information was then provided, and following more in-depth consideration of the proposal, two directorate heads agreed to participate fully in the research. This agreement yielded a pool of 565 (31%) likely participants from a total of approximately 1800 employees in 40 business units/branches.

An overview of the research project was then distributed to all employees within the two participating directorates.

Refer to APPENDIX 2 for copies of relevant planning documents.

Preliminary Organizational Analysis

Within the two directorates, a preliminary analysis was carried out to identify the most suitable branches and workgroups.

Thirteen (13) different branches, comprising a total of 29 work groups undertaking different work activities were clearly identified. These directorates, branches and workgroups were also accommodated in two different buildings.

Building A was constructed in 1975 and had been altered and reconfigured over time to meet the needs of an expanding workforce.

The workgroups participating in the research were accommodated on the ground floor of a "warehouse" type structure with flat roof supported by steel pillars and
having a 2700mm high-suspended ceiling. The building was serviced by a central, chiller-fed air-conditioning system. In the two years prior to the research, this building had undergone significant renovation to bring the site up to a modern office environment. Upgrades related mainly to workplace health and safety non-compliant issues and staff working in environments that had been largely unchanged in the past 15 years. Prior to the upgrade, the internal workspace had inadequate access to natural light with enclosed, traditional perimeter offices restricting views of the outside world. Work-desks were antiquated and in a poor state of repair. Air conditioning was a constant problem and temperature fluctuations were almost impossible to manage. The total building has a net lettable area (NLA) of approximately 10,500m², with the workgroups participating in the research accommodated in approximately 1/3 of this space. Refer to APPENDIX 3 for floor layouts.

Building B is a 5 level, B+ Grade commercial office building, approximately 20 years old, served by 3 lifts and a central air-conditioning unit. It is rectangular-oval shape, east to west, with curved external walls and floor to ceiling glass. There is a central common corridor with the services core is on the south wall. Each floor has 1200sqm of NLA, excluding the corridor.

The Level 1 tenancy accommodating some of the workgroups (2a – 2d) was refurbished in 2006. The Level 2 tenancy for workgroups (4a – 4e) was finalized in 2007. There is a large area on Level 2 providing lunchroom space and meeting rooms. The building receives northern sun in the winter and can be very hot on the western walls in summer. Air-conditioning is not zoned to differentiate between window seating and central seating. Recent new fit-outs were designed to the requirements of the specific workgroups. Refer to APPENDIX 3 for floor layouts.

Within each of these buildings different workspace layouts and work-point standards were in use:
- Standard 1 (S1): older style work-points in a 90° right–angle configuration
- Standard 2 (S2): more modern work-points in a 120° Y configuration
- Standard 3 (S3): innovative “pods” in a 120° Y configuration

These standard layouts and work-point types are also shown in the APPENDIX 3. Standards S1 and S2 were the predominant work-point configuration types.
All employees within the selected workgroups were accommodated in an open plan arrangement. The workspace layouts for the workgroups in APPENDIX 3 confirm largely self-contained branches with a relatively uniform distribution of workstations across the floor-plate. That is, there is no trade off between (potentially higher) space density at the workstation, and that in the shared space. Workgroup managers/supervisors working in the very few enclosed offices were excluded from the data collection phase of the research.

As open plan arrangement have largely been universally adopted as the “standard” in this organization, there being very few enclosed offices (also provided on the basis of need), the accommodation strategy employed is consistent with current industry practice. This suggests the findings from this research could reasonably be expected to have wider application beyond the HO.

Further, the application of these standards varied across workgroups, resulting in different workspace densities for different workgroups. Workspace density was calculated as net lettable floor area (NLA) allocated to each branch, less the floor space allocated to any shared services (kitchens, meeting rooms and the like), and common circulation corridors, divided by the total number of work-points to deliver a m²/workpoint figure.

The preliminary analysis also revealed different space densities for workgroups in different branches, directorates and buildings in the HO.

Of the 13 initial branches, 4 were quickly eliminated from the research data collection phase due to their small total size (14, 24, 27 and 40 persons respectively). Prior to this phase commencing, one branch also opted out citing concerns about interference with business as usual.

**Workgroup Selection – Practical Considerations**

The work group (team or business unit) selected should not be at start-up, but have some longevity and history. Because group spaces are “gradually constituted” the study was limited to well-established work systems. Even within these established work systems, it may be appropriate to ensure the rate of group space constitution
(or reconstitution) is not so rapid as to be a consideration for workgroups in different physical space densities (Tohidi & Tarokh, 2006), citing also Moreno, Valls & Marin, (2004).

Initially, the workgroups needed to be described by at least some of the following factors:
- Average length of employee service
- Approximate time within the team/workgroup construct
- Age profile
- Other demographics as appropriate

As well, where practical the important team design or contextual variables identified within the frameworks summarized above for effectiveness were used to describe the workgroups.

Risk Assessment

An assessment of risk was carried out in order to determine whether a formal Human Subjects Ethics Research approval was necessary.

The assessment, carried out to AS4360: 2004, focused on:
- Identifying the nature of any likely risks
- Estimating the probability of occurrence of the risk
- Estimating the consequences of the risk to relevant stakeholders
- Placing the risk in a presentation form (e.g. matrix) for ease of interpretation by a third party
- Rank ordering the risks
- Presenting any risk minimization or avoidance strategies should they be required
- Ensuring the risks were periodically reviewed over the life of the research project to ensure they remain below an acceptable threshold

The questionnaires were administered by and on behalf of the HO hence the retention and storage of the responses resides with them. The Risk Assessment outcomes are in APPENDIX 4.
Staff Briefings
A series of staff briefing sessions were conducted to outline the aim of the research and proposed research method. These informal briefings were made in the actual workspace being the subject of the research. Individual employee involvement/commitment to the research was requested on behalf of the employer (HO) through whom and for whose benefit the data collection was conducted. These briefings stressed the voluntary nature of the participation sought, the level of communication to be provided by the researcher, opt out and feedback mechanisms, and proposed incentive scheme. The briefings also provided ample opportunity for questions and answers relating to the proposed research.

Research Data Collection
Workgroup Business Operations Context
The operating environment for each workgroup was summarized, based on interviews conducted with each of the branch heads. Additional workgroup descriptive data was also collected.

Branch heads were asked to provide information from their performance management system or to confirm workgroup performance outcome measures where they existed. Refer to APPENDIX 5.

Each workgroup was classified according to its primary work flow/work process type using a proprietary tool (identified as a paper-based “Workflow Questionnaire”©) developed by the researcher and described elsewhere (Purdey, 2009). The findings are included in APPENDIX 6.

Managerial Support
Managerial support relates to the ability of management to respond to employee or team dissatisfaction with either the work itself (job) or the work environment. For the research period it is assumed there will be no change in material support provided by the organization to address any reactions to space density.
Workgroup Complexity
Task Load Index Workload Rating (Hancock & Meshkati, 1988) and the Job Descriptive Index (JDI), (Smith, Kendall & Hulin, 1969) are considered appropriate instruments, with the latter selected. However, no specific analysis of group work complexity or information intensity was proposed.

Workgroup Characteristics
The Group Environment Questionnaire (GEQ), (Carron, 1982) was selected to collect data on characteristics of the workgroups. Being a well-accepted research instrument, it could be used to identify if any significant changes in characteristics occur over the research data collection phase.

A number of workgroup characteristic categories (scales) were not relevant to this research so the questions were removed. The modified GEQ, identified as a paper-based “Workgroup Characteristics” survey questionnaire, was hand distributed to all participating employees, at both the beginning (pre) and end (post) data collection phase. Completed questionnaires were collected by the RC and forwarded to the researcher.

In relation to the data analysis the instrument authors indicate individual questions can be used on their own, or the separate scales may be presented as aggregated or averaged scores for each of the workgroup characteristics.

