

**An investigation into estimation and spatial sense as aspects
of workplace numeracy:
a case study of recycling and refuse operators
within a situated learning model.**

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ABSTRACT

The abilities to estimate and to exercise spatial awareness are important elements of adult numeracy and are embedded in many workplace activities. However, contributions of these elements of numeracy in workplace activities are often overlooked. Although estimation is noticed, spatial awareness in particular seems to be rarely acknowledged (Marr & Hagston, 2007). This research study first investigates the use of these two elements by drawing on the perspective of numeracy as a situated social practice (Lerman, 2006; Street, Baker, & Tomlin, 2008) in a case study of the work of urban recycling and refuse collection operators. Ethnographic approaches such as observing the operators' roles in their daily collection work and interviewing them are used to determine which strategies and numeracy practices the operators employ. What is seen is that a collection operator's ability to estimate and use spatial awareness are important contributors to many of the critical decisions that are regularly made by him or her.

A second part of the research is an investigation of how these operators have acquired the capabilities to make estimates and to be spatially aware. Although estimation and spatial awareness are established at an early age and then partly fostered in school mathematics themes such as number sense, measurement and geometry, the operators in the main did not recognise a great deal of mathematics in their everyday work. Instead their previous workplace training and experiences of driving and operating heavy equipment appeared to be the main sources of their senses of estimation and spatial awareness. This study demonstrates to trainers and educators they should not assume that these elements of numeracy are common knowledge or even common sense to their staff or students (Sorby, 2003). This study also suggests that estimation and spatial awareness practices which are concealed in workplaces and are probably overlooked, are challenging to assess by traditional measures. Hence trainers and educators need to continue to promote and model estimation practices, and even more deliberately, provide learning opportunities of those relevant components of spatial awareness for learners of any age.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

P J Kane

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CHAPTER ONE

INTRODUCTION

Estimation and spatial awareness are each key elements of many workplace activities. However, in the formation of lists of relevant mathematics themes needed for workplaces, spatial awareness is often overlooked or at best given minor status (Riall & Burghes, 1996; Marr & Hagston, 2007). Using a case study of urban recycling and refuse collection operators, this thesis will report on how estimation and spatial awareness are embedded in many of their workplace activities. It will illustrate how this work may be an example of other mobile working environments which are similarly infused with activities that require their practitioners to be able to estimate and to be spatially aware.

The initial impetus for this research was from a pilot study with a colleague (Chana & Kane, 2010) which briefly investigated how numeracy (and literacy) concepts are situated in various contexts including refuse and recycling collections. The pilot study enabled the researcher of this study to build trust and rapport with the site managers of the collection companies, to gain some experience of the mobile work environment of the refuse and recycling operators, and to begin to explore more deeply the numeracy concepts that were evident in this workplace. The questions asked of the participants in the pilot study informed the researcher's development of a semi-structured questionnaire for the participants in the current study.

Accordingly, this study focusses exclusively on the numeracy of refuse and recycling collection operators, and in particular their use of estimation and spatial awareness in their workplace practices. A case study research design was employed to focus on the operators in two South Auckland companies with collection territories in the same city. A single-case study design was used since the work of the operators is a typical workplace model of an everyday situation (Yin, 2009). After 2012, one of the companies retrenched to Australia, and its operators were absorbed by the other company who had successfully tendered for the runs and routes vacated by the departing company. A challenge with this acquisition was that the departing company contracted its operators so they were in effect owner-operators; the remaining company however, employed its operators. The enlarged cohort of operators now consists of both employed and contracted operators.

Each operator works as part of a team of collectors, and is responsible for a collection area each day. Refuse operators revisit their territories every week whereas recycling operators revisit their territories fortnightly. Drawing on the perspective of numeracy as a social practice (Lerman, 2006; Street, Baker, & Tomlin, 2008), the researcher accompanied the operators in their collection vehicles to observe events occurring in daily collection runs, and to interview the same operators about their practices in situ. Other research instruments such as taking field notes and sketches, and examining documents and artefacts were also used during the case study. This thesis then has two specific foci and these are presented as research questions below:

- Which numeracy practices, in particular with regard to spatial reasoning and estimation, do these recycling and refuse operators use in their mobile workplaces?
- How have these operators learned these situated numeracy practices?

The first set of findings of this research was distilled to six major workplace practices. These six practices are *driving*, *collecting*, *emptying*, *administration*, *maintenance* and *health and safety* (researcher's italics). The first three workplace practices, along with health and safety, are everyday operational practices in that every operator is expected to carry these out competently and safely. The administration and maintenance practices are organised by the company for its employed operators while the contracted or owner-operators must still manage their own administration and maintenance.

Within these workplace practices, four major numeracy categories of *number sense*, *estimation*, *measures* and *spatial awareness* (researcher's italics) have been created. Importantly, the boundaries between these categories are quite fluid, and sub-categories of numeracy events lie within and between them. These visible numeracy events in turn lead to broader, less visible numeracy practices, which provide the underlying contexts, motivations and meanings to explain how and why the collection operators work the way they do.

The second set of findings of this research focus on how the operators learned their situated numeracy practices. Although all but one of the five participants thought they were reasonably competent at school mathematics, most said that they did not see much school mathematics in their work. Instead, their previous workplace training and experiences of driving and operating heavy equipment appeared to be the main sources

of their senses of estimation and spatial awareness. After a maximum of two weeks initial training as a collection operator, newcomers are expected to be competent enough to work as solo collectors. The balance of their learning occurs as they drive through their assigned collection areas, working out the most effective routes and consolidating their operating strategies. These are important workplace activities for the operators and will be described more fully in chapters three, four and five.

A brief glossary of key terminology appears before the appendices of this thesis.

1.1 Outline of this thesis

The second chapter of this thesis is a review of the key background literature. A discussion of situated activities is followed by a section on numeracy and mathematics. A social practices model is then considered, and examples of workplace numeracy are presented with particular regard to how estimation and spatial awareness appear in various workplaces. The two domains of estimation and spatial awareness are each explored in more depth. The final section shows how this situates the current study in the relevant literature.

Chapter Three addresses the methodology and methods of the study and begins with a brief description of the pilot study (Chana & Kane, 2010). The suitability of a case study approach is discussed. The use of a case study approach for this study was the most appropriate research design since “the case study provides the thick description needed to apprehend, appreciate, and understand the circumstances of the setting” (Lincoln & Guba, 2013, p. 80). The methods employed such as semi-structured interviews, observations, field notes and examination of artefacts such as workplace documents and truck cabin machinery are also discussed. The five research participants are introduced.

Chapter Four presents the findings of the case study. First, background information on the collection organisations, the operators, and their vehicles is provided. The following section describes a working day of one of the operators with regular contributions from the other four operators. From the situations described, numeracy events are distilled. Finally, there is a section of researcher reflection on the processes described above and the time spent with the operators.

Chapter Five attempts to answer the research questions. The learning of workplace and numeracy practices is discussed, and future challenges and opportunities for the operators are briefly described.

A sixth chapter follows with conclusions and recommendations, including the limitations of this study.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

The introductory chapter of the thesis outlined the research project and its rationale. This chapter reviews the literature which underpins the research study, in particular how adults use numeracy practices in contexts such as workplaces, and in particular where estimation and spatial awareness is required. Although estimation and spatial awareness are each listed in the mathematics strands of formal school curricula (e.g. Ministry of Education, 1992), many of the learning experiences met by the participants, and reported in this research, have arisen informally. The knowledge and capabilities of the participants and people in other workplaces have been learned by observations of, and reflections on, individual actions and shared prior work experiences, through conversations with other team members, and by participation in relevant activities.

The chapter begins with a section on situated activity, in which learning from situations plays a significant part. Lave (1993) states that “situated activity always involves changes in knowledge and action” (p.201), and these changes are critical for learning. Newcomers draw on their own experiences and augment these with new workplace or other experiences in order to underpin new learning. As these more recent experiences accumulate, the newcomers become increasingly more familiar and effective members of a community of practice (Lave & Wenger, 1991; Wenger, 1998).

In the next section, a review of numeracy follows with definitions for what being numerate might mean. The concept of *numeracy* (researcher’s italics) was introduced in the Crowther Report in 1959, principally as a numerical equivalent to literacy. However, other more recent definitions have since expanded what numeracy now represents, and the breadth of these other definitions such as mathematical literacy and ethno mathematics draw on several interpretations and particularities. This has created a somewhat shifting set of definitions of numeracy dependent on the contributors’ perspectives. Options for and impacts of learning mathematics are discussed next since mathematics is more broadly acknowledged and familiar to people than numeracy. Mathematics not only provides a foundation for numeracy, but for adults looking back at their time as school students, the learning of mathematics still impacts on their current numeracy practices and how they feel about maths. With this in mind, the formal school learning domain will be considered with the out-of-school informal

learning domain.

Following this review of numeracy and mathematics, a social practices perspective and its modelling of numeracy will be presented. According to Baker (1998), a numeracy practices perspective involves the “occasions, content, activities and kinds of numeracy that people engage in when they do mathematics” (p. 41). People’s everyday actions, beliefs, relationships, habits and values all contribute to these practices. Baker (1998) suggests that numeracy and mathematics are each socially situated practices coexisting and, as such, neither practice is superior to the other. The section on practices will contrast the autonomous, generalizable and abstract views of mathematics with the ideological, localised and socio-cultural views of numeracy.

Examples of workplaces with situated numeracy practices are then described, as well as how workplace experiences, prior and current, are major contributors to the learning process. Although there are several historically useful examples of numeracy in work situations, those workplaces and situations which illustrate people using either estimation practices or spatial awareness or both, have been particularly selected. What emerges in this section, and which reinforces the previous sections, is that people continue to use mathematics covertly and often without recognition, because they are focussed on meeting the demands of their tasks.

The two sections which follow, on estimation and spatial awareness (including geometry) respectively, are investigated separately. Although estimation is arguably more recognisable in workplaces and other situations, spatial awareness is perhaps more common than many people realise or even observe. Also, intersection points between spatial awareness and estimation exist. The sections on spatial awareness and estimation practices will be supplemented with workplace examples.

In the research opportunities and summary section at the end of this chapter, many of the points raised throughout this literature review will be drawn together. Finally, the research questions will be situated in the current research study on urban refuse and recycling operators.

2.2 Situated Activity Approach

Situated activities reside in situations where authentic learning occurs, and where the participants recognise the knowledge being scaffolded, modelled, and investigated (Lave & Wenger, 1991; Brown, Collins, and Duguid, 1989; Herrington & Oliver, 1995; McLellan, 1996). In these situations newcomers or novices work under the supervision

of an experienced staff member. Brown, Collins, and Duguid (1989) assert that a situated learning model contributes to an individual's understanding of the world (or in this thesis, the workplace) both by "using the tools, and of the tools themselves" (p.33). The knowledge that is shared is sometimes not clearly defined and the tasks being tackled may seem complex and vague (Herrington & Oliver, 1995).

However, Gonczi (2004) suggests that situated learning is a major departure from previous traditions where an individual learns by somehow acquiring "propositional knowledge and assuming that this forms the basis of professional competence" (p. 29). Brown, and Duguid (1996) add that "a situated approach contests the assumption that learning is a response to teaching" (p. 48); workers' collaborative and individual actions are practised repeatedly, the workers are continually participating (Lave, 1993) so that these actions become firmly established (McLellan, 1996) and may be drawn on when needed. A newcomer's "cognitive apprenticeship" (Brown *et al.*, 1989, p.34) promotes learning on the job by allowing the learner to carry out authentic tasks under the watch of senior staff, all the while developing the skills, practices and understanding needed for the role.

The use of situated learning means the need for any scaffolding will gradually diminish (LeGrand Brandt, Farmer, & Buckmaster, 1993) as learners develop expertise in the workplace. By becoming mature learners, newcomers begin to carry out these situated action tasks by themselves, becoming fuller members of the workplace as a community of practice (Lave & Wenger, 1991) and their learning becomes more self-directed (LeGrand Brandt *et al.*, 1993). Greeno *et al.* (1998) suggest that situatedness integrates with both the behaviourist perspective through acquiring skills and with the cognitive perspective by grasping key concepts.

Stein (1998) provides four major premises that situated learning experiences are based on. The first premise is that learning occurs in the actions taken by participants during everyday situations. Secondly, any knowledge is acquired in situ and may transfer to similar situations. An example of this could be where a quarry truck driver leaves that job to become a furniture removal van driver. Lave (1993) states that "situated activity always involves changes in knowledge and action" (p.201), so the changes in and between situations promote learning. Stein's (1998) third premise is that learning "is the result of a social process encompassing ways of thinking, perceiving, problem solving, and interacting in addition to declarative and procedural knowledge" (p.). According to Wilson and Myers (1999), declarative knowledge is "knowing that" which

is usually regarded as factual knowledge (p. 59), while procedural knowledge is “knowing how” or knowing the techniques or strategies to carry out a process (p. 59). Mason and Spence (1999) suggest that together knowing-to and knowing-how contribute to knowing-about a subject; however “knowing-about does not in itself guarantee knowing-to” (*ibid.*, p. 135). Mason and Spence state that knowing-to is not just a reactive form of knowledge, rather a flexible form of knowing what to do which may be drawn on when required. Stein’s fourth premise is that situated learning is not a passive activity; action must take place involving people, locations, processes, and situations. Wilson and Myers (1999) support the view that situatedness does not mean a situation is stationary, or somehow set in concrete, and confined to a particular setting. Instead, situatedness describes how social networks are entwined with authentic activities, sometimes in dynamic systems and sometimes in more protracted systems.

There may be many possible connections and levels of relationships within a single situation, to meet the demands of a task. The communities of practice to which people belong are similarly complex. Kanes and Lerman (2008) claim there is some definitional haziness around the community of practice concept, and how participation is emphasized around stable practices. The community will be forced to flex if the practices are in a state of rapid change. Kanes and Lerman (2008) suggest the ongoing studies of school subjects (e.g. mathematics) by a learner who is preparing for assessments and eventual graduation does not lead him or her to become a master of the subject, nor for most people any subsequent inclination to become a mathematician or a maths teacher. In comparison however, the training of a person for work proficiency hopefully leads that worker to become more like the experienced staff members, mentors and coaches in the workplace. It is conceivable that in time the trainee may eventually become a coach to other newcomers. A trainee-turned-coach will need to articulate what is expected of other newcomers in the workplace, sharing their acquired understandings of the tried-and-true knowledge and processes.

Anderson, Reder, and Simon (2000) challenge some of the tenets of situated activity and learning. Firstly, Anderson *et al.* (2000) believe that a balance needs to be struck between the teachings of situational contexts and more generalised concepts. These authors suggest that if learning is grounded in a single narrow context, that narrowness effectively weakens the opportunities of some learners when attempting to transfer to other contexts. A second challenge is the recognition of diversity in contexts, how the contexts are represented, and the amount and the quality of training or practice that

participants receive. Consequently, the amount of transfer may also vary, or be overrated. However, Tennant (1999) counters by suggesting that transfer needs to be viewed more broadly, and most effectively with “the assistance of a teacher or trainer” (p. 167), thereby allowing for a mentor to assist a newcomer to learn the role.

Thirdly, dismissing the learning of abstract concepts solely in favour of strictly contextual experiences might be unwise. Anderson *et al.* (2000) suggest that “the real goal should be to get students motivated and engaged in cognitive processes that will transfer” (p.8), so a blend of both abstract and contextual learning is more effective. The fourth challenge posed by Anderson *et al.* is that instruction does not need to be situated in an excessively social setting. There are workplace settings where people must work individually, and undertake self-directed learning in less public locations. Anderson *et al.* also suggest that individualised training may be more a product of an organisation’s cost-saving in not having to bring a whole team together, thereby maintaining production levels or keeping experienced staff ‘on the floor’, during the instruction.

Deliberate training activities must still occur if newcomers are to acclimatise to any new workplace culture. One of the key training processes in a situated activity model is legitimate peripheral participation. Lave and Wenger (1991) define legitimate peripheral participation in terms of the development of new members of a team (also called novices, apprentices or newcomers), through opportunities to gradually increase their participation in the work situation. New team members then need to negotiate their way through the activities which draw them closer to performance targets since the rest of the team will expect the newcomers to eventually be relied upon in the standard work discourse:

Newcomers become old-timers through a social process of increasingly centripetal participation, which depends on legitimate access to ongoing community practice. Newcomers develop a changing understanding of practice over time from improvised opportunities to participate peripherally in ongoing activities of the community (Lave & Wenger, 1991, p.68).

Not all of a newcomer’s learning will be from action. Learning about a situation will also come from reflections about what went well or what needs to be improved (Wilson & Myers, 1999). Newcomers may need to return to their trainers if unsure of an instruction, or, as Herrington and Oliver (1995) suggest, there is uncertainty about the situation, or if the original explanation about the process was unclear. The other beneficiary of the explanation is the experienced staff member working alongside the newcomer. As Sawyer (2006) notes, having to explain something to another person

involves “articulating . . . in a mutually reinforcing feedback loop” (p.12), especially when the newcomer asks ‘what-if’ questions or notices something out-of-the-ordinary in the process, and needs to quickly find out what to do next. The growing experiences and expertise of the newcomer member is Vygotskian (after the Soviet learning scientist, Lev Vygotsky), in that a learner gradually internalises on-the-job working knowledge which in turn becomes thought (Sawyer, 2006). Critically, the newcomer is expected to draw on these thoughts and experiences when confronted with similar situations.

Lave (1993) sounds a cautionary note however, that some work organisations do not promote legitimate peripheral participation when progressing new staff towards learning the trade. She reports on butcher trainees in a supermarket who were consigned to the meat wrapping machine since those packages were required for sale, although the trainees were a part of the community of practice. More experienced staff members were working in the cool room cutting the meat but the trainees were not invited to be peripheral participants of this more skilled work. The work environment and the continual demands of the retail setting “produces the insiders and the outsiders” (Lerman, 2006, p. 359). According to McIntyre and Grudens-Schuck (2004) this relative power within the staff groups, experienced and novice, could also include “the *type and degree* of incentives or coercion” (author’s italics, p. 172). There are still other workplaces where workers or operators such as those who participate in this research are expected to work individually once they are trained. There is simply no option for an operator to not be involved in the tasks at hand since they are solo operators. The nature of their work, their situations, and for the recyclers their compliance incentives, will be described more fully in Chapter Four.

2.2.1 The role of experience

One of the supporting concepts for helping people to explain the mathematics and numeracy they may know about when working through a task, is the concept of *experience*. According to Clandinin and Connelly (1989), experience is often “taken-for-granted” (p.5) so that completing a learning outcome is conveniently described as being due to experience. It is difficult to move away from this concept since experience is universal, a “catch-all phrase” (Eraut, 2004, p. 249) with strong links to learning (from experience) and knowledge. Although the caution is noted, in this thesis the concept of experience in reality is pervasive and compounding. In other words, one experience leads to another, then another, providing a learner with a repertoire of familiar strategies built on prior experiences.

Dewey (1997), for instance, argues that every new experience benefits from prior quality experiences, with one experience often continuing into the next. Vergnaud (2000) argues that knowledge is derived from our ability to adapt. So when an unfamiliar situation arises, adaptability intimates that a person recognises how to apply what they know (McIntyre & Grudens-Schuck, 2004) including the ability to draw on relevant past experiences. In one workplace observation about experience, engineering staff strongly believed that “experience and time-served-ness were very important; that you needed to grow into the job and keep yourself updated” (Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002, p. 21). Although Brookfield (1989) cautions that in some learning situations, people keep distorted and erroneous views of their experiences, in workplaces time spent doing the same or similar processes enables people to build caches of strategies and know-how which can be affirmed by other staff. Affirmation by others is typical of the social interactivity within a context and is symptomatic of situated activity and training. That uncouples learning “from a preoccupation with the individual” (Merriam, 2004, p. 211) to a more collaborative learning environment.

2.2.2 Summary of the Situated Activity Approach

In a situated activity perspective, learning takes place when individuals collaborate with others in socially constructed communities of practice such as workplaces, and are trained in increasingly centripetal participation. As the newcomers increase their levels of interaction, they learn through processes of scaffolding, coaching and mentoring by more experienced staff, and by reflecting on the demands of their assigned tasks. As people participate in their communities of practice they are negotiating meanings about their roles and what is expected of them. In many cases, newcomers may refer to some of their own existing funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) so that they are not complete novices and are in effect starting their learning further down the track.

When individuals interact in their workplaces, in other organisations as communities of practice, or with other staff members, there will always be issues of hierarchies and power which cannot be ignored. Power and political issues will be further explored in Section 2.4. Power issues will also be discussed in the next section on Numeracy.

2.3 Numeracy

As mentioned earlier the word ‘numeracy’ first appears in the United Kingdom (Crowther Report, 1959) where, in a discussion of English sixth form curricula, the state

of being numerate is introduced as the “mirror image of literacy” (p. 269). Since the Crowther Report, there have been many definitions of numeracy, or what a numerate person could do (Neill, 2001; Kaye, 2007). Coben (2003) states that numeracy “is a notoriously slippery concept” (p. 393) while Doig (2001) cautions that continual redefinitions of numeracy have led it to becoming “a rather elastic term” (p.3). People draw on prior mathematical experiences or funds of knowledge (Moll *et al.*, 1982) to meet the quantitative demands of everyday life. Drawing on mathematical processes fits Johnstone’s (1994) description of numeracy as effectively bridging mathematics to the real world. Steen (2001) also recognises that mathematics and numeracy have complementary roles, but are essentially different. Steen compares mathematics, the “well-established discipline”, to numeracy as “essentially inter-disciplinary” (p. 115) and likens numeracy to writing since it lies within and across most learning curricula.

2.3.1 Modern definitions

There are several definitions of what it means to be numerate. In one review, Neill (2001) provides about forty definitions of numeracy, or of being numerate. Neill looked for patterns in these definitions of numeracy and unsurprisingly found most specifically mentioned using or understanding mathematics in their statements. Neill also surveyed the numeracy definitions for the concepts of ‘context’ (tasks or situations where numeracy was applied), and ‘location’ (such as workplaces, or homes, where numeracy takes place); he found that although both concepts were mentioned over two-thirds of the time, it was rare to have them both mentioned in the same definition. Beeli-Zimmerman (2011) suggests that context actually includes both tasks or problems and locations or situations.

Neill (2001) concludes that numeracy is a skill. However, the danger of equating numeracy to a skill or a set of skills is that such an approach ignores the social and power influences of what it is to be numerate. Neither numeracy nor mathematics can be neutral (Street, 2011) so a skills definition does not sufficiently acknowledge the socio-cultural aspect of numeracy. Although being numerate utilizes relevant mathematical processes, critically there is an emphasis on making meaning, on context and collaboration with others when meeting demands, and perhaps on having more than one way of reaching a target.

Definitions of being numerate which refer to political dimensions or an influence of power are not included in Neill’s (2001) list. For instance, Yasukawa and Johnston (1994) adopt a more expansive and critical stance with the following definition:

[Numeracy] is a social consciousness reflected in one's social practices which bridges the gap between the world of academic maths and the real world, in all its diversity. The consciousness enables one to challenge the boundaries and the role of mathematics in social contexts. For this reason, numeracy is not linked to any level of knowledge in the hierarchy of academic mathematics; there is a need for numeracy associated with all levels of mathematical knowledge. Further, being an ingredient in the expansion of social justice, if it isn't political, it's not numeracy and if it's not in context, it's not numeracy (p. 198).

As mentioned in the previous section, power and political influences are an integral part of human interaction, and mathematics education is no different. Yasukawa's and Johnston's (1994) definition of numeracy challenges any assumed neutrality. Further, Gerdes (1988) gives an example of political power being wielded in the colonization of Mozambique, where local cultures and institutions were imposed on and subsumed by colonial interests. Gerdes suggests that "the mathematical capacities of the colonized peoples were negated or reduced to rote memorization. African [...] mathematical traditions became ignored or despised" (p.139). The acts of being numerate draw on authentic cultural, societal, and individual activities, and as viewed by Gerdes, are deeply political and contestable.

Alternative terms for numeracy have been in circulation for some time. Closely related to numeracy are concepts such as quantitative literacy (often used in the United States, e.g. Steen, 2001), folk and street mathematics (e.g. Carraher & Schliemann, 2002), mathemacy (e.g. Skovsmose, 2006), techno-mathematical literacy (e.g. Kent, Bakker, Hoyles, & Noss, 2005), and ethno mathematics (e.g. D'Ambrosio, 1985; Gerdes, 1988; Nunes, 1992). Two of these concepts, mathematical literacy and ethno mathematics are representative of the extent of numerate behaviours and are explored further.

2.3.1.1 *Mathematical Literacy*

The Organisation for Economic Co-operation and Development (OECD) favours the term mathematical literacy. In 2010, mathematical literacy (ML) was redefined by the OECD, when attempting to assess what school students learn, in the Programme for International Student Assessment (PISA):

Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens. (OECD, 2010, p. 4)

Hoyles, Wolf, Molyneux-Hodgson, and Kent (2002), and Skovsmose (2006) prefer the term mathematical literacy (ML) to numeracy since ML affords more breadth than numeracy which in their views is considered somewhat basic. Jablonka (2003) seeks to clarify ML using five interpretations. The respective interpretations are:

- an economic “human capital” interpretation;
- an ethno mathematical interpretation;
- a critical interpretation of mathematical and statistical information for social change;
- a civic awareness interpretation; and
- a philosophical interpretation of mathematics itself (p.278).

Examining Jablonka’s interpretations more closely, an economic “human capital” (p.278) interpretation promotes a view that staff in workplaces are better off by having a more mathematical background. Theoretically this provides those staff members with a larger fund of mathematical knowledge to use when confronted with a quantitative issue. An ethno mathematical interpretation is being aware of other cultural and societal groups creating their own mathematics. This is discussed more fully in the next section. A critical interpretation of mathematical and statistical information for social change is about being informed of current events and issues, for instance reading media reports where graphs of social issues provoke discussion. This critical perspective not only critiques how other agencies provide quantitative data, but calls the reader of that data to then also re-examine his or her own perspectives and reactions to the data (Jesson & Newman, 2004). A civic awareness interpretation could intersect with the previous interpretation. An example would be an environmental issue where citizens are alerted to some level of concern. The final interpretation is taking a philosophical view of mathematics itself, “as a problematic tool as many uncertainties and questionable implications emerge from its applications” (Jablonka, 2003, p.279). Mathematics is built on axioms which are themselves contested.

Skovsmose (2006) believes that although numeracy is useful when discussing critical citizenship, the concept of numeracy is limited to competencies in mathematical terms. Skovsmose introduces a concept of mathemacy which he believes signals a more critical view of education, and mathematics in particular. Although there are commonalities among the synonyms for numeracy, there are also diverse perspectives and emphases, with for instance the breadth of mathematical literacy illustrated above. Jablonka’s

(2003) second interpretation in mathematical literacy is ethno mathematics. The next section briefly describes ethno mathematics since this may also be aligned to workplace numeracy practices.

2.3.1.2 *Ethno mathematics*

The ethno mathematics movement formed in the 1970s by recognising alternative discourses through calls for democracy in Brazil, and independence in Mozambique (Knijnik, 2013). High rates of illiteracy and the failure of many children to progress in school mathematics needed urgent attention (Knijnik, 2013). Researchers such as Bishop (1988) drew attention to the dominance of mainstream Eurocentric mathematics as a value-laden cultural entity, and querying the source of the culture and who was interpreting or benefitting from this transplanted culture. According to D'Ambrosio (1985), a dominant culture chooses to teach mathematics chiefly to maintain its own economic and cultural order. McMurchy-Pilkington (1995) claims that a government-dominated agenda filters mathematics education "to preserve the vested interests of the already privileged" (p. 81). At the same time, mathematics has always coexisted and been "practised among identifiable cultural groups, such as national-tribal societies, labour groups, children of a certain age bracket, professional classes, [...] engineers [...] builders, well-diggers, and shack-raisers in the slums" (D'Ambrosio, 1985, p.45). Workplaces are also sites where people work together often in groups, and where ethno mathematical activities take place.

Bishop (1988) identifies six fundamental pan-cultural activities, which are critical for societies or identifiable cultural groups, as they construct their own mathematics. Each of the alternatives to numeracy listed in the previous section has a mathematical or quantitative heritage, so the activities on Bishop's list, "counting, locating, measuring, designing, playing, and explaining" (pp.182-83) are germane. Bishop argues that these pan-cultural activities, in particular local groupings, have often been bypassed though a modern pre-occupation with objectivism, materialism, and technology that is reflected in school curricula. Over time, a gain in power by a dominant discourse "through the activity of [...] teaching people how to deal with abstract entities, *as if they were* objects" (Bishop, 1988, p.186, author's italics) has ensured that local mathematical practices have been side-lined. Gutiérrez and Rogoff (2003) add that culture, people and education cannot be independent of each other. Identifiable cultural groups such as workplace teams do not stand still, nor do the numeracy practices of the membership of the groups. Furthermore, technology encroaches on, and also shapes, many practices.

Steen (2001) provides examples of this technological encroachment listing world wars, the Sputnik launch, the race for the moon, and the growth in computer usage which all “created an unassailable warrant for school mathematics” (p. 109). This impact will be explored further in Section 2.5.

2.3.2 Competing discourses and definitions

As noted earlier, numeracy is a challenge to define (Coben, 2003; Doig, 2001). This is exacerbated because of the undertones of power involved, as exemplified by the Mozambique experience (Gerdes, 1988; Gee, 1996). The political involvement is however, not confined to other countries. Openshaw and Walshaw (2010) describe a post-World War Two debate in New Zealand on the education levels of the literacy and numeracy of school leavers. On one side of the debate were progressive educators while the other side included back-to-basics proponents such as employers and traditional school principals. A change in government enabled one group to become more politically dominant. By gaining institutional power and strategies a group gains better access to promotional machinery (Lankshear & Lawler, 1987; Field, 2004), thereby ensuring the dominant voice is louder and more ‘official-sounding’. If challenged, the more dominant agency “may resort to ‘natural’ reasons that locate the source of the problem in the individuals themselves” (Chaiklin, 1993, p. 397).

Authenticity, meaningfulness, and utility, appear in many of the alternative definitions to numeracy. De Lange (2006) advocates for the OECD definition of mathematical literacy (ML) since in his view ML covers quantitative literacy, spatial literacy, and numeracy. De Lange prefers to omit affective elements such as emotions or attitudes in any definition of ML, although he acknowledges the impacts those affective elements have on learners. Coben (2003) however, includes inclination, and affective elements (such as confidence and comfort) in her definition of what it is to be numerate:

Being numerate is to be competent, confident, and comfortable with one’s own judgements on whether to use mathematics in a particular situation and if so, what mathematics to use, how to do it, and what degree of accuracy is appropriate, and what the answer means in relation to the context (Coben, 2003, p.35).

This definition is favoured in this thesis because the key factor of inclination to use mathematics is acknowledged. The inclination may be a decision based on whether the user recognises that mathematics could be used or not. The decision may be due in part to affective elements, for instance whether someone has faith in their own ability to give directions to a group of people, or if a person feels confident to complete a calculation

in front of others. Evans (2000a) suggests public arithmetic skills such as “someone watching you as you total figures” (p. 57) is an example of numerical anxiety. Anxiety is clearly an affective element and is discussed later. So disposition is an important factor to include in people’s attempts to be numerate and should not be ignored.

Another concept which is alluded to in both Yasukawa’s and Johnston’s (1994), and Coben’s (2003) definitions, is ‘insight’ (Hughes-Hallett, 2001). Hughes-Hallett (2001) suggests that insight goes beyond a working knowledge of algorithms, instead involving “judgement, reflection, and above all, experience” (p. 96). Because of these factors, acquiring insight, according to Hughes-Hallett, is not a straightforward process. She describes a situation where a radio caller gave a personal insight of a taxation context. A government spokesperson claimed that a gas tax of £8 out of a total price of £10 would be 80 percent tax. The caller disputed that percentage, instead identifying the £8 out of £10 as 400 percent. Later, Hughes-Hallett presented the same figures to her students; her students could not see where the radio caller produced the 400 percent or the 80 percent, even though the students could see the ratios between £10, £8, and £2. Hughes-Hallett (2001) writes that although the students can manage algorithms they did not yet possess the mathematical insight, perhaps lacking the contextual experiences of the radio caller.

Instances such as these are not mathematically complex but do illustrate the ‘messiness’ of adult numeracy, or its related terms. The definitions of numeracy are continually evolving so it is also clear that not every contributor shares the same perspectives. Critically, the definitions have expanded to show that numeracy is not confined to number sense and is more than basic mathematics. There are socio-cultural perspectives which need to be taken into account along with factors of disposition (Gal, 1999) when defining numeracy.

2.3.3 The demands of studying mathematics

In the Cockcroft Report (1982), the authors state “that all these perceptions of the usefulness of mathematics arise from the fact that mathematics provides a means of communication which is powerful, concise and unambiguous” (p. 1). There are still situations however, when the work of pure mathematicians is utilised (Atiyah, 2001), as with applied mathematics, although the intersections may not be immediately evident. For students continuing in pure mathematics, Fischbein (1999) suggests that although reality may inspire the students’ pursuit, reality is “never an object of research leading to mathematical truths, and certainly not a final instance for proving a mathematical

truth” (p.149). Barton (2010) states there is something almost addictive about mathematics for mathematicians. Barton (2010) uses an example of the New Zealand Fields scholar, Vaughan Jones, after his discovery of the Jones Polynomial, that all he wanted to do “was think about the maths and any worldly thing was an intrusion” (p. 3). The Cockcroft Report (1982) adds that there must always be a certain number of mathematicians available, particularly as their abilities will be needed for the development of new technologies and practices. Some of these new technologies will change workplace practices. One example which contributes to this research is the development of solo-operated mechanized refuse and recycling vehicles, replacing the work of three people and illustrated in the Chapter Four.

Many learners of mathematics do not see those links to technological advances and are left wondering about the utility of the mathematics they have been taught. What is problematic is extracting the same or related mathematical concept, from one context and immediately transferring the event to a new context (Freudenthal, 1968). Apart from being motivated, even if a learner has actually seen the connection, Evans (2000a) argues that people “do not ‘spontaneously see’ the transfer (or task or goal) which their teachers (or their managers) have in mind” (p. 76), no matter how effective the teaching and learning.

In addition, many people have little desire to study higher mathematics (Freudenthal, 1973; Kanes & Lerman, 2008), nor the inclination to spend significant amounts of time thinking about the subject. A continuing challenge for researchers working on the Cockcroft Report (1982) for instance, was the recruitment of enough adults to be interviewed about their school mathematics experiences. About half of the sample refused to engage in any discussion of mathematics. Of those who did take part, many had experienced “feelings of anxiety, helplessness, fear and even guilt” (p.7), with some of the people closest to them often inflicting the greatest distress:

Criticism by husbands or wives or by other members of the family, especially comment about slowness or the need to use pencil and paper instead of performing a calculation mentally, also eroded confidence and contributed to decreasing use of mathematics. 'I'm afraid I have to write it down. My brother can do it in his head.' 'My husband says I'm stupid' (p.8).

Adult respondents had concerns about appearing unintelligent in front of other people, such as their workmates. Some adults felt that they were behind others since they did not use the proper maths rules and procedures, in the process downgrading their own effective home-grown strategies. The very symbols and notation which provide the

communicative power for mathematics may ironically also be responsible for many of the misconceptions, beliefs, and even blocks for some learners (Cockcroft, 1982).

Some of the adults interviewed in the Cockcroft Report carried several negative experiences with them, such as believing there is always one exact answer to a problem. They also had difficulties with rounding numbers and approximations and feeling they must show all their working out on paper even if they could complete a calculation mentally. In school mathematics showing how you arrive at a solution is highly regarded. Having to complete a calculation in a short time frame was another stressor. An unfortunate outcome for many school students is a failure to make connections between everyday situations and the invented mathematics they are taught (White & Mitchelmore, 2004). Several students begin to develop strategies of avoidance around learning mathematics (Ernest, 2010).

At its most severe this condition may develop into maths anxiety (McLeod, 1992), an impact where learners panic when confronted with situations similar to those given in the previous paragraph, resulting in their being unable to think clearly. Evans (2000a) suggests two dimensions of mathematics anxiety. The first dimension relates to school or college environments, and includes enrolling in courses with a compulsory mathematics component, then being asked questions in class, and also when evaluations or assessments are imminent. The second dimension is described by Evans as everyday situations, including working with money and perhaps having to publicly calculate an amount.

Mason and Spence (1999) believe that the formal lesson structures of a lot of mathematics classroom teaching make it difficult for many students to engage with the content, let alone extend to applications. Skills seem to have been isolated, so that “the traditional sequence of example, theory, exercise, and then application tends to leave the knowledge inert” (p. 150). De Lange (2006) states that students “are not positioned to see overarching concepts and relations, so mathematics appears to be a collection of fragmented pieces of factual knowledge” (p. 20). The challenge remains to somehow situate these mathematical experiences within the grasp of every student, but not as Freudenthal (1968) suggests, overwhelming them or failing to challenge them.

Failure to engage students can have far-reaching effects. In research by Bynner and Parsons (2006), the numeracy and literacy capabilities of two longitudinal cohorts (born in 1958 and in 1970) were reported, and one of the key messages was of an intergenerational impact. Bynner and Parsons found that children of adults with quite

poor literacy and numeracy had concomitantly low understanding of literacy and numeracy. Further, in spite of poor scores by respondents in the assessments, self-reported numeracy and literacy issues in the longitudinal surveys seemed to be very low (around five per cent). Bynner and Parsons (2006) suggest that:

most adults with poor skills have learned how to cope, drawing on local family and community resources to deal with literacy and numeracy challenges that they could not handle themselves ... unless something happens to disrupt the normal course of their lives leading to a reappraisal, such as having a child or facing unemployment, they are not going to have much incentive to take advantage of educational provision to improve their skills. (p. 103)

There are other people however, who when they are working at home, at work or when engaged in other community practices, manage situations including numeracy tasks (de Abreu, Bishop, & Presmeg, 2002). This reflects the localised nature of numerate behaviours where people build up niche expertise, although they may not recognise their own capabilities. It is also possible that others know whom to ask for assistance thereby masking the need for individual capability.

2.3.4 Directions and Domains

When comparing mathematics with numeracy, Orrill (2001) writes that “unlike mathematics, numeracy does not so much lead upward in an ascending pursuit of abstraction, . . . it moves outward toward an ever richer engagement with life’s diverse contexts and situations” (p. xviii). Orrill’s words echo Bernstein’s (1999) descriptions of discursive domains, that subjects such as sciences occupy vertical discourses, made up from concepts that are learned in hierarchical “coherent, explicit, and systematically principled structure(s)” (p. 159). Bernstein (1999) compares this vertical discourse to another more horizontal discourse of common-sense knowledge, which tends to be “oral, local, context dependent and specific, tacit, multi-layered, and contradictory” (p. 159). The horizontal discourse supports the sometimes tacit accessible position of numeracy, whereas one could argue that is not always the case with mathematics.

Resonating with Bernstein’s (1999) model of discursive domains, Dowling (1998) provides a list of others’ definitions, which illustrate “the dual modality of practice” (p.104). Two examples are Dowling’s descriptions of Luria’s duality of “abstract thinking” against “situational thinking” (Table 5.1, p.104), and Walkerdine’s promotion of “formal reasoning” against “practical reasoning” (Table 5.1, p. 104). Dowling (1998) suggests that certain practices in subjects such as mathematics have “high discursive

saturation” (p. 103), since these have high levels of generalisation and abstraction and may be independent of context; alternatively, a subject with “low discursive saturation” (p. 103) is context-dependent, particular and localised.

Kell (2001) contrasts Bernstein’s perspective of shifts from competence models to performance models when discussing adult education in post-apartheid South Africa. Kell describes the competence model as centred on learners by providing them with relative autonomy. In contrast, the performance model is more regulatory as the power resides with agencies including the state, who then prescribe targets for learners along the lines of national standards. With regard to literacy Kell reconstructs Bernstein’s models into two discursive domains. Kell’s (2001) first domain relates to the performance model, where it resides as a one-dimensional entity and where supposedly deficient learners need to meet autonomous state standards and performance criteria. However, Kell states that people engage with this first domain primarily to become certified with their qualification earning “exchange value” (p.103) in spite of that domain having very little use in their everyday lives.

The second domain, Kell argues, involves people using literacy as it is embedded in their everyday lives, and if they struggle with literacy they draw on the assistance of other more literate mediators in their communities to decode critical texts such as power bills. People find ways around their challenges unwilling to see themselves in a state of deficit. Although the second domain has a high use value, it is relatively unrecognised by agencies that monitor the first domain; thus the second domain has a low exchange value. The question should then be asked whether numeracy may be viewed in a similar framework to literacy.

Coben (2002) responds by applying Kell’s (2001) model of two discursive domains to numeracy. In Domain One, Coben suggests that numeracy education, aimed at adults who are regarded by agencies as numeracy-deficient, follows a standardised curriculum including “unitisation and commodification of learning and learning materials” (p. 27). In Domain One learning is formal and students work on standards for credits, becoming credentialed once they reach prescribed milestones. In this domain, examinations and other means of assessing formal learning send a message to learners about which knowledge is legitimate or valid, so complex and ambiguous knowledge is not assessed (Kvale, 1993). Further, the grading of results promotes a preciseness of knowledge which may not reflect the ‘messiness’ of everyday settings.

Coben (2002) states that Domain Two differs in that people work in authentic localised and sometimes messy situations, meeting varying numeracy demands during their tasks. Many people in the second domain may not recognise that they are working with mathematics since they perceive this as the subject they learned at school. In the intervening years these people have perhaps needed to work out a particular quantity, have met a deadline or have taken a certain direction within a situation, but they regard what they do as simply common sense (Coben, 2000).

2.3.5 Intersecting formal and informal domains

Kell (2001, citing Bhabha, 1994) suggests the points of connection between the two discursive domains exist in a possible “third space” (p. 102). As an example of an attempted connection to this third space, text book authors set mathematics problems that appeal to learners’ interests through contexts which require mathematical strategies to find solutions. However, problems solved in this traditional kind of mathematics are often an attempt to simulate real-world situations (Wedegge, 2002) resulting in friendly numbers as answers. Evans and Tsatsaroni (2000) claim that context problems provided to students are examples that are simpler than most real-world situations with “a ‘thin veneer’ of applicability” (p.56). On one level, such tasks do assist learners to practise problem solving, however, those same problems may lead to solutions with narrow and limiting strategies. Usiskin (2001) appeals to educators to specifically include quantitative literacy so that real problems may be provided and numeracy becomes more mainstream in classrooms.

Livingstone and Sawchuk (2005) provide a possible alternative to the space or boundary area between formal learning, which in this thesis equates to learning mathematics in school, and informal learning which similarly is learning relevant numerate behaviours. Continuing education (Livingstone & Sawchuk, 2005) is not used for credentialing, but to meet a possible shortfall in what a staff member may know for their role or to fill a personnel requirement in their organisation. Examples are attending a first-aid course, or fire warden training, or help for a migrant worker needing language and numeracy so that stock labels and barcodes in a warehouse or a supermarket may be read properly. The learning is very task-specific and although each example does not earn credits, each identifies or confronts a problem at the boundary (Akkerman & Bakker, 2011) enabling the participant to meet peripheral work demands, and in two cases meet the risk (and likely insurance) requirements of the workplace.

The boundary area between the domains, or third space mentioned above, requires contributions from both educators and external organisations. The Cockcroft Report (1982) suggests that educators and industry needed to communicate about each other's mathematics. Attempts have been made by educators visiting industries. Hogan and Morony (2000) report on workplace visits by Australian secondary school mathematics teachers; each teacher shadowed a person in their workplace for a day then interviewed the person about the mathematics being used. For many teachers, "school has been their only workplace" (p. 101). As a result, teachers were often surprised at how workers met their work demands either by following standard procedures or, when there was a need to alter a procedure, how the workers then applied their own idiosyncratic strategies to complete the task satisfactorily.

In another example, Williams and Wake (2007) carried out extensive field studies of workplaces with college students. In the boundary crossings between college mathematics and the workplace practices they visited, Williams and Wake describe these practices as "problematic, both for us coming to understand them and the workers who felt obliged to explain them" (p. 340). Clearly, the working tasks are the major foci for staff in the workplace (Wedge, 2002). However, as the two investigations of the boundary area illustrate (Hogan & Morony, 2000; Williams & Wake, 2007), the meetings between educators and industry have been initiated by educators.

Although the college or school mathematics discourse is distinct from the workplace mathematics discourse, they are not unconnected since there is common ground in the boundary area (Evans, 2000b; Wijers, Bakker, & Jonker, 2010; Damlamian, Rodrigues, & Sträßer, 2013). The challenge is to somehow balance the generality of the first discourse with the particular situations of the second discourse. Manoeuvring through the boundary area remains a challenge. However, outsiders must attempt to break into the practices to mathematise the operations, thereby making the invisible visible to observers and users (Cuban, 2001). For teachers who were used to dealing with explicit mathematics knowledge there was recognition that not all mathematical knowledge was explicit. A further benefit to the teachers who visited workplaces (Hogan & Morony, 2000) was their gain in workplace mathematical knowledge, which gave those teachers solutions to the perennial questions from students of where the mathematics they were learning could be used.

2.3.6 Tacit knowledge and future thinking

Contrary to explicit knowledge, tacit knowledge almost appears to be unconscious (Fenwick & Tennant, 2004), and is often difficult to articulate (Eraut, 2004). For many people it appears to be instinctive or intuitive, a “primitive, self-evident term” (Fischbein, 1982, p. 9). So a person can very quickly make a decision or judge something decisively, without being aware of how they learned the action or why they took that option (Schön, 1983). Wenger (1998) provides an example where “people who know how to ride a bicycle often cannot articulate how they keep their balance” (p.69). Similarly, Ryle (1949) describes a comic who “knows how to make good jokes and how to detect bad ones, but he cannot tell us or himself any recipes for them” (p. 30). Both parallel people who are experienced in meeting the demands of a task, but are unable to describe the mathematics that unfolds during the task (Wake, 2014).

Fischbein (1982) sees room for standard analytical mathematics approaches alongside more intuitive approaches. He suggests that the gap is already narrow when one considers how fundamental mathematics is self-evident (e.g. “the diagonals in a rectangle are equal” (p. 11). Dehaene’s (2009) study of intuition around arithmetic gives two examples. First, adults almost instantaneously recognise that eight items is more than four items; second adults can estimate the numerosity (judgement of the quantity) of approximately 30 dots. Dehaene also reports on how pre-school children, when asked to place a number along a line from 1 to 100, instinctively place smaller numbers to the left and larger numbers to the right. Although the number distribution may not be completely precise, and it is possible they may have previously counted out objects in similar directions, Dehaene (2009) believes that even very young children brought up in cultures which count this way have this intuition about left-to-right locating. Fujita, Jones, and Yamamoto (2004) report there is a well-documented history of intuition of geometrical ideas, suggesting that modern curricula should be encouraging students to develop a “geometrical eye” (p. 2), an ability to “create and manipulate geometrical figures in the mind” (*ibid.*, p. 1). Fujita *et al.* suggest that another element of geometrical intuition is knowing where to begin to solve a geometrical problem. That issue is not confined to geometrical problems; students have challenges starting many other mathematical problems.

Carraher and Schliemann (2002) caution that while striving for realism and utility is worthwhile, such attempts need to be tempered with the realisation that what is useful and authentic now may not necessarily be so when one considers future occupations.

Orrill (2001) adds that “change repeatedly outruns continuity” (p. xiv) so the challenge of what might lie ahead may be met partly by continuing with studies of mathematics. In a workplace survey of employees, Kyffen, Paneels, and ACME (2011) noted that several employees acknowledge their formally learned mathematics was at a higher level than what they were currently working with; however, the employees were confident they could tackle any quantitative tasks on the job because their background maths knowledge is secure.

The broad base of mathematics education should attempt to prepare students for future technological changes; accordingly, Cai and Howson (2013) challenge curriculum writers to accommodate changes to traditional contexts. However, Hoyles *et al.* (2002) advise that outside of schools, the needs of mathematics are not confined to future change, improvement and innovation. There are also more immediate goals of “remaining competitive” and “maintaining operations” (p. 9), both vital to the survival of any business. Sometimes the competitive edge may be assisted by tacit knowledge and intuitive approaches, and companies have rewarded employees who suggest strategies which save money or result in larger shares of the market.

Finally, the third space is not just a zone where content and contexts are contestable. There is also evidence that Domain One credentialing needs to be reviewed in light of comments received by Hoyles *et al.* (2002) from employers about recruitment. Some employers found that there was a “difficulty of using school mathematics qualifications [...] as clear and/or reliable indicators of competency in the recruitment process” (p. 14). In lieu of school results, some workplaces administer their own entry assessments. The call by Hoyles *et al.* (2002) is for educators and education agencies to communicate content, qualifications structures, and any changes in curriculum to employers’ groups. As noted earlier, bringing the parties together to examine the boundary area is a continuing priority.

2.3.7 Summary of Numeracy

This section explored several definitions of numeracy and definitions of mathematical literacy and ethno mathematics. Bernstein’s (1999) horizontal learning and vertical learning discourses have been transformed by Kell (2001) for literacy and Coben (2002) for mathematics, into domains. The space between the domains, or boundary area, has been investigated by educators visiting workplaces (e.g. Hogan & Morony, 2000; Williams & Wake, 2007) and although there are commonalities in the mathematics there are differences in context. Dialogue is taking place between workplace sectors and

educational sectors although there is still work to be done (Damlamian, Rodrigues, & Sträßer, 2013). Finally, tacit knowledge and intuition were briefly discussed; the relatively instinctive actions of many people are regarded as self-evident and common sense. In other words, people do not often appear to be aware of their use of maths within their everyday activities.

2.4 A Social Practices Perspective

The social practices perspective of literacy emerged from ethnographic research of the literacy of communities in Liberia (Scribner & Cole, 1981), the Carolinas (Heath, 1983), and Iran (Street, 1984). This research perspective is known as The New Literacy Studies (or NLS) (Gee, 1996), and was a counter to what Street (2011) describes as the traditional autonomous model of literacy, which valued reading and writing over oracy and traditional forms of communication. The autonomous model is purportedly abstract, decontextualized and value free. In a social practices model however, literacy (and numeracy) practices are viewed as meaningful and are created by people within, and in relation to, the social and community structures they inherit and inhabit. As Barton (2006) claims, “literacy practices are what people do with literacy. However, practices are not observable units of behaviour since they also involve values, attitudes, feelings, and social relationships” (p.22). In the social practices model of literacy, Street, Baker, and Tomlin (2008) distinguish between what is meant by literacy events and literacy practices:

The concept of literacy practices attempts not only to handle the events and the patterns of activity around literacy, but to *link* them to something broader of a cultural and social kind. Part of that broadening and extending involves attending to the fact that in a literacy event we have brought to it concepts, social models regarding what the nature of this practice is and that make it work and give it meaning . . . you can photograph literacy events but you cannot photograph literacy practices (p.19).

This is a key distinction in that literacy and numeracy events are visible and may be observed in a workplace setting. Events contribute to the broader entity of a literacy or numeracy practice respectively.

2.4.1 Fitting Social Practices to Numeracy

In section 2.3.4, numeracy could occupy one of two discursive domains (Kell, 2001; Coben, 2002) based on the use of two similar domains from literacy, so is there an opportunity for numeracy to also be fitted into a social practices perspective? This next

section explores possible ways forward with numeracy as a set of social practices plus some cautions about whether a social practices perspective is a true fit for numeracy.

As mentioned in Section 2.3, the mathematics used to underpin the numeracy in a situation is contextual, has a purpose for its users and is not neutral. The mathematics may vary according to the demands of each task, the values and beliefs of the participants engaged in the tasks, and the behaviour and responses to whomever has the responsibility (e.g. hierarchy, backing and power relationships) to complete the tasks. Baker (2008) states that although the mathematics events during the completion of a task may be visible, the meanings of those events may not be readily understood since the events are surrounded by, or embedded in, the values and relationships of the task practices. Street (2011) states that literacy (and numeracy) are “not simply a technical and neutral skill [... they are] always embedded in socially constructed epistemological principles” (p.418). Those principles are that literacy and numeracy are dynamic not static, are processes not objects, and are diverse sets of resources not autonomous sets of rules to be followed or skills to be learned. Numeracy and literacy include the experiences of people and their understanding of the demands of tasks.