Workgroup Satisfaction
The Job Descriptive Index (JDI) was selected to collect data on workgroup satisfaction. Factors not relevant to the research (e.g. remuneration) were eliminated, while the questions from the companion Stress in General (SIG) instrument (© Bowling Green State University, 1982; 1985, © Parra & Smith, 1995) were added in to yield a composite survey questionnaire identified as a paper-based “Job Descriptive Index”, which was hand distributed to all participating employees, at both the beginning (pre) and end (post) data collection phase. Completed questionnaires were collected by the RC and forwarded to the researcher. The Minnesota Satisfaction Questionnaire (MSQ), (Weiss, Dawis, England & Lofquist, 1967) was not considered further, since it requires a qualified psychologist to be administered.
Workgroup Viability

The short-form Work Group Cohesion survey (Carless & De Paola, 2000), identified as a paper-based “Workspace Survey” was used to measure workgroup viability and to provide the data for constructing the time series for the three interdependent variables Cₛ, Cₜ and Cₐ.

To construct these time series, the design of the research data collection phase had to be determined, with respect to the key interrelated factors, viz; the survey period, survey fatigue and survey sample sizes.

A survey period of three-months was considered sufficient, potentially yielding approximately 60 data points for each variable\(^1\).

To collect sufficient data and minimise survey fatigue, two options were considered.

Option 1:
Survey a sample of employees on a daily basis, using a random selection technique, sufficient to generate enough usable responses.

\textit{Advantages:}

All participants are given the opportunity to participate in the survey over the life of the survey.

\textit{Disadvantages:}

A more complex survey method.

Lower participation rates or returns from smaller workgroups likely: or

Option 2:
Survey a sub-group from the total population on a rotating daily basis.

\textit{Advantages:}

Much simpler in terms of the proposed survey instrument distribution method

Work group participants can be selected on a semi random basis (e.g. based on alphabetical name listing).

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Note 1: Personal communications: Dr Mike Wheatland, Physics Department, University of Sydney (29 August, 2008), Dr Charles McAskill, Mathematics Department, University of Sydney (June 27, 2008)
Whilst a rotating daily basis is easy to administer, the sampling of individuals does not have an even rhythm due to the non-sampling on weekends and public holidays, thus increasing randomness.

Not all participants would necessarily participate in the survey every day over the life of the survey.

Stronger likelihood of achieving an overall satisfactory response rate.

**Disadvantages:**

Not every participant would necessarily participate in the survey every day over the life of the survey, potentially decreasing the response rate.

Option 2 was selected. From the eight participating Branches a “Master List” of 254 names was established comprising 3 separate sub-lists. To administer the Workspace Survey independent of the HO and the researcher, the survey questionnaire was hosted on the web site of an independent service provider in the USA (www.surveymonkey.com).

A second independent service provider (www.verticalresponse.com) was engaged to conduct an “email campaign” targeting each of the sub-lists on a rotating three-day basis. That is participants on each list were sent an email on day 1, then not emailed for the following 2 days, the cycle being repeated for a total of three consecutive months. Mailing days did not include weekends and public holidays.

The email campaign was compliant with Australian and US “spam” legislation with all recipients of every email given a choice to opt-out of the research. Email recipients deciding to continue their support for the research were directed to the web address of the hosted on-line survey in order to complete their daily responses.

The Workspace Survey included, in addition, mandatory fields, enabling individual responses to be tied to specific workgroups, via:

- Building Location
- Directorate Name
- Branch Name
- Workgroup Name

There was an optional field for individual Respondent Name identification.
Quality Control

The email campaign was consistent in terms of its word content and format across the entire data collection phase. The email was mailed to the sub-lists at the same time on each day (i.e. 10am AEST), with the opt-out facility always available for each recipient.

The number of emails sent, and the service provider reported the receipt rate, on a daily basis. Recipients who decided to opt-out of the research project were automatically deactivated in both the sub-lists and Master List.

Alternately recipients could choose to remain active in the email lists, but not register their daily response to the survey, thus exercising their discretion to contribute to the survey depending on their particular daily work situation.

While participation in the survey on the selected days was triggered by the email campaign, the on-line survey was actually available to all potential respondents (including those who had voluntarily decided to opt out of the email campaign) at all times leaving open the possibility of corrupting the results by staff responding more frequently than on a three-day basis. However single daily responses, on non-emailed days would still be valid.

As each response was date stamped, it was possible to identify respondents who completed the survey more frequently than third daily. In order to ensure the integrity of the data it was scanned to ensure responses reflected actual variability in reaction to environmental conditions, not simply an attempt to manipulate the incentive scheme.

Maximizing the Survey Response Rates

To maintain the highest number of potential respondents in each sub-list, independent emails were sent to all addresses in the Master List to communicate the status of the research, notify incentive-prize winners and invite any employee who had inadvertently opted out, but wished to be reactivated, to advise accordingly.
This advice was forwarded to the email service provider and sub-lists were updated in readiness for the next “campaign”. This process also ensured compliance with “spam” legislation.

Further, to mitigate against the effects of survey fatigue, and increase response rates, respondents were invited to participate in an incentive scheme. This scheme offered a monthly incentive-prize for those individual(s) who completed the survey most often.

The staff pre-briefing sessions and the daily email message confirmed that Respondent Names would be used only for the purpose of determining the incentive-prize winners. Response rates were cumulative at the end of each month. The HO was dutifully informed of monthly progress and made appropriate arrangements for the distribution of the incentive-prizes, which were more symbolic in nature than financially motivating. The response rates are shown in APPENDIX 7. There is no evidence of survey bias from the sampling technique employed.

Data Analysis and Findings

Workgroup Characteristics

The scores from the pre and post surveys show no significant changes in individual ratings of workgroup characteristics at the branch level over the research data collection period (i.e. three months). The data is shown in APPENDIX 8.

Workgroup Satisfaction

As the “initial conditions” for the work system as a CAS can be established at any point in time, they do not determine a specific outcome, despite system behaviour having a sensitive dependence on same, it was decided not to analyse the pre and post data collected. Stimulus – Response theory would seem to support this decision, since individuals in groups can respond to stimuli (such as changes in space density) at any point in time – either before during or after the change event. System viability being the aggregate of all responses in time is what was measured via the Workspace Survey, however this contention could be explored by examining the data in further research.
Workgroup Viability

Constructing the Data Sets

When the data were sorted by workflow/work process type, workspace density and work point standard type, a number of workgroups were removed from any further analysis due to insufficient responses. Table 4 summarizes the final usable data sets.

Table 4: Summary of Usable Data Sets

<table>
<thead>
<tr>
<th>Workspace Density</th>
<th>Primary Work Flow/ Work Process Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sequential</td>
</tr>
<tr>
<td></td>
<td>Standard S2 (40)</td>
</tr>
<tr>
<td>6.52</td>
<td>Standard S1 (39)</td>
</tr>
<tr>
<td>7.12</td>
<td>Standard S2 (65)</td>
</tr>
<tr>
<td>7.58</td>
<td>Standard S2 (31)</td>
</tr>
<tr>
<td>8.29</td>
<td>Standard S1 (59)</td>
</tr>
<tr>
<td>8.83</td>
<td></td>
</tr>
<tr>
<td>11.24</td>
<td>Standard S1 (28)</td>
</tr>
</tbody>
</table>

Notes:
1 Numbers in brackets indicate number of usable time series data points
2 Workspace Density in m²/workpoint

The following convention was adopted to describe the data sets: Workgroup Number (Work point Standard, Space Density, Workflow Type), e.g. Workgroup 4b (S1, 8.29, S).