Numeracy as a set of social practices draws on some of the ideas such as context and meaning from the concept of literacy as social practice. Evans and Tsatsaroni (2000) state that “meaning is constituted by, supported by, and shaped within, the discourses and practices in which it is inscribed or used” (p.59). Evans and Tsatsaroni provide a comparative example of the relationship between discourse and meaning. In one instance, Evans and Tsatsaroni write about a school discourse, where a calculation is carried out with certain numbers and where all the students attempt to arrive at the same answer by using a taught strategy. Evans and Tsatsaroni (2000) then apply the same numbers used in the school example to a retail situation contextualising the calculation by asking staff to work out a unit price for a comparison between items. This retail context goes beyond the pure mathematical content of just working with numbers. The activity might require each staff member to check their unit price with other staff members’ unit prices.

There are other instances when individuals construct their own experiences but are not able to articulate what they have done (Lincoln & Guba, 2013), particularly when those experiences are longstanding and over time have become tacit. For instance, in the above retail situation, one staff member may show another how to perform the calculation but have little idea why it is done that way.

By considering numeracy as a set of social practices (Baker, 1998; Street *et al.*, 2008), there are reminders of the socio-cultural constructs which people frequently encounter. Dowling (1998) provides four premises to describe these constructs:

- numeracy decisions are made in situ and are part of a larger task
- there is usually a time factor involved
- there is usually a standard to be met or a purpose behind the practice
- the numeracy strategies in use have local settings and particularities

First, numeracy decisions are usually made in situ and are part of a larger task. For example, Dowling (1998) relates a shopping episode where he negotiated a reduced price on smaller tubes of a product when he discovered the larger containers of the same product were cheaper, but out of stock. The numeracy practice lies within the negotiation of the new price following an on-the-spot calculation where the comparison of the two sizes, and the respective unit prices, was made. In addition to the shopping practice, there is also a power element being contested (Baker, 1998) between the retailer and the customer; a dissatisfied customer may always walk away from a sale while the retailer must still try to complete the sale in order to make any profit.

Secondly, there is a time factor involved and this might be in the form of a deadline to meet or a schedule to follow. However, people may sometimes detour from schedules if they can deduce a more efficient means of reaching a target. Scribner (1985) describes how warehouse staff in a dairy operation would pick orders for despatch. Instead of working through the list of stock from top to bottom in each order, staff checked the list of items and assembled these by using their product knowledge and the layout of the warehouse to fill the order as efficiently as possible.

Dowling (1998) mentions the “basis of criteria” (p.2) as a third numeracy premise where there is usually a standard to be met or a purpose behind the practice. Street, Baker, and Tomlin (2008) describe how the mother of one of the families they researched works in the field of benefit fraud although she does not consider herself mathematical. Street *et al.* (2008), however, state that the mother probably has “considerable maths or algorithmic skills” (p.53); she still calculates by using traditional algorithms, and manages both her workload, and her family responsibilities. The mother seemed to be untrusting of calculators so she persists with longhand calculations, all the while believing in her own methodical accuracy to meet the auditing standards of her work tasks.

Finally, the numeracy strategies in use have local settings and particularities (Dowling 1998). In another family example (Street *et al.*, 2008) the father races pigeons. By training younger pigeons the father knew how long it would take the birds to return home and what speeds they were capable of. He also knew the local conditions and he was gradually introducing his two sons to the same pigeon-racing practice. Although Street *et al.* state that numeracy is about competently dealing with numbers in everyday life, in this pigeon-racing situation the authors also acknowledge the presence of space and measurement by stating “concepts of distance, directions, location, spatial relations, time and speed ... had numeracy aspects embedded in them”(p.136). Numeracy must be more than a competence with quantities if a situated practices model is to be useful.

Baker (1998) includes two other premises for numeracy to be considered as a social practice. Firstly, he includes culture as an impact on an individual’s numeracy by including their beliefs, notions, attitudes and values. Baker describes a builder he was working with whose values were time and performance driven. According to Baker, the builder did not completely understand the mathematics that he was applying but he had performed similar construction activities often enough to trust in his own judgements.

Baker’s second premise is ideological which concerns how people approach the activities through different views or stances. In Baker’s (1998) example of the builder, Baker attempted to share a more academic perspective with the builder by initiating a discussion of the mathematics behind the construction project. The builder however, had little or no inclination to delve into the mathematics behind the project instead being far more interested in completing the construction task. Consequently, Baker realised that he was better off leaving the builder to his own perspectives and values since the project was effectively being completed with or without Baker’s input.

2.4.2 Where social practices perspectives may not fit numeracy

Although the social practices approach is a historically useful model for literacy studies, with some parallels to numeracy studies, the fit may not be completely secure for numeracy. First the situation with the racing pigeons raises an issue which is more of a numeracy challenge than a literacy challenge. The father training the pigeons may very likely work out some of the distance, direction, location, time and speed calculations on-the-spot, especially if he has to make adjustments due to wind and weather in order to keep track of his pigeons. If the two sons who are observing the racing are unsure how decisions have been made by their father, this is an instance of the invisibility of

numeracy practices (Coben, 2006) where the father is clearly operating at different levels of numeracy experience to his sons.

Secondly, perspectives of literacies (plural) have been introduced; however, if numeracy is refitted into numeracies, there is a risk of fragmenting mathematical ideas behind numeracy (Coben, 2006). Evidence of this in mathematics studies is already occurring with students who, after gaining some National Certificate of Educational Achievement (NCEA) credits, applied for entry to the tertiary institute at which the researcher works. These students have studied school mathematics courses where the subject is divided into discrete strands. However, many students who enter the programme do not appear to see the links or to make any connections between these mathematical strands. The lack of comprehension or appreciation by the students of the holism of, and the relationships within, the subject has consequences when they begin further study (de Lange, 2006). One example of where students are often found wanting is recognising relationships between representations of mathematical functions. Considering a numeracies (plural) approach might lead to similar outcomes; a more holistic vision of numeracy is essentially more meaningful and probably less contrived.

A third consideration is that although the pigeon racers have rich contexts to draw on, when it comes to their embedded numeracy practices there is still an issue around understanding the mathematics needed. Although this may not be critical for the father who already understands pigeon-racing practices, he is however also coaching his school-aged sons to race pigeons and will need to discuss with them the concepts of distance, direction, location, spatial relations, time and speed. These concepts must ultimately draw on the sons' mathematical knowledge. But if the sons are to develop into successful pigeon-racers, then at some point appropriate mathematical knowledge must be addressed especially as one son has major issues with learning mathematics (Street *et al.*, 2008). This requirement will probably not be met in a situated social practices approach to numeracy (Coben, 2006) by relying solely on pigeon-racing practices to assist the sons with their mathematical development. Although it may be sufficient for some learners, Coben insists that:

it points up a significant difference between numeracy and literacy: the fact that reading and writing a language one already speaks is not analogous to 'doing mathematics' or 'being numerate', because most people do not 'speak mathematics as a first language'; they need to be taught it (p. 101).

The Cockcroft Report (1982) also compares the learning of mathematics with the learning of a language, and the authors suggest that unlike errors in mathematics

notation and calculations, “mistakes of grammar or of spelling do not, in general, render unintelligible the message which is being conveyed” (p. 4). Doing maths does not come naturally to everyone, it often takes time for people to learn and practise its nuances, precision, and notations. Errors in mathematics probably have a greater significance (Cockcroft, 1982) when one takes a wrong turn, or when extra zeroes are inadvertently put on a money figure, then deposited in a bank account. In the instance of pigeon-racing, errors around distance and time could compound although one would expect that the father would not be a passive observer of his sons’ efforts and would step forward to guide their attempts when required.

There are exceptions to formal learning of mathematical ideas, however, when considering preschool learning and infancy. In human infancy, neuroscience research around the bilateral parietal circuitry of the human brain has discovered that being able to recognise up to four quantities without counting is possible (Geary, 2000; Dehaene, 2009) even though these are not specifically taught. Geary describes competencies such as numerosity, ordinality, or the ability to recognise simple more or less quantities, as “biologically primary, or inherent, systems of basic quantitative concepts” (p. 15). More or less in terms of sets of objects could parallel nearer or farther in terms of distances for infants. In the early days and months of a child’s life, confronting and learning about new spatial demands, as a child comes to terms with the environment around him or her, is often underestimated (Clements & Sarama, 2000). Further, Clements (1999) writes that “children’s intuitive knowledge of geometry frequently exceeds their numerical skills” (p.36), so some numerate thinking, and mathematics, which have been developed from early ages, are already “core knowledge” (Dehaene, 2009, p. 233), well before formal education has begun.

2.4.3 Summary of a social practices perspective

In summary, considering numeracy as a model of situated social practices recognises that numeracy practices are embedded in the everyday lives of people, communities and cultures. However, as Lankshear and Lawler (1987) note with regard to literacy, and which could apply to numeracy, “if literacy is socially constructed, we should expect some people or groups in societies like our own to have greater influence than others in the process of what will count as literacy within that social-historical setting” (p. 59). The values, beliefs, behaviour, interests, and relationships to power, of people, and communities are what define these social practices as an ideological model. While a social practices model is similarly convenient for numeracy, there are still other things

to weigh up for this model to address some of the challenges of numeracy, such as the need for deliberate teaching interventions of intermediate, often abstract, mathematical concepts. Be that as it may, workplace activities of which learning is one of many, cannot ignore the social interactions between the players. Cuban (2001, p.89) suggests that pedagogy and curriculum are inseparable, since “pedagogy ... is as essential to learning as fuel is to moving a car”. Similarly, workplace practices and any relevant numeracy practices within cannot be separate from the people involved in workplace learning and training.

2.5 Numeracy in workplaces

In this section, several studies of the mathematics used in workplaces are presented, including the mathematics desired by employers’ groups for prospective school leavers. In this thesis, there is interest primarily on estimation practices and spatial awareness in the workforce. Several numeracy studies are examined to see what elements of numeracy, particularly estimation and spatial awareness, are being used. The section will begin with a description of mathematising, a process which attempts to represent relationships in a problem or a situation in mathematical terms. This will be followed by several studies on the mathematics in workplaces. Next, numeracy-in-workplace research is presented with the examples selected having estimation or spatial awareness practices.

2.5.1 Mathematising

Although there are an increasing number of workplace numeracy studies (e.g. Marr & Hagston, 2007; Black, Yasukawa, & Brown, 2013), the extent of the mathematics used lies largely unrecognised (Sträßer, 1999; Williams & Wake, 2007). To try to excavate the mathematics within workplace practices, researchers use the process of ‘mathematising’. The National Research Council of the USA (2007, p.44) explains that mathematising is the approach taken where the contexts of everyday activities, which may exist at informal or even intuitive levels, are reformulated, restructured and possibly generalized, in mathematical terms. Freudenthal (1973) adds that mathematizing is “learning to organize [a situation] into a structure that is accessible to mathematical refinements” (p.133).

There is also a responsibility, however, when viewing work practices through a “mathematical lens [...] not to privilege a particular interpretation over others”

(Zevenbergen & Zevenbergen, 2004, p. 4). This is never a simple task, particularly as mathematics provides an underpinning and an enduring reference for workplace numeracy. In an ethnographic study of carpenters, for instance, Millroy (1991) describes the navigation required by the researcher to travel between “the overwhelming notion that everything is mathematics” against the “constricting notion that formal academic mathematics is the only valid representation of people’s mathematical ideas” (p.6). The latter approach may then lead a researcher into deciding whether the practice is mathematical or not (Barwell, 2004; Barton, 2004), and which mathematical strands the practice might be aligned with. Wake (2014) advises that “our attention is drawn to practice [...] the coupling of human actions with the relatively complex tasks or problems that workers undertake, and the role that mathematics has to play in them” (p. 272). Reporting on the complex tasks accurately and faithfully representing the data of the people who provided workplace activities are the challenges to be covered in Chapter Four of this thesis.

2.5.2 Workplace surveys of numeracy

This section illustrates how researchers and agencies suggest what mathematics is required in workplaces, and five different surveys are briefly presented. Mention of estimation and spatial awareness factors in the surveys in particular are of interest in this thesis. Three surveys are from the United Kingdom, one is from Australia, while the first is from New Zealand. In a survey of the mathematics used by the New Zealand workforce, Kelly and Arnold (1994) list numeracy, basic arithmetical operations (including money calculations), percentages, and problem solving as major items. In a survey in the United Kingdom, Riall and Burghes (1996) report that employers they interviewed valued the need for some kind of mathematical background more than their employees did; however Riall and Burghes (1996) add that these same employers believe that “numeracy was not one of their principal concerns when recruiting new employees”, rather “literacy, communication skills, and other interpersonal skills were more important attributes” (p.111).

With regard to estimation practices and spatial awareness, Kelly and Arnold (1994) include the position and arrangement of shapes but the overall importance of having or developing spatial abilities is not so clear. Before their survey, Riall and Burghes (1996) inspected the British GCSE syllabus, identified 45 topics, and then asked employers and employees to rate the relevance of each topic on a percentage scale. There were 18 topics which received the highest ratings in the questionnaire. Of these, the three topics

adjudged to be the most relevant are basic numeracy, which Riall and Burghes suggest, is “a good grasp of number” (p.105), mental arithmetic, and calculator work. Only two of the selected topics, coordinates and mensuration (or perimeter, area and volume) clearly relate to spatial thinking.

In *Mathematical Skills in the Workplace* (Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002), twenty-two workplaces and case studies from seven work sectors were visited, and a list of desired mathematical skills was compiled. Though there are variations from sector to sector, there are also common threads such as “communication of data and mathematical information”, measuring, and calculating from simple to “multi-stage calculations including percentages” (p. 16). There are also clear connections to estimation where people are expected to use mental calculations and approximations. Spatial awareness is linked to diverse practices in electronic and optical engineering, such as the need to translate between two-dimensional representations and three-dimensional objects, through to preparing and reading special charts, and use of visualization skills (e.g. X-rays) in health care.

Vergnaud (2000) lists several “mathematical domains” used in a range of workplaces. His list has map and graph reading, each related to spatial awareness, and evaluation proportionality, and approximations which are linked to estimation. FitzSimons (2005) also reports that there are several underpinning mathematical skills and concepts in workplace mathematics. Of a list of seven key areas, FitzSimons (2005) includes arithmetical estimation skills and geometric thinking on her list. Although there is no mention of non-numerical estimation it is possible this form of estimation is implied in the other estimation practices. However, FitzSimons notes that with the complexities of the duties of people at their workplaces, it is not always possible to be completely definitive about which area(s) of mathematics are being engaged.

More recently, the Confederation of British Industry (CBI, 2010) created a seven-point list of desirable functional numeracy skills, or “core maths skills” (p.5), for school-leavers about to enter the workforce. Unsurprisingly, elements of number sense such as mental arithmetic, calculating percentages, ratios, fractions, and decimals, and being able to check an answer for reasonableness, are listed. This check for reasonableness is related to numerical estimation although there is insufficient information to determine if measuring estimation is included. Interpreting and responding to data are also on the CBI list, particularly when considering quality improvement, while risks or likelihoods can be assessed if people know about simple probabilities. The CBI (2010) also believe

that some formula manipulation would be useful in certain places as would being aware of different measures, and being able to convert between metric and imperial units. There is no mention of spatial awareness in the list of desired core skills.

Broadly speaking, core workplace expectations from employers include having staff perform workplace tasks to order, ensuring the quality is sustained, and working through any relevant issues, including breakdowns that may arise. According to Lave (1990), in school work answering a problem completes the task whereas in out-of-school work the solution to a mathematical problem may only be part of a task. Further, the numeracy practices required during the workplace task may not occur at the start of the problem, instead appearing several steps into the task. Gal (1999) suggests that situations in life outside of school usually “have to be *managed*, not ‘solved’ ” (author’s italics, p.10) when engaging in numerate behaviour. Although knowing some number facts and procedures can assist with numeracy, these may not be enough by themselves to manage a situation. What people usually do in those situations (Gal, 1999) along with any external demands on them is to draw on non-mathematical routines. Noss, Hoyles and Pozzi (2000) argue that non-routine problems require a broader set of skills. There is likely to be more than one strategy, and several perspectives according to the persons applying the mathematics.

One common view held by people is that there may be no mathematics involved in spite of mathematising evidence to the contrary. Noss, Hoyles and Pozzi (2000) explain this invisibility of the numeracy with the user having “intimate connections with the specificities of their practice” (p. 33). Noss *et al.* add that for an observer the mathematics in use is not predictable and is dependent on whether the work is routine or whether there is a breakdown; numeracy then becomes visible. Another source of invisibility is production technology, where workers input materials into a pre-set machine and the desired output emerges to specification (Sträßer, 1999; Black, Yasukawa, & Brown, 2013). Still there are other instances when numeracy seems to have been deliberately kept invisible. In their workplace studies, Williams and Wake (2007) observed people who restrict access to knowledge (including mathematics) from others through their own knowledge or technical superiority, thereby exerting authority and control of data and effectively “black boxing” (p. 320) mathematical procedures. This black boxing of processes is described by Latour (1999) as:

the way scientific and technical work is made invisible by its own success. When a machine is run efficiently, when a matter of fact is settled, one needs focus only on its inputs and outputs and not on its internal complexity. Thus paradoxically, the more science and technology succeed, the more opaque they become (p. 304).

The black box is the machinery or settings with reliable inputs and trusted outputs (e.g. electricity through a wire) although most of its users do not need to have an understanding of the invisible mechanisms within (Damlamian, Rodrigues, & Sträßer, 2013). In the following examples of workplaces, there is evidence of several numeracy practices with many of them seemingly hidden from users. Of particular interest in this thesis are any visible and invisible estimation and spatial awareness events and practices.

2.5.3 Examples of numeracy in workplaces

A challenge for researchers investigating numeracy in workplaces, or in any cohort, is the respective perspectives of what numeracy might be. The slippery and elastic concepts mentioned previously (Coben, 2003; Doig, 2001) fall short when numeracy is considered as being equivalent to basic mathematics, or calculations. For instance, Smit and Mji (2012) present research about the numeracy levels of workers in mines. Workers were assessed on a paper test with mathematics questions set at different levels according to the adult basic education sector grades. According to Smit and Mji, only 1.2% of the 870 workers they assessed were considered to be numerate. Although the ultimate intention of the researchers is no doubt to promote numeracy assistance to mining staff, particularly for financial literacy, it seems difficult to accept that 98.8% of the staff cannot meet the quantitative demands of their own or their families' lives. Although financial aspects of numeracy are indeed important, there are other numeracy practices which remain hidden if people are not asked about what they do or even "to elicit the full range of problems that people have" (Bynner & Parsons, 2006, p. 10).

In the workplace studies of numeracy presented below, the researchers spent time beside people in their workplaces, interviewing and observing people about their activities. Accordingly, factors of numeracy beyond calculations emerge, including practices of estimation and spatial awareness. Each of these factors will be discussed toward the end of this chapter. The following workplace studies have been selected as each addresses a factor of estimation or spatial awareness. The workplaces described below include subjects and situations as diverse as milk processing plant workers (Scribner, 1985), apprentice boat builders (Zevenbergen & Zevenbergen, 2007),

carpenters (Millroy, 1991), carpet-layers (Masingila, 1994), and caterers in a marae (McMurchy-Pilkington, 1995). Other research studies briefly referred to include Saxe (1988), Beeli-Zimmerman (2011), and Mesquita (2002) as researchers of street sellers, Bardram and Hansen (2010) on hospital practices, Chase (1983) on taxi drivers, and Smith (1999) on automotive assembly workers. The sections on estimation and spatial awareness that follow also refer to workplaces.

In the earliest study listed above, Scribner (1985) and her colleagues observed and interviewed staff at a large dairy supply warehouse. One of the teams at the dairy is warehouse staff, who worked through the night filling orders before sending them through to despatch. On one particular task, Scribner and colleagues had quizzed all the staff about how they would classify certain products in the warehouse; in almost equal numbers, the warehouse team described products by type, or by size, or (more surprisingly to the researchers) by location. None of the other staff teams (e.g. office staff who took the orders) had classified the products by location. The researchers also observed how the warehouse staff assembled (or ‘picked’), then packed their orders. Working in pairs, the warehouse staff did not follow the product sequence as provided to them on the order forms, but mentally rearranged the list of products according to location, quantity and size. The rearrangement saved them distance and time while picking items. Scribner notes that “each assembler needed to have some internally represented knowledge of the spatial arrangement of the warehouse that could be used flexibly” (p. 206), in order to organise their picking plans. Using this rearranged sequence in the picking plans, Scribner (1985) observed that each warehouse pair picked over a thousand items each shift filling almost sixty orders, but importantly, saving themselves an approximate walking distance of around 2,500 feet each night.

In a boat building shed, Zevenbergen and Zevenbergen (2007) shadowed the work of a young boat builder, and some of his estimation choices. One task was to prepare a ‘bog’ mix to make adhesive. The two parts of the ‘bog’ mix, a catalyst hardener and a polyester filler, needed blending. Instead of using the manufacturer’s recommended ratio of 1% - 2% of catalyst to the filler, the young man estimated how much he would need by drawing a line near the edge of a large pile of the filler. He then added what he considered to be a suitable amount of catalyst and mixed it with the filler, taking into account other factors such as temperature and drying time. Zevenbergen and Zevenbergen (2007) described the young man’s estimation practice as effective, since he completed his set task according to the elements such as temperature and humidity,

in the situation. In an unrelated task, the young man imposed what the authors described as an aesthetic aspect to his work, ensuring that a door catch was located at the most functional height for an adult to open and close a door on the boat. He achieved this by using informal measures such as pencil lengths and finger widths in order to align the door catch with the straight edges of the door. As with the adhesive mixing, the young man's locating of the door catch illustrates how he again estimated, but this time with lengths. Importantly, not every practice at the boat-building workplace is as estimable. The furniture making in the next workplace also requires precision.

Millroy (1991) researched carpenters in a furniture-making company by becoming an apprentice joiner-carpenter. This enabled her to participate and observe any geometrical strategies and ideas the staff created in the furniture-making processes. As Millroy's joinery experiences grew, she was given more complicated projects to complete. On one occasion, Millroy was being instructed on how to draw a star on the lid of a box. The colleague, 'Jack', who modelled the four-pointed star on the lid, found that his drawing was not square; he compared his square rule with that of 'Mr. S', the factory foreman, and they found the two set squares differed slightly. Later, Millroy asked Mr. S and Jack, independently, how each could show how his square rule was indeed square. Mr. S placed his rule at the corner of a doorway, and checked the squareness of the doorway with a spirit level, thereby confirming that if the doorway corner was a right angle, then so was his square rule. Jack was unsure, and initially provided an incorrect approach. However, after questioning by Millroy, Jack returned with an improved model using a horizontal, then a vertical reflection strategy to show how a square rule could be precise. Millroy noted how each man "had developed *concrete problematics*" (author's italics, p.20), in order to explain geometrical ideas such as right angles, congruence, symmetry, parallel lines, and straightness.

Two other factors emerge from Millroy's (1991) study. Although Millroy suggests that the carpenters did not regard their work as being mathematical, each drew on his own extensive funds of knowledge (Moll *et al.*, 1992); further, the curiosity of the two men when responding to the square challenge was piqued especially with a competitive element present. Mr. S went further than Jack, by forming a right angle without using a square rule, showing Millroy how he instead could rely on gravity and the horizon. Jack withdrew from the challenge, seemingly satisfied that he had completed the task but also perhaps deferring to the authority of Mr S. This could be a subtle instance of the power relationship within the workplace.

In her workplace study, Masingila (1994) shadowed carpet estimators and installers. Masingila notes three “common threads” (p. 432) in research around mathematics practices of workplaces. Not only are problems embedded in contexts particular to the workplace, but the mathematics used is different from what is learned in school, and on occasions is more complex and uses higher levels of thinking. The mathematics practices Masingila observed in the laying of carpet included linear and angular measurements, as well as geometrical concepts such as symmetry, bisections of rectangular room lengths to locate the centre, arcs and tangents around protruding pipes, and a form of coordinate geometry across a floor. She also noted the estimators “rounding up to the nearest foot” (p. 440). One of the reasons given is the practice of ordering carpet in square yards whereas rooms were measured in square feet. Masingila asked an estimator, Dean, why he divided by nine, when converting from square feet to square yards. Although he was initially uncertain how to explain this, Dean eventually drew a picture to illustrate (see *Figure 2.1*) that the nine is derived from a three-foot-by-three-foot square, making one square yard.

Masingila (1994) notes that although Dean could not articulate what he understood of the conversion, his drawing (*Figure 2.1*) was sufficient to relay his understanding to her.

x	x	x
x	x	x
x	x	x

Figure 2.1 Dean’s explanation of the conversion from sq. ft. to sq. yds.

In an investigation of caterers in a marae kitchen, McMurchy-Pilkington (1995) observed proportional thinking, measuring, and estimating. In one catering episode, one of the respondents was describing how she prepared bread-and-steam puddings by judging how much flour in bucket-loads would be enough. However, this caterer was never entirely certain how many people would actually arrive for the meal, so she would use what the author described as an “IF-THEN inference . . . if a hundred turn up we will have enough, but if only sixty, then some left for tomorrow” (p. 39). In another instance, another caterer was making cheese sauce, slowly tipping milk into the mix by ‘feeling’ for the appropriate thickness through her stirring spoon. The judgement for

weight or consistency of the blend to decide how much milk was enough in the mix is another instance of estimation. There are parallels with Zevenbergen *et al.*'s (2007) study of the young boat builder and his 'bog' mixing task. At some point each person has to decide when sufficiency has been achieved, recognising that the blend is complete; this relies on their funds of knowledge (Moll *et al.*, 1992) about estimating to meet the demands of the particular task, and not to ruin what has already been blended.