Assumption 1: The Workgroup Cohesion - Space Density Relationship

The literature review points to a non-linear relationship between space density and cohesion, viz; an inverted “U” shape. As space density increases, overall cohesion is assumed to increase up to a point, beyond which it would then decline.
All of the usable workgroup data yielded the following, non-linear relationship between cohesion and space density, suggesting the assumption to be valid. Note: The “usable workgroup data” excluded those workgroups where it was considered there was an insufficient total response to the cohesion survey - i.e. at 7.58m² (S2, 31 responses) and 6.43m² (S2, 32 responses).

Graph 1: Cohesion versus Space Density

It is further determined that the relationship between Cohesion (C) and Space Density (SD) in this instance, can best be described by a second order polynomial, having the highest correlation coefficient, and the equation;

\[
C(SD) = -0.0274SD^2 + 0.354SD + 3.3943
\]

Given the limited data, further research is recommended to test the validity of this specific mathematical relationship.

Assumption 2: Workgroup Cohesion, Space Density and Workflow Type

As questions (Q5 - Q8, variable C_t) in the Workspace Survey relate only to task outcomes, the underlying assumption is that cohesion is independent of work flow or work process type used to deliver these outcomes.
Accepting this assumption leads to the Cohesion-Space Density relationship established above being applicable to the analysis of workgroups with different workflow types, in the first instance.

**Assumption 3: Workgroup Cohesion and Work point Standard Type**

The assumption that workgroup cohesion is not affected by work point type also needs to be tested via further more detailed research.

**Constructing the Work Group Cohesion – Time Series**

Date stamped participant responses were formatted into (.csv) files and downloaded. The responses from only one individual were deleted to maintain data integrity. The overall responses are contained in APPENDIX 9.

These data files confirmed Branch 5 with a low response as it withdrew from the research project due to an organisational restructure. Seven branches participated fully in the research providing useful data, via the Workspace Survey, viz:

- Q1 - Q4, Social Cohesion and the data variable $C_s$
- Q5 - Q8, Task Cohesion and the data variable $C_t$
- Q9 - Q10, Individual Attraction to the Group and the data variable $C_a$

Refer to APPENDIX 12.

Average daily responses from all respondents in a particular workgroup were used to construct the time series, having due regard for the days on which there were nil responses. Refer to APPENDIX 10 for the time series data.

**Workgroups with Sequential Workflow Type**

Workgroups generating a smaller number of time series data points were eliminated in the first round of detailed data analysis.

Table 5 now summarizes only the data for the sequential workflow workgroups, in terms of their Overall Cohesion scores ($C$), Social Cohesion ($C_s$), Task Cohesion ($C_t$) and Attraction to the Group ($C_a$). $C(\text{SD})$ is the calculated value of cohesion from the space density polynomial established above.
Table 5: Summary Data for all Sequential Workflow Workgroups

<table>
<thead>
<tr>
<th>Workgroup</th>
<th>Data Points</th>
<th>Standard</th>
<th>m²/point</th>
<th>C_s</th>
<th>C_i</th>
<th>C_a</th>
<th>C</th>
<th>C(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>34</td>
<td>S1</td>
<td>11.24</td>
<td>5.982</td>
<td>4.496</td>
<td>2.321</td>
<td>4.266</td>
<td>3.912</td>
</tr>
<tr>
<td>1b</td>
<td>28</td>
<td>S1</td>
<td>11.24</td>
<td>3.709</td>
<td>3.477</td>
<td>3.521</td>
<td>3.569</td>
<td>3.912</td>
</tr>
<tr>
<td>7a</td>
<td>58</td>
<td>S1</td>
<td>8.29</td>
<td>6.015</td>
<td>4.757</td>
<td>2.580</td>
<td>4.451</td>
<td>4.446</td>
</tr>
<tr>
<td>4b</td>
<td>59</td>
<td>S1</td>
<td>8.29</td>
<td>4.675</td>
<td>4.166</td>
<td>4.722</td>
<td>4.521</td>
<td>4.446</td>
</tr>
<tr>
<td>8a</td>
<td>39</td>
<td>S1</td>
<td>6.52</td>
<td>5.556</td>
<td>4.267</td>
<td>4.069</td>
<td>4.631</td>
<td>4.538</td>
</tr>
<tr>
<td>8b</td>
<td>35</td>
<td>S1</td>
<td>6.52</td>
<td>5.928</td>
<td>5.591</td>
<td>4.568</td>
<td>5.362</td>
<td>4.538</td>
</tr>
<tr>
<td>4d</td>
<td>54</td>
<td>S2</td>
<td>7.12</td>
<td>6.037</td>
<td>4.900</td>
<td>3.434</td>
<td>4.790</td>
<td>4.526</td>
</tr>
<tr>
<td>4a</td>
<td>65</td>
<td>S2</td>
<td>7.12</td>
<td>4.619</td>
<td>4.000</td>
<td>5.261</td>
<td>4.626</td>
<td>4.526</td>
</tr>
</tbody>
</table>

Testing the Second Hypothesis

H2: That the state of a workgroup as a work-system can be described by a set of non-linear differential equation developed by Edward Lorenz, and mapped mathematically in “3D Phase Space”.

Specifically, Workgroup 4b (S1, 8.29, S), in the “mid-range” of space density, was selected for more detailed analysis, the calculated value of C(SD) closely approximating its measured cohesion value. The actual (bounded) time series plots for each component of workgroup Cohesion, are first presented hereunder. The “trendlines” in the actual time series plots indicate a short-term tendency towards system stability. The sinusoidal frequency plots here are added to illustrate that a particular frequency can be construed that will connect all the data points. Further sophistication is beyond the scope of this research but can be established mathematically by cross correlating all the data to find the exact time series plot. The major feature illustrated here is that virtually all data points lie within the set bounds.
Graph 2: Workgroup 4b Social Cohesion Time Series

Graph 3: Workgroup 4b Task Cohesion Time Series
Graph 4: Workgroup 4b Attraction to the Group Time Series

\[ C_t \text{ bounded in the range between 3.00 and 5.00} \]
\[ C_s \text{ bounded in the range between 2.50 and 5.75.} \]
\[ C_a \text{ bounded in the range between 2.00 and 8.00} \]

The mathematically generated time series (Matlab Plots) for the three aspects of Cohesion, when the Lorenz Equations were solved with a control variable \( \rho = 23.2 \), are similarly presented hereunder. Initial start data in the time series was used with variables \( x, y, \) and \( z \) in the Lorenz Equations replaced by \( C_s, C_t \) and \( C_a \) respectively.
The following comments are also made:

- In solving the model equations, the exact value of $\Delta t$ is unknown but is assumed to be 1 day. Despite the field data collection method being quite rigorous, it still generated data, which in terms of the sophistication of the mathematical equations can be considered quite crude. This points to the need for further research to bridge the data accuracy gap between laboratory measures (using shorter time frames and more frequent sampling) and real-world situations where continuous measurement is more problematic.

- The initial start points are not true start points for the “time series” of the workgroups, since all of the workgroups have been in existence for some time.

Whilst the non-linear differential equations in the model bear a remarkable resemblance to the Lorenz Equations, their applicability is determined by solving them mathematically and comparing the computer-generated time series for the three variables ($x$, $y$ and $z$) with the actual time series generated for the three aspects of cohesion, based on longitudinal workgroup data collected from respondents in the field. The findings here point to confirmation of the first part of the second hypothesis,
while indicating further research is required particularly to improve the accuracy of the data analysis.

Sensitivity Analysis
In order to test the sensitivity of the assumptions to any change in space density, it was varied by +/- 10% to determine the impact on control variable values. For Workgroup 4b (S1, 8.29, S), the control variable changed by only 3.7%, which is not significant, confirming that the assumptions made for this workgroup are reasonable.