These workplace situations occur so frequently that they often go unnoticed by the insiders, or practitioners, unless the situations are being specifically observed, then discussed with them. Although Milroy (1991) teased out the project she was working on, both men drew on their geometrical funds of knowledge (Moll *et al.*, 1992) which would not have been in evidence unless she had prompted each. Similarly, Masingila (1994) extracted Dean's understanding of a conversion through the use of a drawing. When Masingila asked another estimator, Jack, about a geometrical procedure he had undertaken, his response was "after you've done it for a while, you just get a feel for it" (p. 442). The young boat-builder whom Zevenbergen and Zevenbergen (2007) shadowed and the dairy warehouse staff surveyed by Scribner (1995) are all part of diverse teams whose practices include estimation or spatial awareness, or both. In McMurchy-Pilkington's marae study, at some point someone in the catering team would need to organise the setting out of tables, chairs, and utensils in the whare kai (dining hall at the marae), ensuring the spatial configuration could accommodate all the guests, at several sittings if required. In situations such as these, people may be unaware of their own spatial awareness.

The numeracy practices in workplaces may often be masked, and spatial awareness may be concealed as common sense. The next three studies illustrate the use of one of the components of spatial awareness, a sense of location. In Saxe's (1988) study of Brazilian children selling candy for instance, it was seen that the children often received assistance in setting prices for their street sales. Key spatial factors would be *where* (researcher's italics) the children set themselves up to sell their candy, if there are *prime selling locations* (researcher's italics), and whether each seller coordinated locations with other sellers. Similarly, Beeli-Zimmerman's (2011) study explores financial understandings of street sellers, this time adult street sellers in Nicaragua. Beeli-Zimmerman includes geographical and geometrical dimensions in her report of the women in the study as they refer to daily routines around the months in which they enjoyed the best sales, and the street grid system of their city in terms of compass points

and city blocks. Similarly, Mesquita's (2002) street children in São Paulo were uncannily aware of the city's layout and had what Mesquita describes as an "inner compass" (p. 388) in order to return 'home'.

Chase's research (1983) on taxi drivers also refers to a city grid system, and taxi drivers' knowledge of the layout of their city. In terms of spatial awareness, the taxi drivers' navigation skills draw on years of driving practices through parallel and different routes. With many expert drivers, as long as the relative locations in respective neighbourhoods of a start and a destination are known it was found that drivers could either generate the route "or fill it in as the driver goes along" (p.404). Arriving at this instinctive stage is contingent on individual driver experience and an almost global knowledge of the layout of a city and its major arterials, landmarks and points of egress.

In a survey of automotive assembly plants, Smith (1999) suggests that what employees learn in the workplace is due in no small part to how employers manage staff training, whether these people are employers or employees. Smith (1999) adds that it is too easy to blame the formal school sector for failing to create work-ready adults. However, he notes that spatial and geometric reasoning, so critical at several of the sites he visited, needs to have more deliberate teaching time within contexts for school students to experience. It should be remembered in some countries however, that children of school age are work-ready and earning money whether they attend school or not, so these children are unlikely to learn these practices at school anyway (e.g. Saxe's (1998) study of Brazilian children selling candy, and Mesquita's (2002) study of street children in São Paulo). Although there is more that could be done in the formal sector, including dialogue between the school and work sectors, Smith suggests that "it is employers who ultimately decide to seek (and pay) workers with skills (or not), use and develop those skills on the job (or not), and implement technology that makes strong or weak demands (or not)" (1999, p. 871)."

Critically, working adults have numeracy demands over and above those of work. For instance, Beeli-Zimmerman (2011) reports that the street-sellers in her study split their time "between work, their families and households, and sometimes evening school" (p. 40). The evening school is part of an arrangement between small business loan scheme organisers and the street-sellers, though Beeli-Zimmerman reports that some individuals prefer to manage their bookkeeping their own way even though the evening course included numeracy practices such as budgeting. Several sellers did not see how they

could integrate the outside skills learned in the small business course into their own practices.

Sometimes individual practices are followed which appear to bypass traditional or expected mathematical methods. Noss, Hoyles and Pozzi (2000) investigated aeroplane pilots and their numeracy practices. One event involved a pilot bringing an aircraft in to land on a runway at a bearing of 50 degrees, but then having to contend with a cross-wind at a bearing of 100 degrees and a velocity of thirteen knots. Because there are limits to the conditions in which pilots may land aircraft, quick calculations were performed by the pilots using an “angle off-the-nose of the plane” (p. 27), then relating this to a quadrant diagram and the allowable cross wind. In another instance, a pilot used an analogue watch face relating the proportion of the wind speed to give the cross wind with the angle off-the-nose of the plane. This strategy works for angles up to thirty degrees (since the sine function appears almost linear from 0° to 30°) though less accurate for larger angles. However, the pilots’ practices bypass the traditional vectors and trigonometric calculations which mathematicians might expect. The authors suggest that there is so much information pilots must deal with when approaching a runway that “they must be in a state of readiness” (Noss *et al.*, p. 28) to contend with any control tower information and flight decisions which must be made quickly and accurately.

It is also important to note that what might be perceived as individual practices often contribute to a larger practice. For instance, in Bardram’s and Hansen’s study of hospital clinicians (2010), they focus on four “context-based workplace awareness dimensions” (p. 3): social awareness, temporal awareness, spatial awareness, and activity awareness. It is likely that several times a day, all four awareness dimensions coincide with the same work practice, or patient. Hospital workplace practices differ from other workplaces however, in the often rapid change in demands and the need to prioritise incoming emergencies. In one example, a doctor checked on a patient during her morning rounds, then after receiving lab reports and X-rays, conferred with a senior colleague and was able to schedule an operation on the patient in the afternoon. The information about the patient’s status and the conference with the colleague drove the doctor’s decision-making about when and where to schedule the surgery.

2.5.4 Summary of workplace numeracy

These workplace examples illustrate the often complex interrelated nature of workplace practices, with embedded almost subliminal numeracy practices and awarenesses being drawn on as and when required. In particular the focus has been on workplace

estimations and awareness of space. Estimation examples included the mixing of quantities, the judgement of heights, and the purchase of carpet lengths to the nearest yard. Spatial awareness included determining city locations with and without mapping, using warehouse layout of product placements to fill an order, placing a symmetrical design on a lid, checking how square a tool was, and being able to visualise a three-dimensional motor vehicle part on a two-dimensional plan. These diverse situations illustrate the tacit knowledge of people who use mathematics at work, often failing to recognize their own mathematical competence during work (Wedegge, 2002).

In chapter four, the work of recycling and refuse operators will be described. These operators work individually in their vehicles while being part of a larger workforce or joint enterprise (Wenger, 1998), and they share some of the estimation and spatial awareness factors described above. As will be shown, their workplaces also have overt and hidden examples of estimation and spatial awareness.

2.6 Estimation in workplaces

In the previous section, estimates of quantities, locations, and space were presented. These practices may be based on observations and experiences of past and present activities, for instance cooking, playing sport, and travelling. In this understanding, estimation is also a part of numeracy as situated social practice, across diverse workplace contexts (Hoyles *et al.*, 2002) and across age groups (Siegler & Booth, 2005). Estimation is pervasive and according to Siegler and Booth (2005) probably goes beyond other fundamental quantitative abilities. Estimation draws on knowledge of a range of strategies involving time and distance, and concepts such as currency exchange rates and other proportional situations. Adams and Harrell (2010) define estimation as a strategy which provides answers that are close enough to enable good decision-making, but are not reliant on extensive time-laden calculations. Siegler and Booth (2005) suggest that during the process of estimating, when comparing quantities that “at least one ... is inexact” (p. 198). So by knowing that two cities are 84 kilometres apart, a driver can estimate his or her open-road speed (100 kilometres per hour) will result in a journey between the two cities taking slightly less than an hour.

2.6.1 Categories of estimation

Siegler and Booth (2005) divide estimation into two categories. First, numerical estimation involves estimation “in which one or both sides of the translation involve numbers” (p. 198). So the target is not an exact answer, rather a number with the correct

magnitude. Furthermore, Siegler and Booth split numerical estimation into computational, numerosity, and number line estimation. Computational estimation is described as performing a calculation, not to get an exact answer, but to approximate a number within the same magnitude as the exact answer. Numerosity estimation is “assigning a number to a set of discrete objects” (Siegler & Booth, p. 204), such as guessing the number of jelly beans in a jar competition or estimating how many people attended a rugby test match. Number line estimation involves translating “numbers into positions on number lines” (Siegler & Booth, p. 207) which improves steadily with formal education. As discussed earlier, Dehaene (2009) describes how, on a number line, pre-school children place small numbers on the left and large numbers on the right.

Second, non-numerical estimation is a shift away from numerical representations (Siegler & Booth, 2005), and does not appear in the literature as commonly as numerical estimation. The instances of this kind of estimation seem at times to be influenced by natural phenomena or idiosyncratic strategies in this fashion. Adams and Harrell (2010) provide some examples of people who estimate based on local knowledge. A farmer could not plant peanuts until the ground temperature was about 65° Fahrenheit. However, if a cold front was imminent he would delay planting, making this decision without looking at the numbers, relying on what he knew about local temperatures and conditions. A second example Adams and Harrell (2010) describe is the experience of a mechanic who judges tyre treads by using an American penny; if the mechanic placed the upright penny into the tyre tread and could “see all of Lincoln’s head then you have less than 3 / 32 of an inch and your tire is worn out” (p. 12).

Adams and Harrell (2010) suggest there are several key points from their observations and interviews. First, the people who estimate have spent a lot of their time gaining experiences and comparing true measurement units in order to set any useful estimation benchmarks. A second point is that local and particular factors impact on their situations (e.g. weather events, soil temperatures). Third, exercising body parts such as pacing out a length is quite common for estimating yards or metres. Fourth, some estimates may need to be much closer to a true quantity than others. The secondary mathematics teachers who observed people at several Australian industrial workplaces (Hogan & Morony, 2000) remarked how contexts drive accuracy. Whereas one work site had what one teacher described as “very liberal tolerances” (p. 110), another workplace used figures rounded to several decimal places. A fifth point made by Adams and Harrell (2010) is related to the first, with cultural and personal influences such as the farmer’s

father advising his son about planting conditions. The sixth and final point suggested by Adams and Harrell is that people have access to informal tools or artefacts which assist them to estimate, such as the penny used to check the tyre tread.

2.6.2 Reasons for estimating

The ability of people to estimate is relied upon extensively in industrial and commercial situations (Cockcroft Report, 1982; Hoyles *et al.*, 2002, FitzSimons, 2005). In a survey of people who apply estimation processes across many occupations, Adams and Harrell (2003) state the main reason given in the survey is that it saves time. A related reason is that there are times where it is simply impractical to measure everything. Investigating estimation more closely two factors seem critical. The first factor is the element of reasonableness, the knowledge that a measurement taken or a calculation made ‘feels correct’. With this ability workplace errors may be avoided or if made, then speedily detected and minimised appropriately. Hoyles *et al.* (2002) suggest this is particularly critical if the equipment is damaged or unfit to provide measures. In one of their workplace examples a length needed to be measured and the complexity of the situation meant that the computer programme designed for similar tasks was unable to complete this task. The technician who carried out the measurement used trigonometry to find the answer, and he asserted that he was certain his calculation was correct because he had a reasonable idea of what the answer should have been anyway.

The ability to anticipate a quantity is common across seemingly diverse industries. Hoyles *et al.* (2002) describe how financial services staff can almost immediately detect if an implausible number is in the calculation. Seeing and fixing errors along with being able to work out why errors occur is part of an everyday workload. The most frequent reasons for such errors is an inputting error somewhere or a change in a formula or rule that has yet to be communicated (Hoyles *et al.*, 2002). If the incorrect figure is in a financial services document, then it is expected to be readily amended. However, if the incorrect quantity is in a chemical spray mix (FitzSimons, Mlcek, Hull, & Wright, 2005), the consequences can be dire. That wrong spray mix may leave the ground toxic and uncultivable for some time. Errors may also be noticed by visual recognition; in one instance a numeracy tutor informed the author about a local farmer halting a fertiliser being applied to his land because he noticed the load was a different colour to his usual fertiliser. The fertiliser company analysed the load and discovered one of the components was in the wrong proportion. In a manufacturing situation, a second tutor reported that almost a kilometre of plastic spouting was extruded in the wrong

proportions of recycled and raw material. The spouting would have broken down in the sunlight within a couple of years. The error was noticed by someone recognising a streakiness in the spouting colour.

These sighting checks reflect “the ability to make subjective judgements about a variety of measures,[. . .] in situations in which measurement is difficult or awkward, in which trial and error is possible, or in which tolerances are large” (Hoyles *et al.*, 2002, pp. 22-23). These kinds of practices take time to develop on the job as employees become more familiar with which quality ranges are permissible in their industry. According to the Cockcroft Report (1982), new employees may not have a feel for the numbers and quantities in their employment situations, or in the above cases, the correct hues. However, as Smith (1995) noted earlier in Section 2.5, employers train newcomers to their industry standards. It is unlikely that being exposed to mathematical concepts during prior school learning episodes automatically guarantees a direct transfer over to new situations (Noss, 1998; Wedege, 2002).

In Kelly’s and Arnold’s (1994) survey of workplaces to determine what mathematics was in use by employees, estimating (sizes and quantities), approximating, and anticipating some errors, were practised by over half of those surveyed (p.230). More recently, the (United States) Secretary's Commission on Achieving Necessary Skills Report (SCANS, 2000) suggests that estimation is an underpinning practice for work competencies and for any situations which require approximate answers. The SCANS Report states that people need to be able to "summarize information, set upper and lower limits and estimate if it falls within acceptable range, understand precision both as consumer and producer, estimate time and costs, troubleshoot and anticipate consequences" (p.37). There is an economic message when the authors suggest that comparing American workers to a more educated workforce overseas, “you are wasting much more on rework, poor quality, and late deliveries than are your competitors” (p. ix). So not being able to estimate in order to amend a practice in motion has consequences in terms of time, quality, money and output.

2.6.3 Estimation needs of school learners and out-of-school workers

LeFevre, Greenham, and Waheed (2009) dispute how much teaching time should be devoted to estimation particularly as computational estimation may be replaced by calculator checking. Instead the authors suggest that knowledge of place value and simple arithmetic would for instance amend errors with too many zeroes. LeFevre *et al.* (2009) also intimate that if people have managed to go this far in life without needing to

estimate then perhaps for them it was not as useful a set of competences to grasp. LeFevre *et al.* suggest that teaching time would be better spent on conceptual skills around number sense, and ultimately estimation would have a sounder base; also teaching students when to estimate is a more appropriate action. Although LeFevre *et al.*'s suggestion seems to be sound in concentrating on conceptual skills so that estimation will have a useful base, there is also the thought that people who have left school without those skills may be unable to estimate and have become used to avoiding any estimation practices.

In contrast, workplace studies are sprinkled with stories of wider senses of estimation, sometimes “sacrificing precision for convenience” (Gal, 1999, p. 11). While previous studies have investigated numeracy practices in these different domains, few mention estimation *and* spatial sense (e.g., Masingila, 1994; Smith, 1999; Chase, 1983). Chase's (1983) research on taxi drivers in the previous section differs since spatial awareness and estimation questions are included such as giving an estimate of distances. Chase reports that only twenty percent of the drivers surveyed tended to overestimate distances in the same neighbourhood, although distances between locations in adjacent neighbourhoods were almost all overestimated. The overestimation of distance is greatest when a physical barrier such as a river or a park lies between neighbourhoods. Chase states that the taxi drivers do not appear to have a mental map of their city, rather a set of driving experiences and an extensive familiarity with major landmarks.

Although psychology and neuroscience are beyond the scope of this thesis, some results from research in those domains helps to provide background to the speeds at which people estimate. For instance, overestimation and underestimation are of interest to psychologists and learning scientists. Jou, Leka, Rogers, and Matus (2004) observed what happens when people make estimates of physical magnitudes. Respondents' judgements show an overestimation for small physical magnitudes and an underestimation for larger physical magnitudes. Butterworth and Varma (2014) report on the “distance effect” (p. 207) which holds that when two numbers are being compared, the larger the difference between the two numbers the quicker the time taken to respond. A second effect reported by Butterworth and Varma is the “problem size effect” (p. 207) which states that if the two numbers are relatively large, then it takes longer to provide an answer (e.g. $8 + 9$ takes longer to work out than $3 + 5$) and that answer is generally less accurate. Adults may retrieve facts to solve smaller problems,

but larger problems involve them counting or breaking the numbers down into more manageable numbers to manipulate (de Smedt, Holloway, & Ansari, 2011).

2.6.4 Summary of estimation in workplaces

Estimation is pervasive and goes beyond other fundamental quantitative abilities. In workplaces, estimation practices often appear as tacit knowledge by tradespeople. The young boat-builder judged the height of the cabin door handle as well as the constituents of the bog mix. Carpet layers and estimators buy carpet in full yards and although exact dimensions of a floor assist an estimator, they must still convert from square feet to square yards. In other instances, precision is required such as the dairy workers picking the correct stock and quantities for their customers, and the carpenters' designs on box lids ensuring everything is symmetrical. The appropriateness of the accuracy depends on the demands of the context. A good estimator may recognise when it is appropriate to make estimates during a task, or at the least to recognise when a quantity is awry. Diverse occupations such as taxi drivers, carpet layers and caterers recognise when measuring is simply impractical, and they make educated estimates based on experience of benchmarks or landmarks developed over time.

2.7 Spatial Awareness in the workplace

Everyday instances of spatial awareness include manoeuvring shopping trolleys, locating an empty seat on a bus when boarding, or instructing a 16-year old how to carry out a three-point turn in a car driving lesson. In each instance, the use of space is integrated in the activity, almost imperceptible in order to complete the task. However, when spatial words or phrases are drawn from these situations, (manoeuvring, where, approaching) the evidence of our reliance on space and position in these activities becomes clear. These common words and phrases are indicators of how ingrained spatial awareness is since each has some connotation with space or positioning, or proxemics (Clancy, 2005). Ironically, when children begin school their space and movement is usually contained and "it requires constraint and immobility never asked of them before" (Bruner, 1966, p. 114).

The range and quantity of spatial experiences which adults encounter might initially surprise. In working situations for instance, such as commercial driving, those abilities contribute to having to make immediate spatial decisions, perhaps having enough width when in a street of parked cars, or being in the right location. Clearly this is not just

about calculating, expanding earlier concepts of numeracy (Wedegge, Benn, & Maas, 1999) that seemed to be about mastery of basic facts and arithmetic skills.

2.7.1 The kinds of space

People negotiate spaces by moving their bodies, or tools, as in the everyday examples discussed in section 2.5. Tversky (2005) suggests there are four spaces which have functions for people. Tversky calls these spaces:

- the space of the body;
- the space around the body;
- the space of exploration; and
- the space of depictions (p.2).

The *space of the body* (original italics) is a person's knowledge of what their own body, and its parts may do, and how these may be moved to accomplish tasks. This space also allows someone to recognise what another person is doing with their body.

The second space is the *space around our own body* (original italics) which Tversky writes is our earliest "arena for learning about the world" (p.6) and how we might then act in the nearby arena to accomplish tasks. A model known as the "Spatial Framework Theory" (Tversky, 2005, p.7) refers to how a person recalls where objects around their body are located, corresponding to the three dimensions or axes – head to foot, front to back, and left to right. The framework enables a person to localize objects around him or her, then retrieve the object if desired; however, people and objects often shift, (or change space) so the person will revise their perspective of the space and the location of the object.

The *space of exploration, or navigation* (original italics) is the third functional space, and this is a far larger zone than either of the first two spaces. Other sources of information may need to be elicited, such as directions, using maps and diagrams, or even recalling landmarks en route. These different sources of spatial information may need to be integrated. This integration can often seem relatively unorganised, especially when someone is giving directions, and they perhaps draw on experiences of scales, bearings, and distances. Tversky suggests situations such as these, sometimes with mind changes, repetition, and errors seems more like a "*cognitive collage* than a cognitive map, a consequence of incomplete and fragmented mental mapping" (original italics, p.12). One way to meet this challenge is by securing frames of reference such as nearby

landmarks or contours, or other readily identifiable features. A common landmark is our own home, a familiarly stable landmark for most.

Tversky's (2005) final functional space is *the space of depictions or external representations* (original italics) where invented tools or practices assist people to record and represent "inherently spatial relations, as in maps and architectural drawings, and . . . flow diagrams" (p.16). Smith's (1999) study of automotive workers reports that in engineering related trades, the ability to translate two-dimensional plans in three-dimensional space is critical. A key element of this functional space is the freeing up of a person's mind by "offloading memory and computation" (Tversky, 2005, p.16), thereby augmenting human cognition; some computation will be required though if one must use the scale on a map, or the numbers on a distance chart, to estimate a time of arrival at a destination. There are limitations to the use of these external representations, not least human inexperience or lack of confidence to use the representations.

2.7.2 Components of spatial awareness

Spatial awareness and spatial ability are contestable terms and challenging to define. Researchers such as Gardner (1993) and Hegarty (2010) suggest that spatial intelligence is a more suitable overarching concept. These terms have emanated from decades of psychological and psychometric ability assessments including spatial ability testing. However, according to Hegarty (2010) and Hegarty and Waller (2005) many of the tests that have been developed specifically assess certain abilities. After investigating factor-analytic approaches and cognitive analyses of performances on particular spatial ability tests, Hegarty and Waller (2005) claim that much of the testing for spatial abilities is unsystematic and does not account for individual differences of spatial awareness, or the natural variation in people's abilities.

A key early division of what might be considered closely related concepts is the differentiation between visual imagery and spatial imagery (Hegarty & Kozhevnikov, 1999). In their discussion of visuospatial working memory, Logie and Della Sala (2005) carefully distinguish between the two concepts, visual versus spatial, in this description:

By visual we refer to the visual appearance of an object or scene, its colour, shape, contrast, size, visual texture, and the location of objects relative to one another with respect to a particular viewpoint in a static array. By spatial we refer to pathways or sequences of movements from one location to another in the scene, or the processes of change in the perceived relative locations of objects that occur when an observer moves (physically or in a mental image) from one viewpoint to another (p.85).

Logie and Della Sala (2005) agree that descriptions of the term, spatial, are variable and ambiguous, and that some definitions include location and layout. However with their definitions above, they are firmly directing spatial practices towards “the dynamic properties of a scene or representation” (p.84).

Hegarty and Waller (2005) suggest that spatial abilities should include “spatial visualization, flexibility of closure, spatial memory, and perceptual speed” (p.159). Sutton and Williams (2007) claim that spatial ability should include how objects are mentally rotated alongside the ability to see “objects appearing at different angles and . . . how objects relate to each other in space” (p.3). Donohue (2010) adds a fourth related point around spatial ability, adding that a grasp of three dimensions (3D) is essential for spatial ability. This is especially important when people attempt to read two-dimensional plans and maps which represent three-dimensions.

More recently, Hegarty (2010) has explored how experts from medicine, meteorology and stereochemistry exhibit their spatial awareness. Hegarty argues that traditional psychometric tests that measure many of the spatial abilities in the previous paragraph, fall short of matching the spatial needs of people working in the above domains and accordingly she suggests two main components of spatial intelligence. The first component is having a flexible choice of strategies with an ability to construct and transform mental images accompanied by analytic thinking. Secondly, Hegarty (2010) suggests that experts use “meta-representational competence” (p. 293) and she divides this in two related parts. In the first part experts apply “optimal external representation for a task” (p. 293). An example would be where images from ultrasound equipment can support medical teams to make decisions. In the second part of the second component, Hegarty provides the example of software for medical students used to rotate three-dimensional anatomical objects. Hegarty describes this as engaging with “novel external representations” (p. 293), although she suggests that there are clear differences in individuals’ abilities. There are implications for spatial learning, not the least of which is more practice with analytic thinking to support mental imaging, and in some instances for analytic learning to override mental imagery.

There are people able to utilise physical space more deliberately to complete tasks in their time at work. They often use machinery which seems to extend their own space prosthetically, moving their influence beyond their own position as a task requires. Again, however, it is often unnoticed by people when listing numeracy factors (Marr &

Hagston, 2007). This concealment is discussed in Chapter Five with the collection operators' work.

2.7.3 Mapping and Locating

Not every person can use the three-dimensional imaging software described by Hegarty in the previous section, or can operate machinery. Many people believe that a sense of space involves a sense of direction (Kozlowski & Bryant, 1977). In three experiments around their college campus, Kozlowski & Bryant invited students to first rate their own sense of direction. They found that students who rated themselves with having a good sense of direction seemed intrinsically motivated to improve those abilities, whereas those who rated themselves as having poor senses of direction seemed to act in a way that made this rating ultimately self-fulfilling.

Location and layout also feature in maps and plans – these instruments are “not learned in a vacuum” (Taylor 2005, p.319); there is always a purpose when people read maps or plans. This association with an object at a location is something that Schulman (1983) describes as “‘whatnesses’ entailing ‘wherenesses’” (p.360). The sense of navigation, or designing movement for some purpose (Montello, 2005) requires drivers or travellers to remain focused on, or oriented to, their target destinations. Orientation is usually reliant on some partially known reference system – partially known because although the reference system is related to something, it may only be approximate.

Some maps have street grids and as an example of an interpretive framework, these provide one of two possible effects (Taylor, 2005). The first effect is as a distractor, where a reader gets lost with the information in front of them with the street pattern distracting their attention. The second effect is more supportive, enabling a reader to relate two or more locations and any distances between them. So a reader may find one place and then use the street grid system to plan more than one route to a destination. In section 2.5, Chase (1983) described taxi drivers being able to use their knowledge of landmarks, parallel streets and arterial roads in order to generate a route during their journeys. Taylor (2005) writes “the reason for learning a map influences what is represented in memory” (p.321), and as Tversky (2005) notes, remembering map features may eventually free up working memory.

However, there are still challenges to a map reader's memory, with information occasionally becoming distorted. For instance, an individual's prior experiences of an area, or their scheme of a layout is threatened when either their alignment or their

rotation (Tversky, 1981, 1993) are awry. The alignment is threatened if they believe that one landmark is more vertically (or horizontally) aligned with another feature. In one survey (Tversky, 1981, 1993) people were asked which of the two cities, Boston or Rio de Janeiro, is further east. Though most respondents chose Boston, the opposite is true. Tversky writes that the respondents had mentally aligned South America directly below North America. In fact, the South American continental landmass is predominantly eastward of the North American continental landmass. The rotation heuristic is brought about by resetting a landmark more in line with the edge of a map or the points of the compass, or some other convenient frame of reference.

With the possibility of distortion and misjudgement in what people may recall when organising their own mental or cognitive maps, Taylor (2005) suggests that there are two contributions to this process. The first she calls “spatial information, (which) includes the relative and coordinate locations of landmarks” (p.317). The second contribution, Taylor (2005) suggests is often overlooked; “temporal information involves the order the landmarks are examined” (p.317), and this is often manifested in workplaces. For instance, in Bardram’s and Hansen’s (2010) study of hospital clinicians from section 2.5, the doctor who was planning to operate on her patient awaited lab reports and X-rays, then arranged a conference in an office with a senior colleague. The landmarks in the clinician’s case are more likely key checkpoints in her daily schedule on track to operate on her patient.

Clements (1999) suggests that very simple maps may be learned and used even by pre-school children. Clements provides an example “when challenged to learn a route through a (six- room) playhouse, four-year-olds who examined a map beforehand learned a route more quickly than those who did not” (p.42). Clements adds that these children quickly grasped the layout of the house plan, and in particular the best route through the house. Many adults might still get a feel for the layout of a map or plan by running a finger over the diagram, from one place to another in sequence. Route finding and mapping are everyday aspects of spatial awareness that may be introduced at surprisingly early ages.

2.7.4 Geometry

Although the formal teaching of spaces and shapes or geometry resides in the school sector (Clements, 1999), school is not the only source of spatial or even mathematical knowledge and practices (Scribner & Cole, 1973; Lave, 1997). Goldenberg (1999) believes that geometry holds a special place in mathematical topics; not only does

geometry have deep connections to other themes in mathematics (e.g. analytical geometry connects coordinate geometry to algebra), but geometry is one of the few strands in mathematics which may be introduced independently of the others. However, Bessot (2000) asserts that as geometry has developed into a more theoretical domain it almost appears that geometry “has broken with its spatial origins” (p. 143).

Traditional geometries from other cultures are reminders of spatial and practical origins. Gerdes (1988) describes geometrical forms within floor mats, pots, baskets and dwellings in Mozambique. Critically the design and form of these is the result of finding the most efficient shape for purpose, as Gerdes (1988) explains:

It came out that the form of these objects is almost never arbitrary, but generally represents many practical advantages and is, quite a lot of times, the only possible or optimal solution of a production problem. The traditional form reflects accumulated wisdom . . . also mathematical knowledge, knowledge about the properties and relations of circles, angles, rectangles . . . (p. 140).

Referring to a situation with informal mapping, Gardner (1993) describes how Inuit hunters are somehow able to find their way through terrain with what appeared to outsiders to have no visual landmarks, except for remembering what seemed barely noticeable “visual configurations” (p. 184). Pinxten (1991) presents ideas from the accumulated wisdom of Navajo culture, in particular the spatial language of Navajo, where he uncovered a complex interconnected structure with very “culture-specific spatial representations” (p. 48).

Although formalised curricula of geometry may sometimes appear to be less spatially oriented, for young children the learning of geometrical ideas is still predominantly spatial (Clements, 1999). According to Clements and Battista (1992) learning geometry should begin at a much earlier age so the challenge for teachers of mathematics is to relate their students’ spatial experiences to the study of geometry (Hunter, Kotsopoulos, and Whitely, 2007). Perhaps the sense of space falls into the unnoticed category where concepts and skills are called upon as the need arises. A parallel observation by Borovik and Gardiner (2007) is that there are almost dormant unnoticed mathematical abilities of some children, unseen by both “the child and his or her teachers” (p.2). School based learning still underpins much of what we learn and use later and in some instances may ignore a child’s earliest funds of knowledge (Moll *et al.*, 1992).

Many adults need to be continually exposed to spatial and geometrical reasoning (Smith, 1999) through maps, plans, sketches or graphs. Adolescents could also be provided with instances of spatial language with power and political perspectives: the labelling of

political positions, such as left and right or central and marginal may be observed as dominant discourses describing alternative perspectives. Children become more familiar with shapes and their attributes such as heights, widths, and depths, when they imagine where an object fits. This fitting skill remains an important lifelong and for some an intuitive practice that adults in many occupations must contend with. As discussed (Fujita *et al.*, 2004) there is scope to promote geometrical intuition into geometry learning.

2.7.4.1 *The Van Hiele Model of Geometrical Thinking*

In the 1950s, Pierre and Dina van Hiele responded to geometrical challenges facing their middle-school learners by creating a framework of geometrical understanding (van Hiele, 1986; Crowley, 1987).

Table 2.1. van Hiele Levels of Geometric Thinking

Level	Name of Level	What a learner is able to do at this level
1 (prev. 0)	Visual	A learner can identify, name, compare, and manipulate geometric shapes. However, shape properties are yet to be recognized.
2	Analysis	Learners can appreciate the attributes of shapes, recognizing properties of the shapes, and develop the appropriate vocabulary. A learner begins to develop straightforward rules.
3	Informal Deduction	Using understandings from earlier levels, a learner begins to generalize about those shapes, using the formed rules, and shapes and properties. In the process, the learner develops informal deductive language (e.g. if – then), recognizes some converses, and can validate generalizations.
4	Deduction	Theorems are proved deductively by learners, and there is the understanding of an underlying structure of the systems of geometry (as in senior secondary school years).
5 (prev. 4)	Rigour	Learners establish geometrical theorems and can analyse postulates deductively, typically beyond school level.

Instead of waiting for students to mature to a certain age, the van Hieles believed that students would develop understandings and geometrical reasoning through careful instruction and experiences. The van Hieles postulated that learners progress through increasingly complex levels of geometrical thought, starting from a more holistic visual

level (Level 1 – see Table 2.1 above) through to more sophisticated levels. The five cognitive levels created have since become known as the Van Hiele levels (the original levels were numbered 0, 1, 2, 3, & 4).

Some workplaces appear to ‘flirt’ with geometry and the van Hiele levels of geometrical thinking. During a numeracy workshop, the researcher worked with horticultural and arborist tutors. One of the arborist tutors described how he showed trainees to use a straight stick (S) to work out the height of a tree (T), so that when the tree was felled he could get a reliable estimate of how far the top of the tree would fall from its base. The trainees were expected to convert the height of the tree into a distance along the ground (see *Figure 2.2* below), so that the ground could be cleared of anything in the path of the falling tree. When the arborist modelled the lengths and distances involved, it was evident that he was applying knowledge of similar triangles. He walked backwards, away from the tree, until he could see that the top of the stick was aligned with the top of the tree.

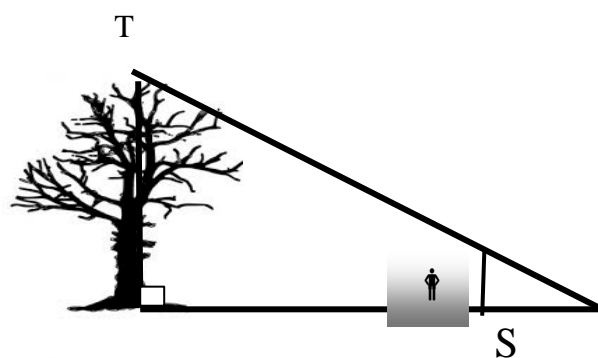


Figure 2.2 Arborist’s estimation of the distance a toppled tree would reach

Tree image from Google Images and <http://all-free-download.com/free-vector/vector-tree-silhouette.html>

The tree to be felled was the height of the larger similar triangle while the upright stick he was holding at waist-height corresponded to the height of the smaller similar triangle. The arborist would then retreat a ‘few more steps’ away from the base of the tree in order to allow for any bounce or slide by the tree once it meets the ground.

This situation appears to draw from at least two of the levels of the van Hiele levels. A challenge with the van Hiele levels is where to locate someone’s current level of understanding if that person moves or oscillates from one level to another. Burger and Shaughnessy (1986) decided that the levels are not set; rather they are dynamic in nature. Shaughnessy and Burger (1985) also suggest that students struggle with formal geometry, and therefore should be exposed to many more experiences of informal

geometry such as the tree-felling example above. There is also scope in analytical geometry to explore graphing opportunities, particularly with the software that is now available (e.g. DESMOS), as well as investigating a relatively accessible (to school students) non-Euclidean geometry such as taxi-cab geometry (Reynolds, 1980; Reinhardt, 2003).

2.7.5 Learning how to be spatial

Directional language is one of several key factors which very young children need to experience. Scaffolding by parents and other older relatives helps to build familiarity with directions and locating. Freudenthal (1973) suggests “geometry is about grasping space ... the space in which the child lives, breathes and moves” (p.403). So providing manipulative experiences with toys, jigsaws, and climbing zones enable young learners to explore how things fit, or do not fit together. By combining these activities, young children will begin to make connections between the living and imagined spatial worlds.

With older children however, Hershkowitz (1998) cautions against the presupposition that all the necessary thinking and understanding factors are in place, ready and waiting for a user to ignite, suggesting otherwise that visual thinking is not such an automatic factor. “It could be that the mathematics education community is making the naïve assumption that human beings are born with visual thinking abilities which are applied when needed, and therefore nothing needs to be done to nurture or develop them” (p. 33).

Challenging learners to think spatially about what they are expected to learn is not a straightforward task. Furthermore, although training may assist a learner to improve their spatial ability in one domain that same training does not necessarily provide similar proficiency in another spatial domain (Wright, Thompson, Ganis, Newcombe, & Kosslyn, 2008). Sorby (2003) speaks of engineering training and the need not to assume what spatial awareness people have, and to be more proactive with encouraging those skill sets:

Most engineering faculty have highly developed 3-D spatial skills and may not understand that others may be struggling with a topic they find easy . . . They may not believe that spatial skills can be improved through practice falsely believing that this particular skill is one that a person is either born with or not. (p.478).

Like Sorby (2003; 2009), Blasko and Holliday-Darr (2010) have deliberately targeted first-year engineering students in their university who may struggle with the spatial demands of the engineering graphics and solid modelling course. Every student has to

attempt a pre-course battery of spatial skills questions. Those students who score under sixty percent are invited onto a supplemental low credit-bearing course specifically designed to develop their spatial skills, during a weekly two-hour session in a computer laboratory. According to Blasko and Holliday-Darr (2010), when the students who had previously struggled with certain spatial skills and who had received extra instruction were reassessed with a post-test similar to the pre-test, they improved their spatial performances significantly. They had superior retention to those who struggled and did not undertake the extra course. In contrast, a control group who were pre- and post-tested with the same assessments but had no extra instruction, showed no significant improvement in their spatial skills.

Clearly, deliberate targeting of spatial skills can assist people to capture visuo-spatial practices which are critical for subjects with high graphic content (Blasko & Holliday-Darr, 2010). For example, Sharp and Zachary (2004) advocate that their mechanical engineering students should approach engineering diagrams through van Hiele levels before the students apply calculation to the engineering problem. In some other (non-engineering) occupations, employers invite prospective employees to undertake psychometric tests, and a market has developed for training resources to prepare for these tests. For example, Wiesen's (2003) resource prepares candidates for the spatial components of psychometric testing. Wiesen's introduction claims that "spatial ability tests measure your ability to think about how flat and solid objects can be rotated, put together, turned over, and folded" (p.1). Although it might seem that there are variations in the way people are spatially aware in much the same way as someone has 'an ear for music', it would seem that spatial skills need to be deliberately introduced, modelled and practised. Targeting these skills has been shown (Blasko *et al.*, 2010) to enhance the spatial thinking abilities of those who are under-prepared or not naturally inclined to this kind of reasoning.

Sorby (2003) reminds us that having a sense of space is not a unitary construct but has several elements. It has been demonstrated that deliberate teaching of spatial skills in particular, can be effective in tertiary course preparation. Early childhood educators suggest that many of the issues that adolescents and adults might have with spatial issues could be intercepted and ameliorated if children are provided with enough opportunities with spatial stimuli at very early ages (Clements, 1999).

Gee (2005) introduces the use of video games for learning, and suggests that one of their many useful features is the feeling of authority as the controls are manipulated

some distance from the virtual world of the game. So users feel as if they are expanding their own space, “empower[ing] them [as they are able to] manipulate powerful tools in intricate ways that extend their areas of effectiveness” (p.8). The time spent on task may be aided by contextual thinking around gaming where strategies (including spatial), language, and other factors amalgamate. As Clements and Battista (1992) have noted the younger a learner is exposed to spatial strategies, be it chess or play, the better prepared they are for later spatial experiences.

2.7.6 Summary of spatial awareness

This section has described how spatial awareness is used in a number of diverse cultures and workplaces. There are several aspects to spatial ability although many appear to parallel what is tested in psychometric and spatial ability tests. Gardner (1993) invokes many capacities for spatial intelligence such as working with mental imagery and not only being able to recognise a transformed image, but also being able to mentally transform an image. Hegarty (2010) suggests that there are two components of spatial intelligence. The first is having a flexible choice of strategies to construct and transform mental images, with appropriate analytic thinking skills. The second is being competent with meta-representations of images. This includes the ability to identify the novel features of a representation. As new software emerges, images may be viewed in more accessible and dynamic presentations.

Sorby (2009) states that faculty and other trainers cannot expect every new learner to have the same spatial awareness that experts possess, especially when these novices are being compared to trained engineers and their funds of knowledge (Moll *et al.*, 1992). Other occupations also have spatial experiences (e.g. taxi drivers) which assist them to make spatial decisions about routes or critical paths, and locations. Clearly, providing learners with spatial experiences geometrically or otherwise is a step forward, although as Wright *et al.* (2008) note, one spatial competence may not translate to others. Using outside geometry like the arborists do when tree-felling is an invitation to investigate larger spaces, while the increasing use of imaging equipment for leisure (Gee, 2005) and also in workplaces provides a modern prosthetic opportunity to engage spatially.

2.8 Situating the current study

This chapter began with a discussion of situated activity and how this might be relevant to learning. Following this an exploration of definitions of numeracy, numerate behaviour and the relationship with mathematical practices was presented. In earlier times, mathematics has been considered a “universal essence, independent of context, and not subject to interpretation” (Evans & Tsatsaroni, 2000, p.57). Mathematics taught in schools has become generalised as the subject attempts to accommodate a wide set of ideas and rules. This has led to many people having to endure mystifying learning experiences with mathematics, and leaving a few with variable degrees of mathematics anxiety. On the other hand, numeracy has managed to maintain its everyday presence in very diverse situations, and although numeracy does not climb the abstract peaks that students of pure mathematics ascend, the contexts that numeracy is embedded within are surprisingly complex and diverse. Numeracy is very situation-specific and the local mathematics being used in a situation may not map easily onto a school curriculum (Resnick, 1987).

This is largely because numeracy in workplaces, communities and societies has evolved from events and conversations between people, and from human values and behaviours, within many everyday activities. Despite the pervasiveness of numeracy practices, numeracy itself goes unnoticed by many of its users. In a social practices perspective, however, there are hierarchical, temporal, political, and power (Valero, 2013) factors that are attached to numeracy and literacy, which underscore their ideological bases. Numeracy in the workplace in particular is hierarchical; the growing technological demands in workplaces may be met in part by the use of higher mathematics. Numeracy is also expected to increase with the need to operate new technology, read and interpret output data and monitor quality within tolerances. However, technology may also be stripping some of the work demands and more standard numeracy activities from workers (Noss, 1998) and the competition (Damlamian, Rodrigues, & Sträßer, 2013). An instance of the former, investigated in this research study, shows how refuse and recycling operators have replaced many of the rubbish bag collectors throughout Auckland.

Two numeracy factors which do not appear to be as prominent as number sense and measurement are estimation and spatial awareness. The pervasiveness of numeracy is no better illustrated than through the estimation which people carry out in everyday individual or team activities. Making estimates does not come naturally to everyone,

some people require instruction. Similarly, there are many common activities which rely on having a sense of space some of which were illustrated in section 2.5. It appears that though almost everyone is imbued with some sense of space and many people have a sense of positioning, when there is any discussion around numeracy the concept of spatial sense or spatial thinking is largely ignored unless it has been specifically targetted (e.g., see Chase, 1983; Smith, 1999).

2.8.1 The current research

As indicated in Chapter One, this research project investigates the estimation and spatial awareness skills required of the operators of refuse and recycling collection vehicles. What sets this occupation apart from almost all the research which is mentioned in Sections 2.5, 2.6, and 2.7, is that the operators are mobile, and have several responsibilities – to private and commercial residents, to their employing organisations, and to a civic authority. The operators' workplace performances are complex and naturally holistic (Eraut, 2004), and involve a mobile medium operating amongst diverse socio-economic communities. Although each operator works individually, they are all members of a community of practice. Not only are the operators driving trucks, they are operating heavy machinery while all the time meeting estimation and spatial demands.

Chase (1983) has described how taxi drivers who are also mobile, use their knowledge of the city to set up routes between points; and Noss, Hoyles and Pozzi (2000) illustrate how aeroplane pilots, when approaching a runway, make estimates of the wind speeds and angles. The refuse and recycling operators in the current study must similarly organise their collection routes. In the case of refuse operators they can visit up to 1400 residential customers every day. This study will draw on the experiences of a small group of these operators, both refuse and recycling, with some who are employees of a company and others who are self-employed but are contracted to the same company.

2.8.2 Research questions for this study

Clancy (2005) suggests that work practices are often described in official idealized language. Job descriptions for instance are couched in “disembodied, generalised, prescriptive” (Button & Harper, 1996, p. 266) language which formally specifies what is expected of someone in that position. As previous studies in this chapter have illustrated however (see section 2.5), workplace practices and especially spatial demands have more breadth and depth than ‘official’ specifications (Hegarty, 2010).

People at work have “real-time actions and interactions” (Button & Harper, p. 264) with other staff and their workplace practices. Their numerate behaviours are both contingent on what is happening around the workplace, people have clear roles and decision-making responsibilities and deadlines (Damlamian, Rodrigues, & Sträßer, R., 2013), and the resulting numeracy decisions can act as catalysts (e.g. discovering a poor quality level in a product) to change workplace practices.

The workplace studies which have already been discussed each identified the numerate behaviours of a number of occupations with particular foci on estimation and spatial awareness. With this in mind, the framework of workplaces as being socially situated practices is drawn on for the current research project. Although the framework of socially situated practices has been challenged on situatedness (e.g. Anderson, Reder, & Simon, 2000), and on numeracy as social practices (Coben 2006), it is, however, considered a reasonable fit to describe the work of refuse and recycling operators. A thorough examination of the literature indicates that the following research questions can fill a gap in the understanding of the numeracy practices of refuse and recycling operators. Such understanding has important implications for the training of people in mobile workplaces and a rethink of how spatial awareness in particular is attended to within mathematics and numeracy.

- Which situated numeracy practices, in particular involving spatial reasoning and estimation, do these recycling and refuse operators use in their mobile workplaces?
- How have these operators learned these situated numeracy practices?

The next chapter presents the methodology employed in the current study.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In Chapter Two, the literature around social practices, situatedness, and workplace numeracy was reviewed, in addition to estimation and spatial awareness, and how people experience and learn these practices. This third chapter looks at the research design used in this study, and the methods applied to obtain data that will answer these research questions:

- Which numeracy practices, in particular with regard to spatial reasoning and estimation, do these recycling and refuse operators use in their mobile workplaces?
- How have these operators learned these situated numeracy practices?

The chapter begins with a brief description of a pilot study which was carried out with a colleague; this short study looked at instances of numeracy on collection vehicles. In the next section there will be a discussion of qualitative research, in particular the constructivist-interpretive paradigm and why it is suited to this study. This is followed by a description of the case study approach used in this research. Then details of the instruments used to collect data, such as interviewing, observations and field notes, and document analysis are provided, as well as information about the participants in this research study. Finally, a discussion about how the data was analysed is presented.

3.2 Pilot Study

This current study was informed by an exploratory study that was carried out with a colleague (Chana & Kane, 2010), to see how numeracy (and literacy) concepts are situated in various situations, one of these being refuse and recycling collections. Benefits of carrying out a pilot or exploratory study include the researcher becoming accustomed to the working environment of the participants, and building trust and rapport with the participants (Sampson, 2004). The questions asked of the pilot participants informed the researcher's development of a set of semi-structured questions with which to interrogate the participants in the current study. Sampson (2004) suggests that pilot studies may expose gaps in the research design of a study that should be amended before the study proper begins.

Maxwell (2005) states that pilot studies provide the researcher with an understanding of how the participants of the study interpret their working situations and their own actions within these situations. Another possible consideration resulting from the findings of pilot studies for researchers is whether a full-scale project would be feasible or fundable (van Teijlingen & Hundley, 2001). As a result of the exploratory study by Chana & Kane (2010), the researcher benefitted by being able to revive contacts with people in the organisations such as the site managers and administrators; these people were critical in providing the researcher with access to their staff for the current study.

3.3 Overview of Qualitative Research

If quantitative and qualitative approaches can be viewed as being at opposite ends of a research approaches continuum (Cresswell, 2007), then as this study is concerned with “interpretation (of what people do) rather than quantification” (Burnard, Morrison, & Gluyas, 2011, p.49), using qualitative inquiry was deemed the more appropriate. Flick (2009) promotes qualitative research as being “oriented towards analysing concrete cases in their temporal and local particularity” (p.21), while Denzin and Lincoln (2005) describe qualitative researching as being akin to a quilter “who stitches, edits and puts slices of reality together”(p.5). However, this reality is always subjective– there is no absolute truth since everyone involved in the study will have a perspective, or multiple perspectives (Hennink, Hutter, & Bailey, 2011).

Denzin and Lincoln (2005, p25) write that qualitative inquiry “connects the researcher to specific methods of collecting and analysing empirical materials”. Therefore, within this qualitative inquiry, the case study research design investigating the numeracy practices of refuse and recycling operators relies heavily on the ethnographic methods of interviews and observation, using field notes, and undertaking document analysis. Qualitative inquiry usually involves an element of flexibility (Silverman, 2001) or researcher “twists and turns” (Lincoln & Cannella, 2004, p.7), to attempt to accommodate the possible directions participants may take the research. However there are drawbacks. Within qualitative research, the researcher as “primary instrument for data collection” (Merriam, 2009, p.15) cannot help but be subjective. As Cresswell (2007) notes, a researcher’s “own background shapes their interpretation, [...] from their (own) personal, cultural and historical experiences” (p.8). Care must therefore be taken that participants’ viewpoints and experiences are recorded accurately.

3.3.1 The Constructivist-Interpretive Paradigm

Within qualitative research, there are several paradigms which present themselves. Johnson and Christensen (2012) define a paradigm as being “a perspective held by a community of researchers based on a set of shared assumptions, concepts, values and practices” (p.31), whereas Cresswell (2007) suggests that paradigms are simply “worldviews” (p.5). Consequently, seeking to understand the numeracy practices the operators use and why they use these could best be approached through a constructivist-interpretive paradigm. In this paradigm, participants are not regarded as merely sources of data, rather the researcher seeks to understand their contexts and their lived experiences as operators of refuse or recycling vehicles, from their own insider (or emic) perspectives (Bryman, 2001). Further, while a positivist paradigm attempts to explain human behaviour by attending to preconceived hypotheses, the interpretive paradigm tries to recognise:

that reality is *socially constructed* as people’s experiences occur within social, cultural, historical or personal contexts. Even though we are individually engaged in acts of sense making we often do this from a wider social context and constructions and interpretations are usually commonly shared . . . (Hennink *et al.*, 2011, p.15).

Hennink *et al.* (2011) caution that although this paradigm investigates and upholds the “importance of these broader contexts on people’s lives” (p.15), there is still the need to ask whether “the behaviour of people can really be studied outside the context in which they live” (p.15). With the researcher accompanying these participants in their own field a strength of this study is that the researcher is able to observe each operator’s workplace and hear each person’s views for himself, within their contexts.

3.3.2 Using a Case Study

Yin (2009) defines a case study as “an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context” (p. 18). The case study in this research is a specific group of operators. Such a case study is a bounded system (Stake, 2005; Merriam, 2009). In this study, involvement was restricted to the operators, their site managers and their working operations. Generalising or extrapolating too far beyond a bounded case study is not advisable (Merriam, 2009) usually with the limited numbers of respondents being queried. Flick (2006) reminds us however, that some single cases have helped to advance both natural and human sciences. Attempting to survey all the individual recycling operators in the city would not necessarily provide a more expansive view of an operator’s perspectives of the most appropriate strategies to

do their work. As van Maanen, Manning, and Miller (1986) explain, this qualitative case study is used to explore “meanings rather than frequencies” (p.5) behind the work of refuse and recycling operators.

Stake (2005) suggests that there are three types of case studies: an *intrinsic* case study, an *instrumental* case study, or a *multiple or collective* case study. Whereas *intrinsic* case studies tend to concentrate on a particular case, mainly because the issue being researched is of interest to the researcher, this research is an ‘*instrumental*’ case study (Stake, 2005, p.445), since the work of the collection operators will “play a supportive role . . . to provide insight into an issue” (p. 445); in this case the issue is which numeracy practices are used in their workplace.

Several possible advantages appear when using a case study research design according to Gravetter and Forzano (2009). The first is the detail from interviewing and observation being able to provide a large amount of information or “thick description” (Geertz, 1973) from respondents. The researcher could see first-hand the numeracy of estimation and spatial skills events as a passenger in the truck cab. The situatedness of the operators’ numeracy events and the possible influences on the decision-making of the operators became more apparent to the researcher. Another advantage of case studies is that occasionally, unexpected information emerges from respondents that may describe “exceptions to the rule” (Gravetter & Forzano, 2009, p.375), and perhaps even eliminate other, previously held notions. Merriam (2009) cautions, however, that although a case study may expose richness and a holism of the working lives of those being studied, as the researcher is the primary investigator of the study care needs to be taken to maintain integrity when collecting data, and any subsequent analysis.