Workgroup Viability
Using the Matlab Software again the Lorenz Equations were used to generate the 3D Phase Space plots to portray the “viability” of Workgroup 4b (S1, 8.29, S), viz:

\[
\frac{d C_s}{dt} = \sigma \cdot (C_t - C_s)
\]

\[
\frac{d C_t}{dt} = (\rho \cdot C_s) - C_t - (C_s \cdot C_a)
\]

\[
\frac{d C_a}{dt} = (C_s \cdot C_t) - (\beta \cdot C_a)
\]

S in the Model replaced by \( \sigma = 10 \)
B in the Model replaced by \( \beta = 8/3 \)
\( \rho \) the Critical Control Parameter = 23.2

Two plots for Workgroup 4b (S1, 8.29, S) were generated in 3D Phase Space for different “initial conditions”, viz:
- using the actual start data in the time series for each variable
- using the average value of all the data for each variable over the full research period. These numbers might be considered more “robust” data.

The results are presented hereunder.
These graphs confirm the second part of Hypothesis 2, and indicate the sensitive dependence on initial conditions for aspects of cohesion at this particular space density.

Testing the Third Hypothesis
H3: The viability of the workgroup as a work system has a sensitive dependence on workspace density, with a likelihood of system collapse if increased beyond a certain critical point.

Based on C(SD), and the control variable $\rho = 23.2$ for Workgroup 4b (S1, 8.29, S), a scaling factor of 5.2282 was calculated and then used to derive values of $\rho$ for the other Sequential workflow workgroups. These data are summarized in Table 6.
Table: 6 Values of $\rho$ for Sequential Workflow Workgroups

<table>
<thead>
<tr>
<th>Workgroup</th>
<th>SD (m²/point)</th>
<th>Standard</th>
<th>Derived $\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>11.24</td>
<td>S1</td>
<td>20.45</td>
</tr>
<tr>
<td>1b</td>
<td>11.24</td>
<td>S1</td>
<td>20.45</td>
</tr>
<tr>
<td>7a</td>
<td>8.29</td>
<td>S1</td>
<td>23.24</td>
</tr>
<tr>
<td>4b</td>
<td>8.29</td>
<td>S1</td>
<td>23.24</td>
</tr>
<tr>
<td>8a</td>
<td>6.52</td>
<td>S1</td>
<td>23.72</td>
</tr>
<tr>
<td>8b</td>
<td>6.52</td>
<td>S1</td>
<td>23.72</td>
</tr>
<tr>
<td>6d</td>
<td>7.58</td>
<td>S2</td>
<td>23.54</td>
</tr>
<tr>
<td>4d</td>
<td>7.12</td>
<td>S2</td>
<td>23.66</td>
</tr>
<tr>
<td>4a</td>
<td>7.12</td>
<td>S2</td>
<td>23.66</td>
</tr>
</tbody>
</table>

To test the hypothesis, 3D Phase Space plots were generated for the remaining workgroups in the Sequential workflow category. Plots using start data are presented below in order of increasing space density. Similar plots for average data are in the APPENDIX 11.

Graph 8: Workgroup 1a (S1, 11.34, S) - 3D Phase Space plot
Graph 9: Workgroup 1b (S1, 11.34, S) - 3D Phase Space plot
These plots clearly show that sequential workflow workgroups in S1 work-point standard exhibiting the characteristics associated with more unstable, less viable work-systems, as space density increases as indicated by the change in the Lorenz Equation plot patterns; i.e. from tight, single point attractor type to more open two point attractor sets. These findings indicate H3 can be confirmed, for these workgroups.

Graphs 14 is extrapolated for workgroups in general, occupying space densities outside of the range in the research, indicating an "inverted U" shape, as theorised: cohesion apparently increases with space density up to a point, beyond which it falls away again.
This graph suggests an optimum range of space density might be found between 5.25 and 7.75 m²/workpoint for workgroups generally, if overall cohesion is to be maximised at (or above) the mid point on the Carless instrument scale, at 4.5.

These data seem to confirm the hypothesis that there may be an optimal range of space density in order to maximize overall workgroup cohesion for different workflow types, with work system viability able to be portrayed by the 3D Phase Space plots using the Lorenz Equations.

**Investigating Assumption 1 Further**

With reference to only the workgroups with sequential workflow, for which there was significantly more robust usable data, an attempt was made to fit a more specific equation to all of the actual cohesion measures, at each space density level, including both S1 and S2 work-points. Again the second order polynomial equation had the highest correlation coefficient ($R^2 = 0.63$), compared with other graph types, although the linear chart also gave a very good fit ($R^2 = 0.60$).
The comparative values of calculated $p$ are summarised in Table 7.

Table 7: Comparative $p$ Values

<table>
<thead>
<tr>
<th>Space Density</th>
<th>Sequential Workflow</th>
<th>All Workflows Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.52</td>
<td>25.8</td>
<td>23.7</td>
</tr>
<tr>
<td>7.12</td>
<td>24.6</td>
<td>23.7</td>
</tr>
<tr>
<td>7.58</td>
<td>23.8</td>
<td>23.5</td>
</tr>
<tr>
<td>8.29</td>
<td>22.8</td>
<td>23.2</td>
</tr>
<tr>
<td>8.83</td>
<td>22.1</td>
<td>22.9</td>
</tr>
<tr>
<td>11.24</td>
<td>20.6</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Whilst the variation in values for $p$ for the different equations is slight, the clearly different relationship between cohesion and space density suggests a possible dependence of workgroup cohesion on specific workgroup workflow type. As there is insufficient data to support the construction of a Cohesion-Space Density equation for another workflow type (e.g. Pooled) this is worthy of further investigation. See also Testing the Fourth Hypothesis below.

Investigating Assumption 3 Further

Firstly, the cohesion – space density equation for sequential workflow groups above contained data for both S1 and S2 work-point types. Graph 16 shows the findings for
only S1 work-points. Whilst the actual mathematical equation is slightly different, the $R^2$ is high at 0.7 and the relationship is very similar. This tends to indicate that for sequential workflow workgroups there may be little influence of work-point type on cohesion outcomes.

Graph 16: Cohesion v Space Density – Sequential Workflow Workgroups (S1)

The 3D Phase Space plots for the remaining sequential workflow workgroups, but different work point standards revealed the following, again in order of increasing workspace density.
The results here are consistent with those for the S1 work-point standard, although suggesting that the S2 standard might support workgroup viability to higher levels of workspace density, before a work-system become more unstable, or less viable.
However, both Graphs 15 and 16, despite being relatively flat, seem to indicate a very narrow range of space densities capable of holding this type of workgroup, such that all three aspects of Cohesion are optimised. The 3D plots using average data are also in APPENDIX 11.

**Testing the Fourth Hypothesis**

**H4:** The impact of workspace density on work-system collapse is different for different workgroups depending on their predominant workflow type.

The following tables summarize the available but more limited data for pooled and reciprocal workflow types, and their respective 3D Phase Space plots at increasing workspace densities.

**Table 8: Data Summary for Pooled Workflow Workgroups**

<table>
<thead>
<tr>
<th>Workgroup</th>
<th>Data Points</th>
<th>Standard</th>
<th>m²/point</th>
<th>Cₕ</th>
<th>Cₜ</th>
<th>Cₚ</th>
<th>C</th>
<th>C(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a</td>
<td>25</td>
<td>S3</td>
<td>8.83</td>
<td>4.216</td>
<td>4.413</td>
<td>4.138</td>
<td>4.384</td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>40</td>
<td>S2</td>
<td>6.43</td>
<td>5.106</td>
<td>4.482</td>
<td>3.129</td>
<td>4.239</td>
<td>4.538</td>
</tr>
</tbody>
</table>

**Graph 20: Workgroup 3a (S2, 8.83, P) - 3D Phase Space plot**
The results here again confirm that increased workspace density is associated with more unstable work-system behaviour, but there is insufficient data to separate out the relative contribution of work-point type and workflow type. These results seem to suggest workflow type might have an influence on the workspace density at which a particular workgroup may become more unstable. The 3D Phase Space plots using average data are also in APPENDIX 11.

Table 9: Data Summary for Reciprocal Workflow

<table>
<thead>
<tr>
<th>Workgroup</th>
<th>Data Points</th>
<th>Standard</th>
<th>m²/point</th>
<th>(C_s)</th>
<th>(C_t)</th>
<th>(C_a)</th>
<th>(C)</th>
<th>(C(SD))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2b</td>
<td>32</td>
<td>S2</td>
<td>6.43</td>
<td>4.897</td>
<td>4.592</td>
<td>3.003</td>
<td>4.164</td>
<td>4.538</td>
</tr>
<tr>
<td>2c</td>
<td>40</td>
<td>S2</td>
<td>6.43</td>
<td>4.988</td>
<td>3.869</td>
<td>3.788</td>
<td>4.215</td>
<td>4.538</td>
</tr>
<tr>
<td>2d</td>
<td>52</td>
<td>S2</td>
<td>6.43</td>
<td>5.759</td>
<td>4.262</td>
<td>2.093</td>
<td>4.038</td>
<td>4.538</td>
</tr>
</tbody>
</table>

Graph 22: Workgroup 2b (S2, 6.43, R) - 3D Phase Space plot
The plots also appear to indicate that all of the workgroups are at the limits of viability at this space density. The 3D Phase Space plots using average data are also in APPENDIX 11.
Discussion of Findings

More appropriate linear models

The research literature points to a general lack of clarity in the definition of satisfaction as an outcome measure, and the need to more clearly differentiate between individual employee satisfaction as a psychological construct, team/workgroup satisfaction as a psychosocial construct, environmental satisfaction as psychosocial or affective response to the built environment and job satisfaction at the individual or team/workgroup level.

Equally the literature highlights consistent challenges in selection of outcome performance measures and the framework used to link input variables to these outcome measures.

For example, Wells (2000) noted the significant contribution of job satisfaction to psychological and physical health and wellbeing, her research on possible links between personalization of workspace, workspace satisfaction, job satisfaction and employee wellbeing indicating work environment satisfaction positively associated with job satisfaction, which in turn is positively associated with both individual wellbeing and organizational wellbeing, defined as (ibid. p. 241) the overall organizational climate – including employee productivity, performance, absenteeism and turnover.

The literature review suggests a more composite, linear model of job satisfaction and job performance could be used to pursue this line of research in the future. Refer to Figure 8.
Figure 8: Composite Job Satisfaction and Job Performance Model

General Workspace Characteristics
- Lighting
- Noise
- IAQ
- Temperature
- Furniture & Equipment
- Aesthetics
- etc

Moderators
- Cognitive mechanisms
- Affective reactions
- Workspace knowledge

Assessment Construct
- Cognitive
- Aesthetic
- Affective
- Functional
- Normative
- Active
- Temporal

Pre-existing Standards and Expectations

Mediators
- Individual differences
- Organizational context
- Workspace environmental features (functional & symbolic meanings)

Workspace Satisfaction

Job Performance

Mediators
- Success & achievement
- Task specific self-efficacy
- Goal progress
- Positive mood

Moderators
- Performance-rewards contingency
- Job characteristics
- Need for achievement
- Work centrality
- Aggregation

Job Satisfaction

Mediators
- Behavioural intentions
- Low performance as withdrawal
- Positive mood

Moderators
- Personality/self concept
- Autonomy
- Norms
- Moral obligation
- Cognitive accessibility
- Aggregation
- Level of analysis
Workgroups can be mathematically described for research purposes

The state of a workgroup can be described mathematically by a set of differential equations, enabling them to be studied as complex-adaptive work systems using non-linear methods. Further it is possible to describe workgroups as complex adaptive work systems using the non-linear differential equations developed by Edward Lorenz, enabling viability to be mapped mathematically and portrayed in “3D phase space”. Thus the research findings demonstrate a capacity to move beyond linear, cause-effect models of mediator and moderator variables and demonstrate the systemic consequences in 3D computational space (i.e. the micro-world of the computer) by changing the initial conditions of the workgroup as it functions in 2D physical space (i.e. the workspace).

Cohesion and space density

The findings confirm a non-linear relationship between cohesion and space density with workflow type appearing to have an effect on this relationship. However, given the limited data available for analysis of other than sequential workflow types, this workflow relationship needs be the subject of further research.

Optimum space density

The research findings point to there being an “optimum range” of space densities within which overall workgroup cohesion is maximized, with this range likely to have a relationship with workflow type, both in terms of its mid point and absolute range of space densities for overall cohesion above the midpoint on the Carless cohesion scale (Carless & De Paola, 2000).

Work system viability and space density

The viability of the workgroup does have a sensitive dependence on workspace density, with the likelihood of system collapse greater if space density is increased beyond a critical point – the tipping point!

Workgroups within the same workflow type (e.g. Sequential), exhibit the characteristics of more-unstable, less viable work-systems, as space density increases. The graphs of the 3D – Phase Space plots clearly show changes in the patterns from tight, single point attractors to open two point attractor sets. These
patterns plotted using the Lorenz Equations are indicative of more chaotic system behaviour, as opposed to simply indicating greater human “agility”.

*The influence of work-point standard type*

The 3D Phase Space plots for the S2 work-point standard, are similar to those for S1 with the workgroups having the same workflow type (i.e. Sequential). However as the two-point attractor pattern is indicated as occurring at slightly higher space densities, this suggests that the S2 standard might better support workgroup viability at higher levels of space density, before work system collapse occurs. However, the plots also seem to indicate a narrower range of space densities capable of holding this type of workgroup “on the edge of chaos” in order to optimize all three aspects of cohesion. Given the limited data available for analysis in this instance, this proposition could be the subject of further research.

*The influence of workgroup workflow type*

The findings are that increased space density is associated with more unstable work system behaviour, and that the impact of workspace density on work system collapse might be different for different workgroups depending on their predominant workflow type.

However, there is insufficient evidence from the data available from this research to isolate the relative contribution of work point type and work flow type, to overall system collapse given workgroup space density level.
CHAPTER 6: RESEARCH CONCLUSIONS

From the research it could be concluded that businesses under pressure to reduce operating costs that resort to reducing the cost of workspace, by increasing workspace density, may unwittingly transfer the stress the organization is experiencing to its employees, i.e. to individuals directly or via the now prevalent organization building block – the workgroup.

This stress affects the social aspects of work organization first, through lower social cohesion, before work group performance begins to decline, the consequence of lower task cohesion. Employees in higher density workspaces, may continue to deliver short term task performance outcomes, under working conditions where the social qualities of the group, including social cohesion, have declined significantly. This effect is now identified by the researcher as “Spatial Codralitis”, to describe how employees in such workspaces “soldier-on”, and continue to perform, despite the constraints imposed on them by global cost reduction strategies.

Despite the appearance of success, this effect has a further impact on the attractiveness of the group to both existing workgroup members and other employees; both, given choice, may be less inclined to want to work under these (social and work performance) circumstances. A decline in the overall attractiveness of the workgroup is reflected in this aspect of overall cohesiveness.

Under these circumstances it might also be concluded that there is a reciprocal relationship between social performance and task performance. Increases in task performance come at the expense of social performance, and vice-versa, although the relationship may be non-linear.