3.4 Data collection instruments

To assist with identifying the strategies in the numeracy practices of the participants, several data collection instruments were employed:

- Interviewing and field notes
- Observation
- Artefact and document mining

3.4.1 Interviewing and Field Notes

Merriam (2009) states that interviewing can be a valuable instrument to find out what participants know. Interviewing allows the researcher to elicit “how people interpret the

world around them” (Merriam, 2009, p.88). However, observations of a phenomenon as it unfolds can make a researcher add to, or review their original interview questions. Therefore, in this study a set of interview questions needed to be designed to provide a less formal discussion format for the participants and give them a broader window to discuss what numeracy practices are important to them in their work as collectors. Questions had to be clear, unambiguous and not distracting since the operators were in control of a large vehicle while being interviewed. Using a set of semi-structured interview questions (Blaxter, Hughes & Tight, 1996; Burns, 1996) allows a researcher to modify the order of the questions based on the perception of what seems most appropriate; accordingly, “direction is given to the interview so that the content focuses on the crucial issues of the study” (Burns, 1996, p.331). Also, some questions can be omitted if they seem inappropriate, or if they have already been answered previously. Either way, it enables the interviewer to converse with each participant at length about what they are doing, acknowledging their expertise in their own working environments. Field notes and sketches are often recorded at the same time as the interviewing and the observing. Merriam (2009) cautions that notes need to be written up soon after the interview or situation has concluded because an observer’s memory cannot be relied on. Bryman (2001) suggests that there is almost a personality to field notes, as a researcher imprints his or her own style into these, perhaps by the phrases being used, and the sketches or diagrams being made. Flick (2009) adds “researchers’ reflections on their observations and actions in the field, their impressions, irritations, feelings, and so on, become data in their own right, forming part of the interpretation” (p.14). These notes and sketches, later supplemented the transcripts of the interviews, enabling the researcher to interpret what was unfolding before him; Bryman (2001) suggests that except “for brief passages ...[field notes] are mainly for personal consumption” (p.306). Silverman (2001) advises that there are other things which field notes provide. One is that when a researcher returns to these later, the notes and sketches may be reinterpreted. A second point is that when first creating field notes, some categorisation and potential coding is inevitable even if the researcher is not consciously creating categories. Consequently, a return to the notes may provide a researcher with new or previously unseen categories, particularly if other data instruments such as interviews have changed a researcher’s thinking. The major challenges in field note taking, however, are to ensure that what people have actually said or done is recorded authentically and economically (Silverman, 2001), but with enough detail to make it seem as if the reader was there (Merriam, 2009).

3.4.2 Observations

Wolcott (1992, p.22) writes that a key aspect to being a good observer is about learning “to pay special attention to a few things which others ordinarily give only passing attention” (p.22). Merriam (2009) adds that some practices become so routine that participants do not notice these, but a researcher-observer could find interesting practices within the everyday worlds of the operators. It also provides the opportunity for a researcher to be in place and to follow up with a pertinent question.

Bogdan and Biklen (2007) suggest that researchers in the field with participants begin their approach relatively “passively and unobtrusively” (p.91). The presence of a researcher in the participant’s setting often leads to a change in the latter’s behaviour that is often unavoidable Wolcott (1992). Therefore it is the responsibility of the researcher as the visitor to the participant’s setting to apprise the participant of the researcher’s role openly, and if necessary, to demonstrate what information is being collected from the participant.

Another consideration is the role of the researcher, on the continuum of observer to participant. In some cases researchers do participate, and in effect become observers who occasionally participate. In this aspect, Merriam (2009) notes that the researcher “cannot help but be affected by the setting” (p.137), and might feel the need to contribute to the work or the situation. A positive aspect could be that rapport and trust between researcher and participant are enhanced.

3.4.3 Artefact and document mining

The methods described above are carried out in situ with, and around, participants. The same might be said for some artefacts used by participants in their work. According to Merriam (2009), artefacts are “physical objects found within the study setting, such as tools, instruments, implements, and utensils” (p.146). In the situation of the refuse and recycling operators, most of their artefacts are in their truck cabs, and these are fixed in that environment. Examples in the truck cab will be presented in Chapter four, and these include mirrors, a monitor, a bin counter, and a control stick.

Most documents, on the other hand, are generally not in situ, and this can be an advantage in

sourcing these. These are a “readymade source of data” (Merriam 2009, p.139) and in most cases may be scanned to become electronic files. Also, these are not subject to a researcher’s input, rather they are relatively stable, they may show past and future

developments and changes, and “exist independent of the research agenda” (ibid., p.156). Their independence from the research agenda can also be disadvantageous – if they are not specifically research-focussed, usually extra interpretation will be required. Also, in some instances, their reliability and accuracy may be questionable (Merriam, 2009).

3.5 This research project

This study investigated which numeracy practices were employed by truck operators of two waste collection companies in their work situations. This study was given ethics approval (11/162) by the Auckland University of Technology Ethics Approval Committee on 14 July 2011. The operators perform their assigned collection runs weekly and fortnightly, collecting in the same areas. Flick (2009) writes that qualitative research is about “analysing concrete cases in their temporal and local particularity” (p.21), therefore the working conditions of these participants often meant that the researcher could attend an after-work meeting, or try to locate operators’ trucks by listening for the hydraulic lifting sounds in a neighbourhood or by the GPS monitoring facility of the administrative staff at the company’s Greenmount depot.

Figure 3.1 on the next page illustrates the path taken by the researcher for this research study. The pilot or exploratory study illustrated that the current project was feasible, and provided an inkling of the funds of knowledge (Moll et al, 1992) which the collection operators possess. The principal instruments used to collect data for this study were participant observation, participant interviews using a semi-structured set of questions, field notes and diagrams, and some document analysis.

The first three methods could be carried out in the same place and time (in *Figure 3.1*, these are indicated *On the Road*), when working with the operators during their working hours and runs. The *Off the Road* panel provides other data collection points by using document analysis, and attending meetings (principally with site managers). The pathways returning to the Literature Review show how this was continually informed and updated by the information provided from the analysis of the research instruments.

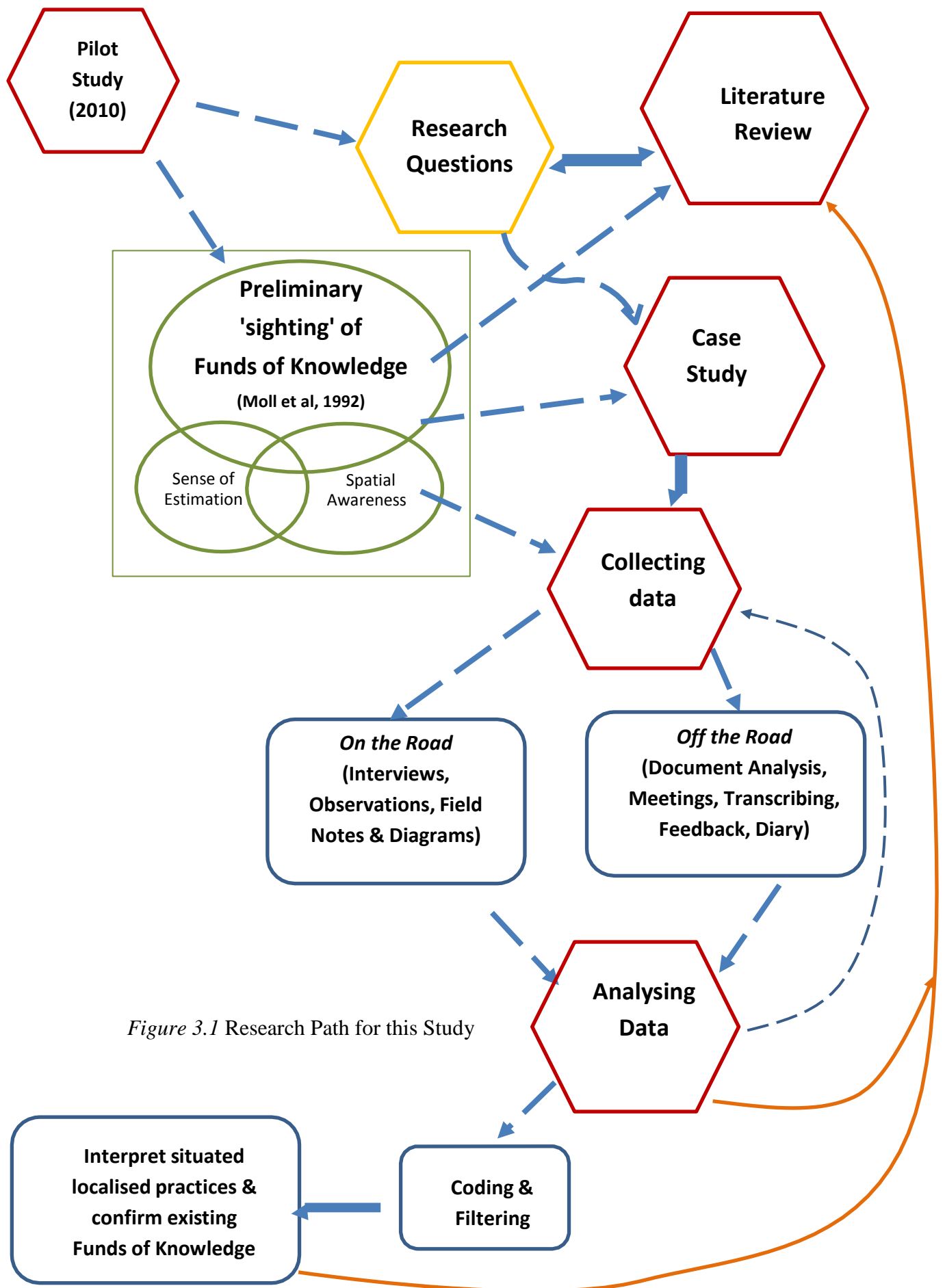


Figure 3.1 Research Path for this Study

3.5.1 Interviewing participants and using field notes in this study

The research interview included an information sheet for participants (Appendix A), a consent form (Appendix B) and the questions (Appendix C). These questions asked about work and school backgrounds, prior driving experiences (if any), and what knowledge of mathematics (if any) the operators thought they needed. Data were recorded on a digital recorder and by note-taking. The interview proper would usually be attempted once the researcher and operator had been driving and collecting for 5 – 10 minutes. This assisted the participants and the researcher to develop some rapport beforehand.

Background noise during the interview was occasionally difficult, but not insurmountable. Interviews were paused when recognising there were times an operator needed to concentrate on a narrower part of the road, or where traffic became busier, and were resumed when it was safe to do so. Field notes and diagrams were completed during the times when the operator was occupied with concentrating on the bin alignment or when driving through a busier part of a road. Not every observation can be committed to memory so having a record which jogs the memory is invaluable. Some of the situations occur quite quickly but fortunately five operators were accompanied so situations and practices were usually duplicated although locations changed.

A dilemma facing a researcher is to try to record everything (Silverman, 2001; Bryman, 2001), therefore some sensible decisions on note-taking length had to be made; the researcher needed to complete these notes quickly, especially as the truck had to exit one collection zone for another. Accordingly, the researcher's notes needed to be concise but clear enough for later reading and transcription. The field notes had sketches of some of the situations and these rough pictures made it easier to map out some of the collection territories and provide diagrams of decisions made there. Further, they provided the researcher with a degree of reflexivity (Merriam, 2009) after the run.

3.5.2 Observing participants in this study

The same operators who were interviewed were also observed as they collected refuse or recycling from their trucks from the cab of the truck, where the researcher sat beside the operator of the vehicle. Residents usually place bins on their berms or footpaths outside their properties; if other vehicles were parked beside or in front, the bins were at too great a distance from the hydraulic lifting arms on the truck and could not be lifted. Although there primarily to observe, on a few occasions the researcher left the truck cab to help

with moving and realigning bins. Bryman (2001) comments on this degree of involvement, writing that “there may be contexts in which either participation is unavoidable or a compulsion to join in in a limited way may be felt” (p.300). Although this involvement was used sparingly, it did assist with the rapport being developed between operator and researcher and probably saved the operator time.

Operators were aware that the researcher was seated on the road side of the cab and so would be in more danger when alighting on the road side (as opposed to the footpath side), so rarely asked for assistance. Also, opening the roadside door moved the operator’s roadside mirror, thereby blocking the operator’s view of the ‘blind spot’ of any approaching traffic from behind the truck. However, when the load was full most operators would switch seats with the researcher and the truck would then be driven to the refuse transfer station or the recycling plant.

Observation sites were selected according to the scheduled runs of the operators and their trucks on those local collection days. There was no particular day favoured, so the researcher accompanied operators on a Tuesday, a Thursday, a Friday and a Saturday (used as a deferred collection day if a public holiday fell on the Monday of that week). Refuse was collected weekly and recyclables fortnightly. Hence, refuse operators have five scheduled runs, while recycling collectors have ten scheduled runs, in their respective collection cycles. Five operators were observed and interviewed.

3.5.3 Document and artefact mining in this study

Several documents were uncovered during the research period. Two of the following documents described were in constant use by the operators so a drawback was these two documents were not available to the researcher to take away after the interview. The maps of the collection territories were in continuous use by the operators and so could not be removed. Also, the recyclables operators were given a weighbridge ticket each time they visited the recycling plant and this was kept by them for their administrators’ records. The third set of documents in occasional use is warning notices in three different colours. These are described in more detail in Chapter Four and an example is in Appendix D. A fourth set of documents was two spreadsheets kept by one of the recycling contractors (Appendix E), showing the record of the bin numbers and some weights of collections carried out in that operator’s runs over the previous month; also a summary printout of all the operators’ bin numbers and weights was provided (Appendix F).

The last document was an executive summary of preliminary findings before accompanying the last operator for an interview/observation (Appendix G). Health and safety posters were on the noticeboard in the staffroom at the depot. As stated, health and safety is a serious matter for all staff and it is one reason why managers act as gatekeepers to visitors, but more importantly as monitors of their own team of operators. Driving a large machine brings its own set of demands and responsibilities, so the additional roles of collecting and emptying bins add to this mix. On the occasions that operators must leave their cabs, perhaps to align a bin, the heights they must descend, from their seat in the cab to the footpath or berm, means they cannot jump. One poster describes the forces at work on truck drivers if they fall from relatively low heights (even under a metre) and the potential injuries that could happen. The display had a photographed driver, and reminded people that when they alighted they should ensure they were always in contact with three points on their descent.

The types of information collected from each method were complementary; the interviewing (and later transcribing) provided a record, in words, of the participants' thinking about what they do in their work. The observations provided views of the collecting and driving that unfolded before the researcher with clear perspectives of the processes and predictive nature of the tasks. Operators had to constantly look ahead to see what needed to be completed next.

Observing the operators at their work also prompted the researcher to ask other questions not originally on the list of interview questions, and sometimes provoked the operators into asking whether the researcher had noticed something. Field notes and diagrams were used to augment the other two methods, mainly with sketches of some of the street layouts and how operators moved their vehicles in and out of these locations. Field notes also helped when listening to some interviews later, to compare what was noted with what was being described in the conversation. Together, each method of data contributed to the research by enabling identification of numeracy concepts and events, and with analysis promoted exploration of the operators' numeracy practices.

3.6 The study participants

Each participant typically drove a dual-controlled truck (steering wheel on either side of the cab) that collects refuse or recyclables. Each truck has a pair of hydraulically operated arms or claws that extend from the berm side of the truck, to grab, lift and empty 120L (refuse) or 240L (recycling) plastic bins into the rear of the truck. Although each operator can communicate with other team operators and the depot staff by a radio

telephone in their cabs, they remain as sole operators for most of their working day, visiting every street in their allocated area. Communication with other operators might be more active if one of the trucks has a breakdown, and other drivers in adjacent areas are asked to assist with completing the day's collection once their own areas are finished. This is described more fully in the next chapter.

The people in this work are appropriate for the study because they have varying experiences with collecting refuse or recycling loads. They have diverse backgrounds and do their driving and collecting in settings that vary across their working weeks. For instance, on one day an operator may be working in an older part of the city with narrower streets while on the following day they might be collecting in a newer suburb with wider lanes.

When this study began, one of the companies employed all its operators and they were collecting both refuse and recyclables. The other company was contracting all of its operators and was only collecting recyclables. During the study, the second company withdrew from collecting, and its drivers, contracts and plant were taken over by the first company. Out of respect for the changes being experienced, and any possible new stresses introduced, the research was discontinued with those operators adjusting to the new regime, until a suitable amount of time had elapsed and they were in a position to take part again.

In Table 3.1 below, each operator's name (pseudonyms) in alphabetical order is given, if he operates as a recycler or a refuse collector, and whether he is an employee or a contractor. The two operations have differing collection responsibilities and requirements to meet. One group of operators collects refuse, while the other group of operators collects recycling. The refuse collectors are all employees.

Table 3.1 *The five operators who participated in the research*

Name (pseudonyms)	Collection Operation	Type of Employment
Brian	Recycler	Employee
Dennis	Refuse	Employee
Josh	Recycler	Contractor
Noel	Recycler	Employee
Sean	Refuse	Contractor

Within the group of recycling operators however, there are two employment cohorts in action; the first cohort has operators who are also company employees, similar to the refuse operators while the second cohort of recyclers are owner-drivers or contractors to the company. This small group of owner-operators remains a legacy arrangement and the first company inherited this set-up. This will be described more fully in the next chapter.

3.6.1 Participant recruitment

The operators selected to be participants for this study were primarily recruited by their site managers. These managers were met initially during the pilot study (Chana & Kane, 2010) and so were familiar to the researcher. With the managers' overview of their respective plants, they are key people (Merriam, 2009); the managers are defined by Hennink, Hutter, & Bailey (2011) as "community gatekeeper(s)" (p.92). The gatekeeping roles are standard positions in many industries due to the commercial sensitivities of their respective operations. In this particular work, the continuous movement of large vehicles requires sensible health and safety protocols for anyone visiting their plants. Naturally, managers are careful to vet anyone who wants to gain access to the staff (Easterby-Smith, Thorpe, & Lowe, 2002). With the early starting times of the operators, the initial visiting often meant that only the managers and office staff were at the depot; operators would already be out collecting and would have no need to be at the depot until their daily runs were finished. Operators would only stay at the depot if a 'tailgate' meeting (with management) had been scheduled. Fortunately, the interviewer was invited to attend one of these where the research detail was shown to a set of drivers and left with them to consider.

A limitation of the study is that although the researcher initiated a poster for the workplace and information sheets for prospective participants, the managers or 'gatekeepers' were involved in inviting most of the operators who participated. Although one of the newer operators had attended the tailgate meeting and volunteered, most of the others were asked if they would take part. Fortunately, these operators appeared very knowledgeable about their roles and their information was very useful to the researcher. And the operators had the right of refusal, if they did not want to take part. The managers also had local knowledge of the working community to identify eligible study participants, but a researcher could identify any potential problems in their selection (Hennink *et al.*, 2010), and suggest alternatives.

Five interviews were completed and this was deemed sufficient. Bryman (2001) states that one should continue until it is felt "no new or relevant data ... emerges" (p.301). The

final participant was interviewed and observed several months after the other operators; his experiences and strategies resembled most of the collection practices and experiences of the others, confirming that the relevant data had in the main been captured.

3.7 Data Analysis

As the fieldwork was getting underway, and before any transcription of the individual interviews of each participant was completed, a “provisional list of codes” (Miles & Huberman, 1994, p.58) and likely headings was created. These were generated from the interview instrument. The preliminary headings matched traditional broad mathematical strands such as number sense and measurement. Transcripts of the operators’ interviews were searched for evidence of the strands and in particular, sub-categories such as proportional reasoning activities were recorded.

According to Miles and Huberman (1994), data reduction refers to the condensation of the original transcribed interview and field notes by focussing on the themes that relate most directly to the research questions. Data reduction is a continuous process throughout the study with new ideas emerging, while other less relevant factors are deleted.

3.8 Summary of Chapter Three

This chapter began with a brief description of the pilot study before the current research study. Next, an overview of qualitative research, and in particular, the constructivist-interpretative paradigm, were described, in essence to lead into the methodology and research design used for the current study. The suitability of the case study approach to this research was justified, and the ethnographic instruments employed, interviewing, field methods, observations, and document and artefact mining, were each presented. *Figure 3.1* illustrates the research pathway taken by the researcher. The questions used for the semi-structured interviews may be found in the Appendices along with the other documents mentioned in sub-section 3.5.3, including the executive summary provided to the managers. Data analysis for this research was briefly described, from transcribing the interview data to constructing key headings.

The next chapter, Findings, begins with a background section to provide some of the information behind the operators’ data. This section includes information about the two companies, the prior working and mathematical learning experiences of the operators, as well as several key features of the trucks used to collect refuse and recyclables.

CHAPTER FOUR

FINDINGS

4.1 Introduction

As indicated in the previous chapter a case study approach was employed in this study. This chapter sets out the findings. This chapter sets out the workplace events that led to the identification of numeracy practices involving estimation and spatial awareness. The five participants will be introduced. A working day of one of the recycling collection operators, Josh (pseudonym), and the various practices he uses during his work will be described. Josh is one of the original owner-contractors, and his story was chosen mainly because he provides workplace documents and commentary typical of his and the other operators' collection experiences. Miles and Huberman (1994) caution researchers against bias by "overweighting data from articulate, well-informed, usually high-status informants (at the expense of) less articulate, lower status ones" (p.263). In this section however, opportunities are given to the other participants to describe their own workplace experiences and practices. Highlighting Josh's account therefore appears justified in this discussion of the findings of this case study.

Brian, one of the other employed operators in the study, was interviewed and observed several months after the other interviews. Not only did this enable the researcher to confirm some of the earlier findings with Brian, but it also provided an opportunity to pursue some answers to other questions prompted by those earlier findings. In the fourth section of this chapter, the numeracy practices of the refuse and recycling operators are distilled from their working situations. A final section records the reflections of the researcher.

4.2 Background to the organisations, the operations and the participants

4.2.1 The two companies

As already outlined, when this study began all the refuse collection operators and over half of the recycling collection operators were employed by Company X. Another group of recycling collection operators own their collection vehicles and are small businesses in their own right. These owner-operators were originally contracted to a second company, Company Y. Since the dual bin collection system of both refuse and recycling bins was introduced, Company X has managed the refuse collection in the

Eastern half of the former Auckland City (*Figure 4.1*: yellow region), and the recycling collections there as well as in South Auckland (*Figure 4.1*: orange region) and East Auckland (*Figure 4.1*: purple region).

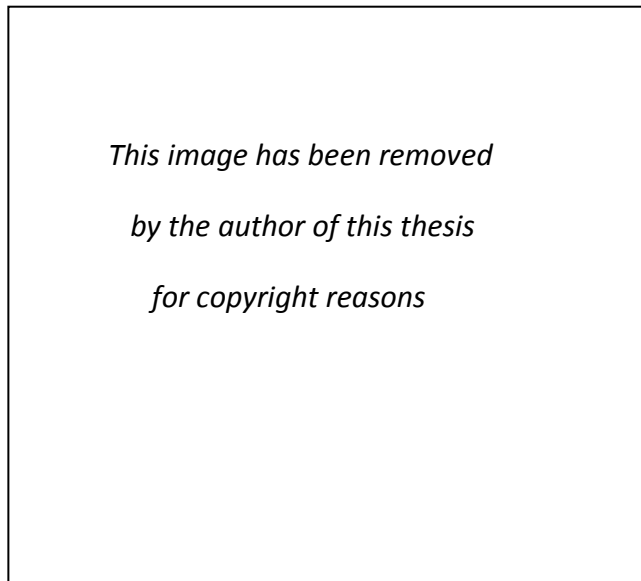


Figure 4.1 Map of Greater Auckland Territories prior to 2010 ‘Super City’ Amalgamation

Company Y concentrated only on the collection of recyclables, and its contracted owner-operators worked the area between the Central Business District and the western boundary of the former Auckland City (left half of the yellow area shown below). Company Y has its headquarters in Australia, and promoted the owner-operator arrangement that it had been using in Melbourne.

According to the previous site manager, two events in 2011 were major reasons for Company Y selling its New Zealand recycling collection interests. First, Company Y’s Australian parent company failed to win two large commercial construction contracts, and second, the company fought a protracted legal challenge over a safety incident in Queensland. This led Company Y to consolidate its financial holdings including any interests in the Auckland recycling operation, and to temporarily reconfigure its other existing business interests in Australia.

Company X successfully tendered for the recycling collection runs of Company Y, and also inherited the employment arrangement with the thirteen owner-operators. In one of the earlier meetings with the Company X site managers, it appeared that Company X’s preferred management position was having employed operators and not owner-operators. However, about three months before the transfer, the site manager of

¹ Fig 4.1 has been removed by the author of this thesis due to copyright reasons

Company Y told the researcher that after meeting with representatives of Company X he was optimistic his team of operators would maintain the arrangement of owner-operations. While Company Y was operating in Auckland and before any issues emerged leading to its withdrawal from New Zealand, its owner-operators had this contractual arrangement in place (explained by Josh):

I've got a seven year contract, which is good. If we meet all of our performance standards, KPIs (Key Performance Indicators) for the seven years, then we get a rollover of another two years which again is good, um – the truck's paid off (to the company) in seven years.

In the most recent meeting the researcher had with depot site managers at Company X, the legacy arrangement with owner-operators was still functioning and is likely to remain in place until it comes up for renegotiation at the end of the seven years.

Three other circumstances may have an impact on this situation in the long term. The first is that Company X was itself sold in 2013 by its Australian owners, Ironbridge Funds, to Cheung Kong Infrastructure Holdings Limited (CKI Ltd), a Hong Kong company. In this most recent discussion with the researcher, the depot site manager was unsure in which direction new owner CKI Ltd would take the company, especially in any future employment arrangements.

A second impact is the anticipated growth in Auckland's population and the associated construction of new dwellings, including infill housing in certain areas. This will mean an increase in the number of bins to be collected in those areas. Many of the vehicles used for recycling have a compliance tonnage of under four tonnes (the compliance factor is explained later in this chapter in section 4.3.3). The need for fleet replacement or expansion has resulted in Company X purchasing new vehicles, some with a compliance tonnage in excess of five tonnes. The increase in bin numbers and the resulting tonnages of those recycled materials means the larger vehicles could accommodate more bins each load. This growth situation may eventually influence the owner-operators to replace their smaller recycling vehicles with larger trucks. Whether the owner-operators have the means to do so and the motivation to continue in these roles, are questions for further research.