Thus whilst the stress the organization is experiencing (e.g. as a result of global competition, or need to improve financial performance) is being transferred to individual employees, the associated, and largely unmeasured costs are socialized in the form of the need to address newly emergent issues such as declining personal health/wellbeing and the importance of achieving a better work-life balance.
Short-term performance outcomes may not be sustainable under these circumstances. A revenge effect for business might ultimately become apparent in both increased employee health and wellbeing costs and the decreased attractiveness of this kind of work environment to existing or potential employees.

These cost implications could far exceed the cost savings achieved by increasing space density. Whilst employee wellbeing and work-life balance issues are receiving attention in some organizations and in the media generally in the interior design field, increased attention is also being given to using workplace design as a means to improve individual employee attraction and retention.

Notwithstanding these issues, it could be concluded that this research holds out the promise of being able to more accurately calculate the optimum amount of space an organization requires based on the relative mix of workflow types for all employees and the differential space densities appropriate for each predominant work flow type. Allocating workspace on this basis, using sound research and mathematical formulae, should allow a business to increase its space density in order to save money, but only up to a calculated point (or set within a narrow range), rather than using anecdotal evidence or architectural design "gut feel" as has been the case in the past.

Hence, the adverse consequences for social and task performance where team/workgroup is carried out in higher workspace densities, may be mitigated against, or not incurred, while the attractiveness of the group to insiders and outsiders can be maintained.

The research findings suggest that by mapping the distribution of work across an entire organization, according to workflow category types, the optimal amount of overall space required for the organization might be more scientifically calculated. This could lead to higher certainty in performance outcomes, when business attempts to manage the adverse consequences of any strategy aimed at saving costs or decreasing its environmental footprint, by endeavouring to squeeze more people into a given work area.
CHAPTER 7: FURTHER RESEARCH

Questions raised by the desk research worthy of further investigation

To develop the composite linear model (Figure 8), further research needs to consider "job complexity" as a primary moderator variable, since modern work is becoming increasingly information intense and more complex.

While this study has focused on the impact of space density at the work group level, do the findings have relevance at higher organization system level – e.g. business unit or total organization levels?

What is the relevance of replicability of findings, when research is viewed from a complex adaptive systems theory perspective? Thus, can a reliable “formula” be developed to explain the impact of workspace density on workgroup viability?

If a work-system is shown to collapse under certain spatial conditions, and social cohesion precedes task cohesion, is it the work task, or the social component of the work-system that is most affected by changes in workspace density?

Is it possible to maintain a workgroup at the “edge of chaos” such optimal space density and workgroup performance outcomes can both be delivered?

To what extent can the consequences of business demands for workspace cost saving, resulting in higher workspace density, be adapted to by individuals, or be learned, giving those employed in workgroups, the ability to manage the “tipping points” at much higher levels of workspace density, before their work system fails catastrophically?

What capability does an individual or workgroup need to have, in order to “stress buffer” the impact of increased spatial density?

If employee satisfaction (happiness) is operationalized as wellbeing (in the workplace), does this outcome performance measure strengthen the relationship
between job satisfaction and job performance, further supporting the case for environmentally sustainable building design?

Harter, Schmidt, & Hayes (2002) proposed that employees are “emotionally and cognitively engaged...when they have what they need to do their work”. This proposition begs the question as to what employees actually need to do modern work, in terms of the mix of people, technology and spatial “tools”?

Also, complementing this line of research, these questions:

- Which strategies are most effective in compensating employees for the stress and environmental instability associated with constant workplace change?
- It is more cost-effective to pay employees more or offer increased work flexibility than it is to provide work environments with higher levels of flexibility or aesthetic qualities?
- Does increasing user participation and environmental awareness throughout the design and construction process, provide a more cost-effective way to enhance employee satisfaction and performance?
- To what extent are built environmental factors more significant if individual/team work processes are highly dependent on such factors?

The literature indicates stimulus-screening ability can moderate the relationship between space density and individual job performance but highlights the need for further research, particularly for complex work involving higher levels of interaction in open working environments. Employees with high screening ability have been shown to be more effective in adapting to higher density environments (Baum, Calesnick, Davis & Gatchel, 1982), but this ability has also not featured prominently in research into the design and effectiveness of teams or workgroups.

Further, if stimulus screening is a skill, is it possible to be learned to moderate the effects of higher space density?
Questions raised by the field research worthy of further investigation

*Aggregation Issues*

Tesluk, Mathieu, Zaccaro & Marks (1997) indicate that data on measures such as cohesion collected through individual's ratings are typically aggregated at the group level. Carron & Brawley (2000) and Carless & De Paola (2000) aggregated individual data, confirming the Carless Cohesion Survey as a legitimate instrument for this research.

Future research, may consider the application of more rigorous statistical criteria to aggregate the individual data, such as calculating an Index of Interrater Agreement ($r_{wg}$) to assess the homogeneity of member perceptions Tesluk et al., (1997) citing James, Demaree & Wolf (1984; 1993) and Kenny & La Voie (1985) or to conduct multi-trait, multi-source analysis citing Thomas, Shankster & Mathieu (1994).

*Cohesion and Workspace Standard Type*

This research assumed that workgroup cohesion is not affected by workstation or work point type. There was insufficient data collected to confirm the validity of this assumption. The preliminary findings suggest this is an area of research worthy of more detailed analysis within specific workspace density ranges.

*The Cohesion-Space Density Relationship*

The Cohesion-Space Density relationship(s) determined in this research could be shown to have a dependence on workgroup workflow types. There is insufficient data to confirm this here but the preliminary analysis suggests a more detailed analysis within specific workflow types should be possible, based on additional data for other than the sequential workflow type.

*Specific Aspects of Cohesion*

Social cohesion has an influence on individual attractiveness to the group. A preliminary analysis of the extent to which the relationship is further influenced by workspace density was undertaken and the findings are presented in Graphs 25 and 26 below.
These two-dimensional plots were prepared using the Lorenz Equations to indicate the relationship between Attraction to the Workgroup ($C_a$) and Social Cohesion ($C_s$) at two different space densities for only a serial/sequential workflow type workgroup. These findings suggest space density has a differential impact, representing a field warranting further research using these methods.

Graph 25: Workgroup 1a (S1, 11.24, S) - $C_a$ v $C_s$

Graph 26: Workgroup 4b (S1, 8.29, S) - $C_a$ v $C_s$
A further line of analysis could be to ascertain whether the viability of the workgroup has any further relationship with weekdays.

Integration of Human Resources and Facilities Management Strategies
Future research could investigate the stress-related behavioural affects of workgroups, and specifically how facility management and human resources strategies could be used in tandem to optimize performance and reactions such as absenteeism outcomes.

Could an organization potentially increase spatial density (cost-benefit) without generating negative reactions if the employees only had low tenure? How could low levels of tenure be achieved without increasing levels of employee turnover, and thus associated costs? How would this cost-benefit relationship be affected by job complexity, or knowledge requirements?

Oldham, Kulik & Stepina (1991) indicated low tenure employees respond more positively when work is more complex and space density is higher. This is because the increased social interactions are seen as helpful, not as a hindrance. Low tenure employees, may also become more involved with their tasks, experiencing workflow (Csikszentmihalyi, 1998), absorbing all available attention (psychic energy) to the exclusion of all distractions to conscious awareness. It would be useful to also understand how long these flow states could be maintained by employees, given that many employees seek some form of stimulation of the senses in order to “feel” alive at work.

These questions potentially frame further research topics to better understand the economic cost-benefit to the business, given key factors such as job complexity, employee turnover costs and cost of workspace.
REFERENCES


Appendix 1: Characteristics of the Lorenz Equations (Sparrow, 1982)

The Lorenz Equations are a 3D set of differential equations to model unpredictable behaviour, a set of formulae that express the values of all the variables at the next step in terms of their values at the current step (Lorenz, 1993, p12.).