A third factor is the requirement of the local council to reduce the domestic waste quantities of almost 800 kilogrammes per person per year (Auckland Council Waste Management and Minimisation Report, 2012). In the same report, 2010 figures suggest that an average refuse bin contains by weight, fifteen percent of recyclable materials

and a further ten percent of green materials which could be composted. The focus is on sending less refuse to landfill so encouraging the removal of non-waste materials will be prioritised by the council in the next three years. This may mean that a green waste collection is also required, although several households already have this service performed by private contractors. Whatever is decided, it is clear that changing the collection arrangements in Auckland will also change the workloads of operators.

4.2.2 The collection process

The refuse collection is a weekly event, and for every resident occurs on the same day each week. Where residents are located indicates which kind of refuse receptacle is collected. Within the former Auckland City (yellow area on *Figure 4.1*), each residence has one 120-litre bin for refuse and one 240-litre bin for recycling. In other areas such as Auckland South (orange area on *Figure 4.1*) and Auckland East (purple area on *Figure 4.1*), a rubbish bag system is used for refuse collections, in addition to the kerbside recycling bins. Southern and Eastern areas were parts of other territorial authorities outside of the former Auckland City boundaries and had their own refuse and recycling contracts in place, hence the variance in refuse systems and in bin lid colours (see *Figure 4.2a* and *Figure 4.2b* below).



Figure 4.2a Dual bin system in Auckland



Figure 4.2b Refuse bags and recycling bin in South and East Auckland

To collect refuse in bags which are often heaped together on a grass verge (*Figure 4.2b* above), teams of at least three, including a driver of a rear-loading truck, are required. Recyclables are collected fortnightly, usually on the same day as refuse collections, in bins emptied using automatic side-loading trucks. These trucks are briefly described below.

4.2.3 The collection vehicles

Residents must roll their wheeled 120-litre refuse or 240-litre recycling bins to verges or footpaths outside their homes, before 7am on their allotted collection days. Each truck draws alongside a bin and has an automatic side-loading arm which extends towards the bin on the verge or footpath.



Figure 4.3 View taken through cab rear window as the drive chain extends towards a bin

A drive chain extends or retracts the side-loading assembly arm along a track (see *Figure 4.3* above taken through a rear-window of a truck cabin). As this arm assembly approaches a bin in the pick-up position, two protracting ‘claws’ at the end of the arm grip the bin.

Depending on how far a bin is from the truck, the bin is either lifted from there, or the bin is drawn closer to the truck then lifted. Each lift is an upward arcing motion until the bin is over the top of the truck. The bin lid drops open and the bin contents are tipped into the receiving area of the truck hopper. Once an operator is satisfied a bin is empty after viewing the hopper camera and sometimes by shaking the bin (see *Figure 4.4*), an emptied bin is lowered in a downward arc to the verge near the residence it has come from, and the claws release the bin. The side-loading assembly is retracted, then the truck moves forward to the next bin location, where the collection cycle is repeated.



Figure 4.4 Bin about to be emptied

These vehicles are classed as “medium rigid trucks” (New Zealand Transport Agency, 2007, p6) with two axles; each truck is around 8m in length (in comparison with an urban passenger bus, which is almost 11.5m long). The trucks are designed to collect, compact, and then, up to four times a day, empty several tonnes of materials by tipping at designated sites. Each truck has dual controls meaning that there are two-steering wheels and sets of driving controls. The twin-steering wheel arrangement allows an operator to drive the truck from either side of the truck cabin (or cab – see *Figure 4.5* below). Mirrors, seats and steps are placed on each side to accommodate both seating positions.

Drivers in New Zealand have steering-wheels on the right side of the vehicle; when an operator has to drive longer routes he almost always drives in this standard position. But during collections, the operator sits on the left-hand steering position since this is the side of the road where residents place their bins, and the side where the automatic side-loading arm and cabin monitor are mounted.

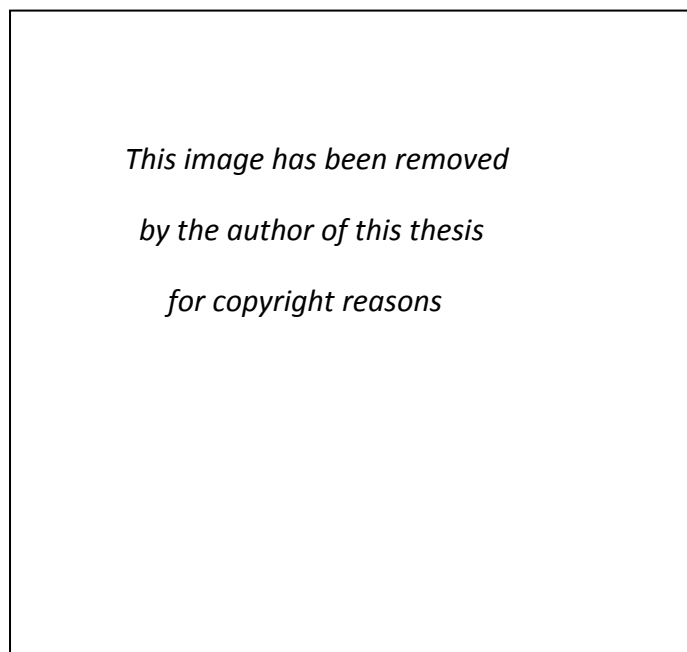


Figure 4.5 Layout of Dual-control Cab in a Collection Vehicle

² Fig 4.5 has been removed by the author of this thesis due to copyright reasons

The control mechanisms to lift and empty a bin in later model trucks are managed by a 'joystick', slightly larger in size than gear levers found in many manually-driven cars (*Figure 4.6*). The joystick is located on the right side of the left steering wheel, with several buttons on the top pad of the stick to control the arm, its claws, the hydraulic lifting and lowering, and the shaking of the bin. Operators do not seem to look at the button controls on the joystick; instead they prefer to view the bin manoeuvres in their side mirrors or over their left shoulders, while simultaneously running their right thumbs over the required button functions as they lift, empty and return each bin.

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*Figure 4.6 Joystick control*³

With so many bins being emptied into each truck hopper, the contents of all loads, particularly recyclables, need to be constantly monitored. Brian told the researcher that operators are not permitted to look in a resident's bin unless they have had to alight from the truck to attend a bin that is either overfull or that appears unstable, so in the view of the operator the bin may spill when it lifts. In lieu of getting out of their cabs, operators continually scan their onboard screens or monitors (see *Figure 4.7* below).



Figure 4.7 Cabin monitor showing material in hopper, bin count, time, and hours of use

³ Fig 4.6 has been removed by the author of this thesis due to copyright reasons

The monitors are connected to a camera mounted in each hopper. At most, operators glimpse the contents of each bin as it empties into the hopper. After time, because of the experiences of the different operators in their roles, their eyes are attuned to see foreign (non-recyclable) material. If an operator finds foreign material in a recycling bin there are consequences for a resident, and these are explained later in this chapter, in section 4.3.4.2.

The screen serves several purposes for an operator. Not only does it link the operator to what is being emptied into the hopper, but it also keeps a running count of how many bins have been emptied on each run. The significance of this will again be described later in this chapter. In Figure 4.7 the operator, Brian, has collected 161 bins in this load. Two other numbers are shown on the screen. The figure on the top right of the screen is the current time (around 10.30 am), while the figure on the lower right is the number of hours since the previous servicing of the hydraulics of the automatic side-loading assembly.

Once the waste material is in the hopper it starts being moved towards the rear of the vehicle by a hydraulic moving plate or a rotating paddle. With either mechanism, the commingled waste material is forced through an opening, being compacted as it moves, and when it eventually arrives in the main body of the truck it is pressed against other refuse or recycling at the end of the truck further compacting the material. The type of collection material, whether refuse or recyclables, determines how compactible a full load may be. Load limits will be presented later in section 4.3.3.

When a load is full each operator interrupts the daily collection run, switches positions from the left seat to the right seat in his cab, then either drives to one of four refuse transfer stations or to the Visy recycling plant in Onehunga. Refuse transfer stations are locations where the contents of the operators' refuse vehicles are emptied; then even larger trucks transport the contents of several refuse trucks in one load to the North Waikato Regional Landfill near Hampton Downs, about 55 kilometres south of Auckland. The transfer stations and the recycling plant are located in commercial and industrial locations while the landfill is in a largely rural area. Each facility is close to major arterial roads or highways.

4.2.4 Backgrounds of the Operators

The participants are all males with ages ranging from 40 to 54. One of the companies has a female employee but she was unavailable for the study. Three of the five, Dennis, Brian, and Sean, are employees of Company X while the other two, Josh and Noel, were originally contracted to Company Y as owner-operators. Of the Company X personnel, Sean was comparatively new to collecting having only recently returned to Auckland, and at the time of the interview he had been collecting for three months. Dennis and Brian had been with Company X longer with Brian stating that he began work as a relief driver, so he was familiar with the collection runs of all the other operators.

Table 4.1

Brief description of the operators from the two companies

Name (pseudonyms)	Collection Operation	Type of Employment
Brian	Recycler	Employee
Dennis	Refuse	Employee
Josh	Recycler	Contractor
Noel	Recycler	Contractor
Sean	Recycler	Employee

One owner operator left before the Company Y collection runs were acquired by Company X, while the other operator has remained and is now working alongside the other employed operators. When Company Y set up in Auckland all of its new operators were trained in Melbourne for up to two weeks at the parent company there. Company X employees however, are trained locally.

4.2.4.1 *Truck driving experiences*

When answering a question about previous truck-driving experience, four of the five operators responded that they all had heavy vehicle licences before undertaking these roles. Two of the operators had military experience that included the driving of army troop trucks in New Zealand. One of these men had also driven overseas as part of a team engaged in a logistics assignment in a peace-keeping tour of duty. A third operator had experience driving container trucks including trucks with rear cranes to unload their containers. A fourth had driven car transporter trucks (up to 32 tonnes) and had loaded and unloaded up to eight cars from the truck at both depots and

destinations. Only one operator stated that he'd had no previous experience with driving trucks, although he had worked internationally in service industries. Josh was typical of those who have truck driving experience and he was aware of the challenges for drivers who are new to operating heavy vehicles:

This (truck) is actually relatively small compared to some of the stuff I've driven. But again for the guys who've only ever been in a car before, you've got the elevation thing, you've got the spatial awareness thing – you know, trying to judge getting through tight areas.

Very early in the interview Josh has acknowledged two aspects of spatial awareness in his workplace, a three-dimensional reference to elevation above other vehicles, and being able to drive a larger vehicle through narrow spaces.

4.2.4.2 *Mathematics learning experiences*

The operators were also asked to give information about their learning of mathematics in school. Two of the recycling operators and the refuse operator believed their mathematics was good. Josh stated that he understood mathematics in school and passed School Certificate, although when the subject moved into more advanced topics such as calculus he lost interest:

Um, because of the teachers I enjoyed the subject. I wasn't that flash at it. Basics yes but then you know [. . .] I couldn't even remember what they're all called now, all the different mathematical calculations and that sort of thing. When it got onto that I sort of struggled a bit.

However, after joining the army with all the other new recruits in their first year of training, Josh undertook Mathematics and English at a level which he judged was between Year 11 and Year 12. It appears that recruits who entered without School Certificate subjects and who then passed the army equivalents were still not awarded School Certificate but in effect “were signed off by the Army educators at a level that the educators were happy (with)” (Josh).

Dennis thinks that he is comfortable with mathematics too. However, he also described how the teaching circumstances changed as did his motivation for learning mathematics:

I thought I was good at maths – liked competition – was fast at working stuff out. This teacher had five of us doing more advanced stuff than the other kids, then they (school) stopped teaching us and we lost interest [...] the five of us were no longer challenged.

Brian is another who believed his learning of mathematics was generally satisfactory and that he had “no problems with Maths”. Noel is similar to Brian in that he was schooled overseas and thought that “Maths is very important in life”, although he was not forthcoming as to why. He was concerned about the lack of study his son was doing at university and how expensive this was for him. As owner-operators, Noel’s and Josh’s accountants handle their business calculations for them as long as both operators keep records of mileage, road user charges, and fuel consumption. In contrast, Brian, who had been in retail for eleven years including some as a manager and with associated experiences with business finance and staffing costs, is pleased that he no longer has to “worry about the GST (New Zealand Goods and Services Tax) anymore”; he is content to be employed, not to be an employer.

Sean is different from the others in the cohort; he thinks his schooling had not been as significant in his early learning. He states that he had “learned from life experience not from education”. Sean also thought others, including family members, underrated his work:

My sons think I’m only a dumb truck driver. That’s what a lot of our customers think, that we’re just truck drivers. I’m a truck driver that’s it. Doesn’t matter whether you drive a big truck or a truck and trailer unit [but] there’s a lot of skill in it.

Although Sean’s children and others might think the refuse and recycling operators are ‘just truck drivers’, the fact remains that their jobs require some mathematics. No matter how variable the mathematics experiences of the operators may be, during the interviewing and observing all the operators talked about counting, measuring, using space and estimating. When asked about particular parts of mathematics Sean could estimate how many more bins he could empty and which streets he could drive through to complete a load. Other operators commented on the almost hidden links to their work. Josh talked about “the amount of maths that you do without realising you’re doing it... but it’s all probably subconscious”. Dennis also mentioned the more intuitive aspects of quantitative work:

You know, I think a lot of things you do you take for granted – you know you do it, just – second nature really. Just estimate all the time. There are things some people do in their work but it [estimating] helps.

This is not only one of the first references made to the use of estimation, but also introduces an intuitive way of thinking about the quantities in Dennis’ workplace.

4.2.4.3 *Prior working experiences*

All the operators had worked in other industries including those which involve commercial driving. Dennis explained that when he left school he worked in a sheep-shearing gang. He had then applied to become an air traffic controller although the tests at the application round were more challenging than he was prepared for. His prime motivation for becoming an army driver was so that he did not have to sit in the rear of an army truck. The work was occasionally interesting, especially those times where search and rescue situations were organised with less than twenty-four hours' notice. In his words Dennis left the army "when the cutbacks started".

Josh had also driven army troop transport and air cargo loaders while Sean had driven large transporter trucks which carry up to eight vehicles and weigh up to thirty-two tonnes. Noel worked in customer service roles in Europe and in Australia before immigrating to New Zealand. Noel is the only operator who had not driven heavy vehicles in previous work roles so he had to obtain this class of driver's licence before starting.

4.2.4.4 *Recruitment*

There are recruitment and training differences between the employed operators and the owner-operators. The original thirteen owner-operators (of Company Y) went to Melbourne for up to ten days to learn how to drive the collection vehicles. Noel describes his accompanying a driver trainer in the Melbourne suburbs, then after two days of observation being given the steering wheel to take over the run. As someone new to heavy vehicle driving, this was a challenging time for the newly licensed Noel especially with the variations in traffic rules at New Zealand and Australian intersections. A major intersection rule is now aligned and will be described in chapter five. When Josh was asked about the entry requirements to work as a contractor with Company Y, he explained that there were several things that were being considered:

It wasn't any literacy / numeracy competency stuff although in the interview process, the company made it fairly clear that they were looking for people that had business skills you know, because this is an individual business for the thirteen of us rather than just out and out drivers. Yeah, because I guess they've got a vested interest in us. It's a fairly wide-ranging group [but] driving skills they tested.

Sean is a relatively new employee of Company X, and he was one of two operators who began their employment with the company at the same time. One of the positions

involved one new operator collecting refuse while the other new operator collected recyclables. Sean states they were replacing people who had resigned and there was really no choice about which collection option they would get. After “a week-and-a-half to two weeks of training then I was out on my own”. He was unsure if there were any numeracy requirements when they began as operators but he believed that the new pair of operators “took to it quickly enough while there are others who take a lot longer – still getting it right”. Sean was adamant that it was “up to the individual really. Do what you’re told, you can’t really go wrong”.

The work of one of the operators, Josh, will now be described as he went through a typical daily run in a residential suburb. Using Josh’s words and documents, the numeracy practices which coincide with his work will be identified. Additional information about the environments they work in, with comments from the other operators as they describe their own experiences, will expand this picture of recycling and refuse operations.

4.3 Josh’s day as a recycling operator

As indicated at the start of this chapter, Josh is one of the thirteen original owner-operators contracted by Company Y to collect recyclables. When the researcher met up with Josh and his truck, he had already started on the second load of his daily run. In collection work, a run is considered a whole day’s collecting in an assigned area; a load is the amount of refuse or recyclables in the truck at any one time, so a load is emptied when it is full or it has reached a limit. A typical run may comprise up to four loads collected and emptied on the same day.

The researcher’s vehicle was left at the depot in South Auckland, and he was driven out by an administrative assistant to meet Josh, who was collecting recyclables along a relatively straight residential road in a western suburb of Auckland. This was a week in the winter school holidays and the traffic was noticeably quieter. Josh’s day began when he departed the South Auckland depot at 5.30am for a 6am start to his collections. On main roads, and along commercial, retail and industrial precincts, operators are permitted to begin collecting earlier than 7am. However, on residential streets operators cannot begin collecting until 7am. On the inside of the lid of every bin, a notice informs residents that they must put their bins out before 7am on the day of their collection. As will be described in section 4.3.1.2, when a resident is late taking their bin out, this creates extra work later for an operator and the company.

4.3.1 Factors that impact on the operation

4.3.1.1 *Time, School Environments and Seasons*

Josh explains how 7am appears to be a key time, and is not just a starting point when collecting bins in residential streets. He comments that driving anywhere after 7am usually impacts on his driving time between the depot, the collection area, and the recycling plant:

So if you're talking about equations and that sort of thing, at this time of the morning, to get from here back to (the depot) and back out to here will take 40 minutes ... just average it, 20 minutes each way; it only takes 2-3 minutes to tip off ... if you're before 7 o'clock in the morning you'll get a good run (but) if you're between 7 to 8 o'clock you can add 10 to 20 minutes to your run just because everyone is jumping into their car at 7 o'clock in the morning, listening to the news on the way to work. (In this passage, Josh's use of 'you'll get a good run' refers to having a shorter drive)

All the operators reported that their collections during school holidays are more straightforward for them since there is “less traffic on the road so it means the peak hours are less” (Josh). During the school term, however, the collection picture is different. Operators would only attempt school bin collections well before the school day starts, or between 9.30am and 2pm. Noel identifies these more rigid time constraints on their operation, “we have to get there (at least) half an hour before closing if school is going”. Dennis reports that the school traffic quickly builds up after 2 o'clock. At the time of the interview he had yet to collect those bins and he was very aware that he had only two hours left to be near the school before parental cars arrived to collect children. Sean describes trying to anticipate those parental drop-offs and pick-ups. Though he tries hard to get the collections completed before school begins he also acknowledges that “sometimes it doesn't always work – (during) parent drop-offs or pick-ups . . . sometimes they park their cars near entrances, blocking bins”. If this happens Sean usually has no option but to return when the cars have gone.

Traffic rush hours and school days are not the only time factors that operators must contend with. The seasons also seem to play a role when they are collecting. Winter collections generally have fewer loads. Josh commented during this run that at busier times of the year he would collect and empty four loads in this area. The weight issue is more critical for recyclers than the numbers of bins, although the two are related. As is outlined in 4.3.3, compliance around weight limits is critical for them. In December and the other summer months there are more bins to collect and as Josh notes “also the

bin weights are generally up [...] more barbecues, a lot more people entertaining”. Each operator notes that in the winter months people tend not to entertain as much, instead spending more time indoors. The bins appear to be rolled out less “so rather than putting a recycling bin out every fortnight they might put it out every second or perhaps every third time” (Josh).

Several of the operators suggested that in summer months people appear to drink more, so more glass is linked to heavier recyclable bin loads. As they became more experienced, the operators could detect when a bin was heavier than usual. Noel, Dennis and Josh all commented on feeling a heavier-than-usual bin when they operated the joystick – they feel the stick straining with the lift. It is a cue for them to check the camera in the hopper to see what is being tipped out. Recycling is a more detailed operation than refuse collecting and it sometimes appears to the operators that people discard just about anything. Dennis notes that when a refuse bin is too heavy, the hydraulic arm strains to lift the bin and might fight to reach even a halfway height. When asked what the weight limit is on his truck side-loading arm, Dennis estimates that the “max is about 110 (kg) on arms, maybe 100 – can vary a bit truck to truck”. Further, if he could not lift a bin Dennis would contact the depot so another vehicle could collect it allowing Dennis to continue and complete the rest of his run.

4.3.1.2 *Public Holidays and Weekend Collections*

Another instance involving time is when public holidays occur and a long weekend results; then the collection day is pushed back one day later. This usually means that Saturday is used as a collection day in lieu of the ‘lost day’ during the week. For those residents who now have their collection on a Saturday, Noel says that almost every bin is out. Residents appear to have used their Friday evening after returning from work to load their bins and take advantage of the extra time to fill their bins to the brim. Conversely, an advantage is that the traffic is usually lighter and as Noel notes, “I’m ten minutes ahead of myself . . . I am usually getting to (name of road) at 11.10am, but today we are here at 11am. A lot less motorway traffic on the way to the recycling plant” (Noel).

During the same Saturday collection, Noel and the researcher came across a group of three men standing near their recycling bin. Flattened cartons and packaging from recently purchased electronic items had been crammed into the bin. However, they had more packaging than their bin could fit and some had spilled out across the

surrounding grass verge. Legally Noel only had to lift the contents of the recycling bin and leave the remainder. Noel, however, had seen non-recyclable materials in the bin such as polystyrene packing foam and plastic strapping so he asked them to remove these items before he lifted their bin into the truck. On returning the bin to the verge, Noel invited them to load the bin with any other cardboard then he repeated the operation. Although Noel was obliged to do only one lift and empty, he did this in three lifts remaining vigilant to ensure that the men did not include the non-recyclables.

This instance of customer interaction with Noel is not an isolated case. Noel believes he was helping to teach these residents to recycle the correct materials and to place polystyrene and strapping in their refuse bin. Noel recognised his load still had some additional capacity and that he was near the end of his run. But he also confessed that he had made a note to check this bin in the next fortnight so that they had not put the packaging refuse back into the recycling bin. Offenders are usually cautioned using a system of cards, and these will be described later in section 4.3.4.2.

The Christmas season has some of the busier times for both refuse and recycling collectors. However, residents may not be as well organised. Brian describes how statutory holidays usually have no collection. Although Christmas Day is not a collection day, Boxing Day is. Several of the operators find that some residents have slept in or are away. In some streets on Boxing Day last year, Brian estimated only about 30 per cent of the bins were put out on time. This meant that operators had to offer some leeway and the daily run was not typical with some streets having return visits later that Boxing Day. Though this distorts their loading during the day, the twin elements of customer care and avoiding council complaints appear to be considerations for the affected operators.

4.3.1.3 *Collection Rates and Vehicle Maintenance*

Operators gain experience and efficiencies over time but they remember their beginnings as collectors. Noel recounts his first day as a recycling operator where he estimates he emptied “about ten bins in my first hour”. Dennis believes refuse operators have a steeper learning curve than recyclers but that they have “a faster rate of improvement” in collecting bins, since they must visit the same neighbourhoods once every week and they simply empty more bins. Dennis recalls a personal achievement by developing speed and competence in the collection operation during

his first month. He was pleased when he achieved his first 1000 bin empties. Now, if he has a run of relatively light bins, Dennis is often able to “empty 1000 bins before lunchtime” (Dennis).

In order to maintain these lifting and emptying rates, vehicle maintenance on all of the moving parts is critical. During a collection run, each time a truck moves between bins it has a stop-start motion. Not only does this consume diesel fuel, but over time it is also exacting on the brakes (which are checked monthly), with each truck stopping and restarting up to 1400 times per day. It is no surprise then that truck tyres last about three months before being replaced. Josh states:

Just as a truck gets more and more tired over seven and then nine years, mechanically the engine may need some sort of an overhaul. We actually don't do a lot of kilometres compared to other road users but we're quite hard on brakes and tyres.

Noel says that each tyre costs him over \$600, and that when he was due to replace tyres, he would usually then replace two (either both front tyres or both rear tyres). On trips to the depot, the researcher noticed the frequent visits of a tyre repair truck. The hydraulic system for the side-loading mechanism is one of the most used parts of the truck. The site manager stated that in refuse trucks (which lift smaller though normally heavier bins), the arms typically lift and return over 1400 bins every day. At close to 7000 lifts and returns per week, the drive belts and hydraulic systems need to be monitored closely and repaired if there are signs of fraying. To this end, Company X employs an auto-electrician who works on the weekends checking and servicing the trucks, including the on-board electronic systems. In the case of the owner-operators, they are liable for all of their own truck costs.

4.3.2 Counting Bins

As Josh's second load proceeded, he describes his bin counts and how he observes the limits. When the interview began, Josh had already emptied one load at the Visy recycling plant, and he was progressing through the second load of the day's run.

Table 4.2 *i!preadsheet Cf Josh's col/ectie>l lisle»-y in the preceding month Retrieved from the owner- operate»-, .hsh and Company Y.*

r-	DAY	DATI	THHO			■	1110- HOUS	IW)MilliD	TOTALME eouHT	!Of WI!IOHI	I.Oo\l),		LOAD2		LOAD I		LOAD<				
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Josh shared the records (Table 4.2 above) of bins he collected during the previous month. He looks for indicators throughout his run such as the weights and bin numbers after completing the first few streets; these then give him a sense of how his collection day will unfold. Table 4.2 above is the spreadsheet of Josh's collections in the previous month (a copy is provided in the Appendices). This spreadsheet provides Josh with, amongst other data, the numbers of bins collected each load, for each daily run, and during the month. The weights have still to be added to the spreadsheet. Some details in the table have been blocked to protect the operator's identity.

On this particular Wednesday with the researcher, Josh had made decisions based on the spreadsheet of previous loads (see the circled dates in Table 4.2 above). He explains that "in my first load I always push the boundaries of the number of bins I can put on, or the weight, because that will give me an indication of how the rest of my run is going to go". Referring to Table 4.2:

I'll look at the last fortnight that I did this run, then the time before it, and find out what I had. This run will average about 850 to 900 bins so I can do that in two ways: I can split it in four and do four runs of 200-ish or I can do three runs of 300. And this morning I picked up over 300 bins (310 bins) and weighed in under four tonne (3.88t).