- The trajectory is not periodic
- The plotted figure does not show a transient phenomena – i.e. it doesn’t settle to periodic or stationary behaviour
- The general form of the equations doesn’t depend on choice of initial conditions (e.g. team characteristics, behavioural or affective responses to space density) or the choice of integrating routine (e.g. how team characteristics are combined)
- Detail of the plotted figures does depend on changes in initial conditions (e.g. the reactions to space density) and changes in integrating routine
- Lorenz equations apply to dissipative chaotic systems
- When a system is bounded and dissipative, we can deduce that all trajectories eventually tend towards some bounded set of zero volume lying in the phase space. This set contains all the recurrent behaviour of the flow and we expect that all true trajectories will tend towards it.
- To know the important things about the differential equations we need to know;
  - the structure of the bounded set of zero volume (the non-wandering set)
  - the way the flow behaves on the non-wandering set
  - the parts of the non-wandering set that are attracting
- The details of the (numerically computed solution to the Lorenz equations) plotted figure depend on the computer program that produces it; the chaotic nature of the solution does not. The definition of chaotic is loose, numerical and non-rigorous
- Bifurcation is central to the understanding of the different kinds of chaotic behaviour. A slight modification or imperceptible change can produce a qualitative change in a system behaviour. These changes are called bifurcations. A bifurcation can be caused when a “state of equilibrium” is rendered unstable when some constant is increased (e.g. space density).
- As the parameters $\sigma$, $\rho$, $\beta$ change, the behaviour of the flow will only change in an important way when the topology of the non wandering set changes.
- It is always possible for some finite value of the parameters not examined, that the behaviour of the system will be different.
- The Lorenz equations for different parameter values seem to display most of the kinds of chaotic behaviour observed in other three-dimensional systems of chaotic differential equations.

Lorenz indicated that the variables $X$ and $Y$ in his equations were differentials — i.e. the distances from their respective reference points. The mapping of the system using $X$ and $Y$ shows that certain states do approximate again and again, and these restricted sets are called attractors. It is possible to map in as many dimensions as the number of variables in the system. Thus for 3 variables it is possible to map in 3D Phase Space.

**Appendix 2: Research Planning Documents**

Refer to Attached Disk
Workgroup
6a to 6f
Appendix 4: Risk Assessment

Risks Identified

Possible Risks to the University of Sydney
- Loss of reputation caused by researcher dishonesty
- Liability for personal injury of research participants

Possible Risks to the Host Organisation
- Loss of reputation caused by researcher dishonesty
- Liability resulting from not understanding or misunderstanding the research project for which it consents to be involved
- Liability for personal injury of research participants
- Loss of business continuity
- Exposure of business or confidential information

Possible Risks to the Research Subject
- Not understanding or misunderstanding the research project for which they consent to be involved
- Risk of being pressured to participate
- Risk of exposure of personal or private information
- Loss of work continuity

Table A4.1: Risk Evaluation Summary

<table>
<thead>
<tr>
<th>Possible Risk Identified</th>
<th>Probability</th>
<th>Consequence</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of University of Sydney reputation caused by researcher dishonesty</td>
<td>Unlikely</td>
<td>Minor</td>
<td>Note 1</td>
</tr>
<tr>
<td>University of Sydney liability for personal injury of research participants</td>
<td>Highly Unlikely</td>
<td>Minor</td>
<td>Note 2</td>
</tr>
<tr>
<td>Loss of Host Organisation reputation caused by researcher dishonesty</td>
<td>Unlikely</td>
<td>Minor</td>
<td>Note 1</td>
</tr>
<tr>
<td>Liability resulting from not understanding or misunderstanding the research project for which Host Organisation consents to be involved</td>
<td>Unlikely</td>
<td>Insignificant</td>
<td>Note 3</td>
</tr>
<tr>
<td>Host Organisation Liability for personal injury of research participants</td>
<td>Highly Unlikely</td>
<td>Minor</td>
<td>Note 2</td>
</tr>
<tr>
<td>Loss of business continuity</td>
<td>Possible</td>
<td>Minor</td>
<td>Note 4</td>
</tr>
<tr>
<td>Exposure of business or confidential information</td>
<td>Possible</td>
<td>Minor</td>
<td>Note 5</td>
</tr>
<tr>
<td>Not understanding or misunderstanding the research project for which subject consents to be involved</td>
<td>Possible</td>
<td>Minor</td>
<td>Note 6</td>
</tr>
<tr>
<td>Risk of being pressured to participate</td>
<td>Unlikely</td>
<td>Minor</td>
<td>Note 7</td>
</tr>
<tr>
<td>Risk of exposure of personal or private information</td>
<td>Possible</td>
<td>Minor</td>
<td>Note 8</td>
</tr>
<tr>
<td>Loss of work continuity</td>
<td>Likely</td>
<td>Minor</td>
<td>Note 4</td>
</tr>
</tbody>
</table>

Note 1: All participant responses were collected electronically using an independent service provider. The files of these responses will be burnt onto a CDROM and locked in the research supervisor’s office for seven (7) years. These data will only be available to the Host Organisation, the supervisor and the researcher.

Note 2: The research involved no physical activity beyond that normally associated with office work being undertaken by the subject. The possibility of any psychological...
harm resulting from completing either the on-line or paper based surveys is improbable.

Note 3: There was extensive briefing of the HO by both the researcher and the RC. The researcher had been in close consultation with the RC in the twelve months prior to the field research being conducted, allowing sufficient time for management within the HO to become familiar and comfortable with the research objectives and scope. A detailed research project plan was submitted for internal discussion and final research approval. Branch participation in the research was entirely voluntary.

Note 4: The on-line survey was short, comprising only 10 questions enabling its completion in approximately 1 minute. Subjects were surveyed on a known, regular but not daily basis. Paper based surveys were administered at the beginning and end of the field research phase (approximately 4 months), with completion taking less than 15 minutes and again being voluntary.

Note 5: The identity of the HO is not revealed in the research thesis documents. Information contained in the thesis is of a general nature and largely already in the public domain. No business critical information was provided to the researcher.

Note 6: As per Note 3 plus subjects were provided with an internal project brief communication and invited to attend a project briefing session run by the researcher. Participation in the research project was entirely voluntary.

Note 7: All participation was entirely voluntary with opt out mechanisms provided in the on-line survey. Participants could choose to opt back in at their own discretion.

Note 8: Use of separate external service providers for conducting the email campaign and hosting the on-line survey ensured the risk of personal information becoming public was minimised. Both service providers complied with US Spam legislation. Participation in the incentive scheme where personal information was requested was entirely voluntary. Once the monthly data to confirm the incentive prizewinners had been analysed on a monthly basis it was destroyed. Presenting the incentive prizes was the responsibility of the RC in the HO.
Appendix 6: Workgroups Classified by Workflow Types

Table A6.1: Workgroup Workflow Types

<table>
<thead>
<tr>
<th>Workgroup</th>
<th>Workflow Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Sequential</td>
</tr>
<tr>
<td>1b</td>
<td>Sequential</td>
</tr>
<tr>
<td>7a</td>
<td>Sequential</td>
</tr>
<tr>
<td>4b</td>
<td>Sequential</td>
</tr>
<tr>
<td>8a</td>
<td>Sequential</td>
</tr>
<tr>
<td>8b</td>
<td>Sequential</td>
</tr>
<tr>
<td>6d</td>
<td>Sequential</td>
</tr>
<tr>
<td>4d</td>
<td>Sequential</td>
</tr>
<tr>
<td>4a</td>
<td>Sequential</td>
</tr>
<tr>
<td>2a</td>
<td>Pooled</td>
</tr>
<tr>
<td>3a</td>
<td>Pooled</td>
</tr>
<tr>
<td>2b</td>
<td>Reciprocal</td>
</tr>
<tr>
<td>2c</td>
<td>Reciprocal</td>
</tr>
<tr>
<td>2d</td>
<td>Reciprocal</td>
</tr>
</tbody>
</table>
Appendix 7: Workspace Survey (Cohesion) Response Rates

Table A7.1: Branch Survey Response Rates

<table>
<thead>
<tr>
<th>Branch</th>
<th>Workgroups</th>
<th>Response Numbers</th>
<th>Response %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1a, 1b</td>
<td>165</td>
<td>12.5</td>
</tr>
<tr>
<td>2</td>
<td>2a, 2b, 2c, 2d</td>
<td>247</td>
<td>18.0</td>
</tr>
<tr>
<td>3</td>
<td>3a, 3b, 3c</td>
<td>114</td>
<td>8.3</td>
</tr>
<tr>
<td>4</td>
<td>4a, 4b, 4c, 4d, 4e</td>
<td>488</td>
<td>35.6</td>
</tr>
<tr>
<td>5</td>
<td>5a, 5b</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>6a, 6b, 6c, 6d, 6e, 6f</td>
<td>158</td>
<td>11.5</td>
</tr>
<tr>
<td>7</td>
<td>7a</td>
<td>33</td>
<td>2.4</td>
</tr>
<tr>
<td>8</td>
<td>8a, 8b, 8c</td>
<td>143</td>
<td>10.4</td>
</tr>
</tbody>
</table>

Appendix 8: Workgroup Characteristics
Refer to Attached Disk

Appendix 9: Time Series Raw Data (.csv) Files
Refer to Attached Disk

Appendix 10: Time Series Data and Graphs
Refer to Attached Disk

Appendix 11: Workflow Groups 3D Plots – Average Data
Refer to Attached Disk
# Appendix 12: Survey Instruments

<table>
<thead>
<tr>
<th>Workspace Survey</th>
<th>Name: ______________________</th>
<th>Date: ____________________</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Branch: __________________</td>
<td>Location: ________________</td>
</tr>
</tbody>
</table>

This questionnaire consists of statements, which describe the level of cohesion in your team or work group.

Please indicate the extent to which each statement describes your team or work group. The common response scale is: 1 = Strongly Disagree to 9 = Strongly Agree. Please mark a number from 1 to 9 to indicate your level of agreement with each of the statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Our team is united in trying to reach its goals for performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>I’m unhappy with my team’s level of commitment to the task</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Our team members have conflicting aspirations for the team’s performance</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>This team does not give me enough opportunities to improve my personal performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Our team would like to spend time together outside of work hours</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Members of our team do not stick together outside of work time</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Our team members rarely party together</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Members of our team would rather go out on their own than get together as a team</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>For me this team is one of the most important social groups to which I belong</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Some of my best friends are in this team</strong></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
This questionnaire asks you about your team, and how it functions as a work group.

Please indicate the extent to which each statement describes your team. Please leave blank if you don't know or the statement is inapplicable.

1 = Strongly Disagree 4 = neither Agree nor Disagree 5 = Agree
2 = Moderately Disagree 6 = Moderately Agree
3 = Disagree 7 = Strongly Agree

Self Management
1. Most work-related decisions are made by the members of my team rather than my manager
2. As a member of a team, I have a real say in how the team carries out its work
3. My team is designed to let everyone participate in decision making

Team Tasks
4. Most everyone on my team gets the chance to do more interesting tasks
5. My team makes an important contribution to serving the Council's customers
6. My team helps me feel that my work is important to the Council
7. I cannot accomplish my tasks without information or materials from other members of my team
8. Other members of my team depend on me for information or materials to perform their tasks
9. Within my team, jobs performed by team members are related to one another

Membership
10. The members of my team have skills and abilities that complement each other

Flexibility
11. Most members of my team know each others jobs
12. Its easy for members of my team to fill in for one another
13. My team is very flexible in terms of changes in its membership

Team Work Preferences
14. If given the choice, I would prefer to work as part of a team rather than work alone
15. I find that working as a member of a team increases my ability to perform effectively
16. I generally prefer to work as part of a team

Communication and Cooperation between Workgroups
17. I frequently talk to other people in the Council besides the people on my team
18. There is little competition between my team and other teams in the Council
19. Teams in the Council cooperate to get the work done

Team Spirit
20. Members of my team have great confidence that the team can perform effectively
21. My team can take on nearly any task and complete it
22. My team has a lot of team spirit

Support
23. Being in my team gives me the opportunity to work in a team and provide support to other team members
24. My team increases my opportunities for positive social interaction
25. Members of my team help each other out at work when needed
26. My team receives a high level of organizational support

Workload Sharing
27. Everyone on my team does their fair share of work
28. No one in my team depends on other team members to do the work for them
29. Nearly all the members on my team contribute equally to the work

Communication and Cooperation within the Workgroup
30. Members of my team are very willing to share information with other team members about their work
31. Teams enhance the communication among people working on the same project
32. Members of my team cooperate to get the work done

Work Environment
33. The general office layout facilitates team work
34. I am able to stay focused and "on track" at work
35. I am able to be productive in my present workspace
36. I am able to complete my planned tasks for the day

Thank you for your support.
This questionnaire consists of statements, which describe your job in general, the work you do at present and your level of stress.

<table>
<thead>
<tr>
<th>Your Job in General</th>
<th>People on your Present Job</th>
<th>Work on your Present Job</th>
<th>Your Stress at Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Think of your job in general. All in all, what is it like most of the time? In the blank beside each word or phrase below, write</td>
<td>Think of the majority of people with whom you work or meet in connection with your work. How well does each of the following words or phrases describe these people? In the blank beside each word or phrase write</td>
<td>Think of the work you do at present. How well does each of the following words or phrases describe your work? In the blank beside each word or phrase, write</td>
<td>Do you find your job stressful? For each of the following words or phrases write</td>
</tr>
<tr>
<td>Y for &quot;yes&quot; if it describes your job</td>
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<td>Y for &quot;yes&quot; if it describes your work</td>
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<tr>
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<td>N for &quot;no&quot; if it does not describe them</td>
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<td>? for &quot;?” if you cannot decide</td>
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</tr>
</tbody>
</table>

Pleasant, Stimulating, Fascinating, Routine, Demanding
Bad, Boring, Routine, Satisfying, Pressure.
Ideal, Slow, Boring, Boring, Hectic
Waste of time, Helpful, Routine, Calm, Calm
Good, Stupid, Boring, Calm, Relaxed
Undesirable, Responsible, Good, Good, Many things stressful
Worthwhile, Fast, Satisfying, Respected, Pushed
Worse than most, Intelligent, Gives sense of accomplishment, Uncomfortable, Irritating
Acceptable, Easy to make enemies, Pleasant, Pleasant, Under control
Superior, Talk too much, Useful, Challenging, Nervy
Better than most, Smart, Challenging, Challenging, Hasted
Disagreeable, Lazy, Simple, Simple, Comfortable
Makes me content, Unpleasant, Repetitive, Repetitive, More stressful than I'd like
Inadequate, Gossipy, Creative, Creative, Smooth running
Excellent, Active, Dull, Dull, Overwhelming
Rotten, Narrow interests, Uninteresting, Uninteresting, Overwhelming
Enjoyable, Loyal, Can see results, Can see results, Rotten
Poor, Stubborn, Use my abilities, Use my abilities, Poor

Thank you for your support.
The Job Descriptive Index

This questionnaire consists of statements, which describe your job in general, the work you do at present and your level of stress.

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Calm
Relaxed
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Pushed
Irritating
Under control
Nerve wracking
Hassled
Comfortable
More stressful than I'd like
Smooth running
Overwhelming

Thank you for your support.
Appendix 13: Preliminary Built Environment Research

Refer to Attached Disk