The two fortnights of the previous month may have been relative irregularities compared with the way the run was unfolding for Josh (see circled features in Table 4.2). In the earlier fortnight for instance, a point to note is that the Monday was a public holiday, so instead of collecting on the usual Wednesday Josh had to collect the bins in this area on a Thursday. A second point is that Josh needed four loads to empty just under a thousand bins on that collection day. Reasons behind this increase may include people having had functions or activities on their public holiday, thereby generating extra recyclables in this neighbourhood. Alternatively, Josh may have had to assist another operator who could not complete his own collection area hence necessitating an extra load.

The later fortnight (circled in Table 4.2) returned to the usual Wednesday collection day and Josh picked up a total of just over 840 bins as opposed to the total of 989 bins collected in the previous fortnight. Again, Josh went with four loads and he explains that even with the difference in bin numbers between the fortnights, the traffic and the peak time were what he considered here:

There's a difference of 140 bins there straight away, or 150 nearly, but it only weighed ten-and-a-half tonne... I did (the run) in four, a quick run – the reason for that was the traffic was crappy, and to go from here all the way to the south-western tip-off and come back. So I did a dash for cash basically; I grabbed those bins, whipped it in, nice and light, was only half of what I needed to put on, the next load slightly higher but still underweight, and the same ones there (pointed to the last two loads).

Based on the spreadsheet in Table 4.2 above Josh thought that for the day's run he would err on the side of caution, estimating that his load would “fall somewhere in the middle, you know, hence the 300 bins for the first load, um so I could have done (previous fortnight of 841) that in three loads of 270-280”.

The spreadsheet Josh provides in Table 4.2 also illustrates the effect of the seasonal variation mentioned by the operators. Compared with the summer months, winter weeks have one less load to collect, and one less visit to the recycling plant to manage in their day. In the above table, only six of the twenty-two collection days saw Josh needing to take on four loads, and two of those loads appear in the week immediately following the public holiday. In the case of owner-operators Noel and Josh, there are business efficiencies with one less load, since that means less mileage and less fuel consumed by their vehicles for that collection day, and therefore less wear and tear on their trucks overall.

The figures in the spreadsheet in Table 4.2 are usually collated by the administrators and summarised for each operator. The owner-operators originally at Company Y also had their respective data for the month summarised in a second spreadsheet (Table 4.3 on the next page - also presented in the Appendices). That monthly summary for June in the previous year, for Josh, Noel, and the other eleven owner-operators, follows.

Josh's figures have been transferred to this spreadsheet (from Table 4.2) along with those of the other operators. Although Josh has collected the most bins in the month, there are similarities in the figures for all the operators in Company Y. Examining the respective rows for Josh and Noel, some quantities appear to be close. Josh travelled 2096km in total for the month, whereas Noel travelled 2098km. Their total weights were also similar, with Josh emptying a total of 234.44 tonnes against Noel's total weight emptied of 232.44 tonnes; and Noel and Josh each completed an identical 72 loads for the month (see Table 4.3 below).

Table 4.3 Spreadsheet of Company Y owner-operators' collection histories in the preceding month. Retrieved from the owner-operator, Josh, and Company Y.

MONTHLY SUMMARY OF TRUCK STATISTICS													
AUCKLAND RECYCLING								MONTH - JUNE 2010					
Name	Rego	Fuel	Truck Hours	Lt's/hour	Km's	k/100 L	Km's/hr	Bins	Bins/hour	Total Weight	Kg/bin	Loads	Weight / load
Josh	886	1185.00	155	7.65	1810	152.74	11.68	17607	114	229.30	13.02	70	3.28
	890	1402.00	153	9.16	2096	149.50	13.70	18563	121	234.44	12.63	72	3.26
	881	1490.00	164	9.09	2050	137.58	12.50	17408	106	241.46	13.87	75	3.22
	883	1557.00	174	8.95	2098	134.75	12.06	17873	103	230.20	13.42	73	3.29
	884	1269.00	163	7.79	1748	137.75	10.72	17639	108	230.58	13.07	69	3.34
	889	1350.00	161	8.39	1741	128.96	10.81	18167	113	237.68	13.08	72	3.30
	887	1285.00	155	8.29	1955	152.14	12.61	17390	112	236.38	13.59	72	3.28
	882	1435.00	140	10.25	2269	158.12	16.21	17406	124	234.44	13.47	74	3.17
Noel	970	1237.00	142	9.30	1956	158.12	13.52	17161	118	236.20	13.76	71	3.33
	885	1331.00	156	8.53	2164	162.58	13.87	17346	111	239.84	13.83	75	3.20
	969	1371.00	160	8.57	2098	153.03	13.11	17608	110	232.54	13.21	72	3.23
	888	1321.00	146	9.05	1885	142.69	12.91	17973	123	241.18	13.42	75	3.22
	972	1610.00	141	11.42	2294	142.48	16.27	17081	121	236.02	13.82	75	3.15
Totals :		17843	2010	116	26164	1910	170	229222	1485	3060.26	174	945	42
Averages :		1372.54	154.62	8.96	2012.62	146.96	13.08	17632.46	114.22	235.40	13.40	72.69	3.25

There were also variations between the two drivers, such as Josh's total bin number of 18,563 bins, compared to Noel's 17,808 bins. When considering the closeness of the total weights emptied, this accounts for Josh's mean weight per bin of 12.63kg being lower than Noel's 13.21kg. Note that each of these operators' mean recyclable bin weights (in Table 4.3) is well under Dennis's refuse bin weights, which on occasions can be over 100kg. Finally, Josh's faster mean bins emptied per hour (121 to 110) may be responsible for his lower truck hours. This rate however, and the fact that Josh emptied over 750 bins more than Noel driving almost identical distances, might also account for Josh's relatively higher fuel consumption.

However, some discretion is required with the data in Table 4.3. Although Josh has worked 163h, 45 min in total (from the previous spreadsheet on Table 4.2) he is credited with having 153 truck hours over the month (Table 4.2). Josh's bin rate of 121 bins per hour is dependent on his total collection of 18,563 bins divided by the 153 truck hours. When viewing these truck hours it appears that some of the hours are used up with travelling from the depot to the collection area, then on to the recycling plant. But the ten-to-eleven-hour difference between the total working hours and the truck hours does not accommodate all of this travelling time. So this non-collecting time is probably included in both sets of hours. If the truck hours only included collecting time, then the bins per hour rate would be much higher, and more closely reflect the pace of collecting that the operators appear to manage.

This pace of collecting is also considered when operators are estimating when they need to depart the run to empty their loads. For example, as Josh was nearing the end of the second load he was already deciding on an exit strategy. This was aided by his knowledge of the run and the small number of bins in one particular street:

Thinking ahead, how I said that I've probably got around 50 bins if I go this way. Up ahead on the right-hand side there's a cul-de-sac which has got about six to eight bins in it. To get me up again I'll go and do those six to eight bins.

Although Josh gives the impression that he could see the mathematics in many of his actions, there was an isolated case where he did not recognise what he was planning to carry out as being anything mathematical. One example of the invisibility of the quantitative information he refers to, including directions and counting, was:

Usually I would go in here and do a big figure-eight, so I go down, left – left – left – left, back to this point, and then straight across, then left – left – left and come back out of that street again. That will put me over the number of bins

that I want to have for my 300, or as close as to 300 as possible, so I could do that but it means that I'll come back on the third run and start half a street. ... I'm a Libra (laughs), I like things being equal so I'll try and get this as close to 300 doing it this way and starting afresh on a completely different area for my third run. There's no mathematics involved in that at all.

Although Sean is one operator who did not believe he had any mathematical ability, as a comparative newcomer to being a recycling collection operator he could still however, identify several numerical demands in his workplace practices. He knows that once his load is at a certain weight, he would "keep doing weigh downs. You could put only another ten bins on, and that might finish the load already". He was beginning to realise that as he comes to the end of a load, there are a "couple of streets I don't go into when you're almost full . . . just too many bins". So he acknowledges that collecting along these streets would make his load overweight. Instead, as a new operator he sought advice from more experienced staff stating, "drivers that did this run before me told me where to start".

Other operators were also asked whether they could guess how many bins are expected in a street. When Brian was asked to quickly estimate how many bins were on the road ahead of him, he answered there would be ten or eleven and he was correct. Others' responses usually came down to experience with working in the neighbourhood. Sean's reply included the observation that the number of bins in a street would alter with new residences being built; also if there are many flats down a driveway, that makes the estimate more challenging. An instance of this occurred with Dennis when visiting a set of terraced flats and apartments, where there were between twenty and thirty bins lining a right-of-way out of sight of the road. Dennis knew this arrangement of bins would be here since the number of bins corresponded to the array of letterboxes at the opening of the right-of-way. In another instance, during Dennis' earlier load, he had deliberately gone to "a tricky street" in his run, which he knew from experience had bins habitually heavier than others on this run. Instead of waiting until later in the day, Dennis "took care" of these bins as he was almost certain the bins in adjacent streets would be lighter in weight and he could empty more bins.

The operators also link bin numbers with time. In one instance, Brian states that he would lift a bin every twelve to fifteen seconds. This timing was later verified by the researcher from observations outside the collection vehicles of several operators. This time range is possible if the operators have unrestricted access to each bin without needing to alight from their cabs. It also means that experienced operators will look

down a street and anticipate the time to collect. Josh stated during his second run that he could, “predict ten minutes collecting here, fifteen to twenty minutes there”, and he appeared to be accurate to within two minutes each way. Dennis forecasted that in the busier weeks, the refuse loads would have at least 10 per cent more bins, and this equated to another thirty minutes added to the day’s run.

4.3.3 Weight Compliance

As mentioned earlier in this chapter, there is a compliance factor for recycling operators but not for refuse operators. In theory Dennis could keep emptying as many refuse bins as he could fit; however, he reports that a load of nine-and-a-half tonnes is a safe load in his vehicle, and this is dependent on the loading on his axles. In comparison, as Josh reached over 70 per cent of his second load of recyclables, he was taking care to ensure that the load complied with the limits imposed by the recycling company, Visy. The site manager had explained earlier that the load limit is part of an agreement between the city council and the recycling plant, Visy, and involves acceptable compaction ratios at the recycling plant. If a commingled load arrives at the plant overweight, the inference is that the materials are too compacted and therefore will take staff and machinery at the plant more time to separate. The collection companies must comply, otherwise they sustain financial penalties for taking overweight loads into the recycling plant.

The smaller recycling vehicles such as Josh’s and Noel’s, both owner-operators, have just under four tonnes of recycling capacity, so both men are very alert to any loads which are nearing three tonnes. Brian’s vehicle has a larger capacity, of over five tonnes, so he has some runs which collect over 30 per cent more bins than Josh or Noel. Constant monitoring of recycling load weights is therefore vital if financial penalties are to be avoided. Josh states “when my truck is about two-thirds full, I stop regularly and check”. The collection company pays overweight loads of those operators in their employ, but the operators suggest it is a rare event. With Josh and Noel being owner-drivers of recycling trucks, they are vigilant about their loads as they must pay any overweight fee themselves. Josh describes the likely chain of events for an offending load with “if we put on too much weight then we get penalised going across the scale by Visy who put it on to the Council, who put it on to us!”

To assist each operator a set of weighing scales is in the truck hopper; these are generally inaccurate if the truck is on a slope, so operators wait until their collection

run is on a level piece of road before checking. Earlier in the run, Josh referred to these in an approximate sense:

The scales work off the back air bags. But you need to be on a fairly level area for them to give you an accurate weight. So here we're actually going slightly uphill – that's telling me I've actually got about twelve tonne on. The truck weighs about ten so I'm about half-full at the moment. So I wouldn't double that (170 bins on counter) and put on 340 bins but I will push towards 300 (bins) again. Trying to press for that three trips rather than four.

Not everything always goes according to plan unfortunately. Returning to an early part of Table 4.2, Josh illustrates the vagaries of the bins and their weights by showing another run on the first day of the month, in the Eastern zone. On that day's run (see Table 4.4 below extracted from Table 4.2), Josh had picked up almost 900 bins, using three loads, with each load respectively 310 bins, 294 bins, and 290 bins. But though the load numbers were similar, the loads had quite different weights.

Table 4.4 *Spreadsheet of Josh's first week of the preceding month, including one non-compliant load. Retrieved from the owner-operator, Josh, and Company Y.*

DAY	DATE	TIME			FUEL LITRES	ENGINE HOURS	KILOMETRES	TOTAL BIN COUNT	TOTAL WEIGHT	LOAD 1		LOAD 2		LOAD 3	
		START	FINISH	Hrs:Mins						BINS	WEIGHT	BINS	WEIGHT	BINS	WEIGHT
*Enter Previous Months last Engine Hr & Kilometre						3,623	49,209								
E	Tuesday	01	5:30	14:30	9:00		3,636	49,387	894	310		294		290	
A	Wednesday	02	5:30	11:00	5:30			783		313		297		173	
S	Thursday	03	5:30	14:00	8:30			900		307		313		280	
T	Friday	04	6:00	13:30	7:30	157.6		828		275		273		280	
	Tuesday	08	6:00	13:15	7:15	160.06		984		348		318		320	

Josh's total weight for the run was below the compliance loading but there appeared to be one rogue or disproportionate load when comparing bin numbers to overall weights. As Josh explains:

I've tried to do three runs of 300, um and I've done it, come in underweight, but I've gone over. Underweight for the day but overweight for an individual load. And that is one I'll be penalised on. Funnily enough, you see (the first load) has the most (310) bins, but only weighed 3.78 (tonnes). The middle load is the second lowest total there, but weighed 4.12 tonnes, . . . less bins than the first one but still slightly more (weight), it's still over 200 kilos heavier (than permitted).

However, there are other comparatively light days where the scales may not even be used. On an earlier run in the week, Josh anticipated a total of only 750 bins in the collection area and "that is likely to result in there only being a daily total of nine-and-

a-half tonnes”. When the day’s second load passed two hundred bins, Josh began to scrutinise the scale readings more purposively. As the load weight readings approach the limit, Josh’s estimates, conversions and calculations about how many more bins may be emptied appear to increase in accuracy:

This truck’s about 10,070kg when empty . . . add the driver’s weight, and a full tank of diesel, the full weight will be 10,260kg; if diesel is a quarter full, it’s a bit under 10,200kg . . . each load max should be about four tonnes and if we could do that every time then it would save us in driving and that sort of thing.

After Josh collected the eight bins in the short cul-de-sac, he turned the truck right onto another street and collected more bins until reaching a corner. After finding a level piece of road, he weighed the truck and the load and adjudged he had collected enough bins to complete his second load of the run (276 bins), without running the risk of being over the limit. Josh explains that originally scales were not fitted into the owner-operators’ trucks. The only time that an operator would find out whether his load was compliant was at the weighbridge:

If I’m only over by say 4.01t, say, that’s only 10 or 20 kilos, but if I go over 4.32t or 320 kilos that will probably be a fine of a couple of hundred bucks. Yeah, ouch – in the days before our scales . . . when we were still learning the trade . . . some of the guys were getting fines of up to \$600 to \$700 a month.

Josh switched positions with the researcher to sit in the right-hand side seat in order to drive the truck to the Visy recycling plant in Onehunga. As each recycling operator drives the laden truck into the Visy plant, it stops on a weighbridge near the entrance; an electronic sign advises the operator of Gross (weight) of the truck plus its load, and the time it arrived. The display below, in *Figure 4.8*, is of a 14040 kg gross weight as an operator passes over the weigh bridge on entering the recycling plant.



Figure 4.8 Electronic display at Visy weighbridge informing operator of the truck’s fully laden weight of 14040 kg

When operators drive in to the recycling plant, they take their trucks to the yard at the back of the plant for unloading. Noel explained how his rear camera allows him to reverse his truck to the pile of recyclable materials then tip his load (*Figure 4.9* below).



Figure 4.9 Recycling Truck emptying its load at Visy Recycling Plant, Onehunga

When the researcher had visited this large yard previously, there was usually material emptied from other recycling trucks which a front-end loader then prepared for sorting. Noel also suggested that a rear camera allows them to remain seated, with no need to alight from their cabs, though he is alert (using his mirrors) for any broken glass near his tyres. Noel states that this load is 3.68 tonnes, and when asked if he had considered squeezing another 30 bins in to the load, his response is “no point – I have another 210 or 205 bins left. So (those) will fit in the last load. I don’t need to take any risks.”

As each operator drives his empty truck back to the exit, he again stops on the weighbridge, this time to register the weight (tare) of the empty truck, and receive a small paper printout. Josh retraces his path, and he is already “planning the route out of here, depending on a (final) load of up to 270 bins”. That day, his expectation of less weight and an estimated total collection of 840 to 850 bins meant he safely negotiated the weight limit and emptied a second load of 276 bins. Since he had already collected 310 bins in his first load of the 840 bins in his original estimate, he then expected that this (third) load would be his last load of the run.

4.3.4 Driving practices

During the last run, Josh describes the mirror features on his vehicle. All the collection trucks are fitted with wing mirrors on each side and these appear to be used extensively by all the operators who were interviewed. Josh describes himself as a “mirrors driver” rather than looking out the window:

I think when we all began we probably all started to look out the window and that sort of thing, and you do have to do that in quite cramped or close areas, but yeah I will probably just sit here and use the mirrors, especially again today because it’s a relatively easy run to me.

With an operator driving and collecting from the left side of the cab, the right-hand wing mirrors assume considerable importance when checking for roadside traffic passing the truck. Left side mirrors are used to line up the side-loading assembly with a bin however, operators do occasionally check over their left shoulders for bins that are not lined up or are being returned to uneven ground. Some grass verges are not level and these may slope towards the road, so returning a lighter bin is sometimes a stability challenge especially on days with more wind gusts. Josh comments on this stability by comparing the 120-litre refuse bins with the 240-litre recycling bins which are wider:

That's good when it comes to putting the bins back down again – a bigger surface area (240L bins) means they can fall over less. Their ones (refuse bins have a similar height but are slimmer than recyclable bins) – there's only a slight fall or rise on this hill here and it doesn't take much to tip the bins over. Takes even less to tip the red (lidded refuse) bins over.

Dennis collects refuse and like Josh mainly uses the mirrors; he has these “angled to see but sometimes I need to look outside too”. A central rear-vision mirror is of no use to the operators as the back window of the cab is completely filled by the truck hopper. However, as drivers of other vehicles and motorcycles approach the truck they may be unaware of this restricted vision, and as Dennis suggests operators need to anticipate anything with, “you’ve got to be aware and expect ... maybe cyclists in your mirrors.” Sean considers the footpath side too and adds that although he also uses the mirrors, he still prefers to leave his window open as, “I like to look out and see who’s behind you and stuff; kids running up behind you, beside you”.

4.3.4.1 *Safety*

Keeping curious younger residents at bay is not unusual, as they may be drawn to the noise of materials such as glass bottles being tipped into the hopper, and also to observe the moving arm and claws. According to Josh, the reach of the arm is almost two-and-a-half metres and sometimes these need to be fully extended. Operators thus position their left-hand mirrors so that the nearer of the two claws is fully visible, they can see the bin approach, and check the area around the bin is clear. As each recycling and refuse bin is tapered from the bottom to the top, the claws grab bins about halfway up the bin for a firm grip and a stable lift while emptying, to ensure all the material drops into the hopper. When bins are overfull, care is taken but inevitably some materials fall out. Operators often alight from their cabs if they see that an overfull bin

is going to be a challenging lift, and if they believe a roadside mess would result. While on the ground, an operator ensures the bin lid covers any protruding material, and he straightens the bin before activating the lift. If the bin is too challenging, other options are available to the operator, such as calling their administration or tagging with a sticker (see 4.3.4.2).

There are however, dangers when getting in and out of truck cabs. In fact, with the heights of the cabs that the operators work in, it is less a case of getting in and out and more about climbing up and down. Experienced drivers appear to know the safety risks associated, particularly with descending from cabs, and Brian reminded the researcher about this when leaving the cab. There are other resources, including overseas websites, which remind drivers of the impacts and injuries which may be caused by a fall from a cab. One overseas website (Trucking Safety Council of British Columbia, 2011) is shown below in *Figure 4.10*, where a user is invited to interact with the photograph of an open truck cab, by clicking onto each of the three steps leading to the cab.

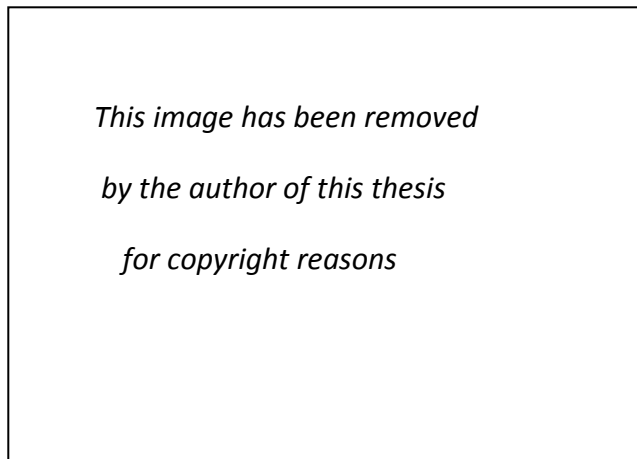


Figure 4.10 Image from a Canadian website showing hazards when descending from a truck cab.

The green figure appears, representing the driver, then jumps from the different steps onto the ground, and the forces on the figure and possible injuries are shown on the graph to the right. Similar messages from the Accident Compensation Commission (ACC) are provided in posters placed on company noticeboards, reminding its drivers to always use three points of contact on descent. Descending from or ascending to the cab is something each operator would prefer not to do too often. However, there are responsibilities that each has with the bins on their runs.

On the third run Josh approached several bins with their lids ajar and with recyclable materials clearly visible. Josh stated that all the council brochures and other sites say:

that the lids aren't allowed to be up or raised at all so technically I should sticker that bin and say it is overfull and all that sort of thing ... um for me to get out and spend two or three minutes writing that for every twentieth bin it's a bit unrealistic time wise.

So as long as a bin may be lifted without spilling its contents then it usually does not seem to hinder the operators as they collect, and they judge whether they need to leave their cabs. Unfortunately, there are other bins and residents which need attention as described with Noel's situation during his Saturday collection. Josh describes the possible hazards:

It's the bins that you may see that are overfull and full of bottles that the drivers are wary of – because if we don't pick the bin up square and shake it then we are responsible for any spillages that we incur while we're out there. So you spill a bin that's top-heavy or too heavy with bottles in it, then you've got to stand there for the next ten minutes to clean up the mess that you've caused.

All the operators mentioned that having to tidy up after a bin load is spilled is a nuisance that they would rather avoid due to of the time taken away from their collecting.

4.3.4.2 *Bins which cannot be collected*

Some materials in a recycling bin cannot be ignored as the whole load may become contaminated. Sean and Brian have different approaches. Sean was doing a recycling run in Manurewa, a large southern suburb. "We get more rubbish out here – some mow the lawn and put it in the (recycling) bin. You can't pick it up". However, Sean has found the remedies are more about communicating with residents than putting regular cautions on bins, believing that some local residents might not be able to understand the warning notices:

I find it better to communicate with someone than to put that on their bin. A lot of people out here might not understand what it means... Yep. It's about training. A bit of paper may not work. I find talking and showing them what to do, and they'll learn quicker not to put, say, dog poo in the bin is probably better understood by them.

Brian's approach is not so remedial with bin offenders. On one morning of the recyclables run in a southern suburb, Brian and the researcher come across several bins that could not be emptied, not because the bins were overloaded, but the refuse

contents that had been put into the bins were not recyclable. In one bin, Brian notices an old ironing board that was squeezed between two large sheets of cardboard.



Figure 4.11 Brian attaching a red (not being emptied) notice to an offending bin load

In a second bin two streets later, an overfull bin had discarded infants' nappies near the top (see arrow in the photograph of *Figure 4.11* above). With these offending bins being on adjacent streets, Brian's response was the same in each instance, to descend from the cab and 'sticker' each bin. The 'sticker' or card system (see Appendices) is a means of communication between an operator and the residents on his run.

The system uses three colours. The yellow card is an *Attention* message or a first reminder that although a resident's bin has been emptied, there are issues with overfilling, bin weight or damage, or other recyclables outside of the bin. The orange card is marked *Warning* and states that incorrect items such as plastic bags, clothing, or hazardous items are seen. Unfortunately, these items may be noticed too late, as the contents of the bin have already been emptied in the truck hopper. The sternest sticker is red and marked, *Your Bin Has Not Been Emptied*. This is the card that Brian attaches to or 'tags' the bin in *Figure 4.11*, and which is provided in *Figure 4.12* below. Its text is similar to the non-recyclable items on the orange card.



Figure 4.12 One of three resident advice cards which every operator carries

Operators usually see these offending materials and items before the bin is lifted and have little option but to mark the bin. The bin is left outside the residence without being emptied and the address is written on a recording sheet which the operator keeps in the cab. Adding to this household's offences (from the photograph on the previous page) is the carton that can be seen on the right of the bin. An operator would not collect this since it is considered extra and, as Sean adds, it encourages residents to repeat the act on following collection days:

A lot of people leave other stuff like cartons and crates and bits around beside the bin. If you pick everything up (beside the bin) then you'll be here until 9 o'clock tonight. And they'll put even more out next time.

That is the reason Noel made a note of the address described earlier in section 4.3.1.2, where he had seen three men attempting to put non-recyclable materials into their bin.

4.3.5 Locality variations

4.3.5.1 Inner-city suburbs

Josh mentioned that the area he was working that day was a relatively straightforward place to collect bins as every house has a driveway and berms between. Though these neighbourhoods were never designed for bin collections by the collection vehicles such

as these, the collecting did appear to proceed smoothly with fewer challenges than other operators face. Josh estimates:

As you can see there are parked cars but I think I've only had to get out once since you've been in here. Some of the guys today are working Ponsonby, Franklin Road, Grey Lynn – all of that sort of thing, where it's 1930s sort of villas, no off-street parking or very little [. . .] everyone's got a car or two . . . so everything's parked on the road, and in the time that I can put on 200 bins they'll be doing only 80 or 90.

The oldest suburbs often have residences which were constructed before automobiles became the predominant mode of transport, so there are still some houses which do not have their own driveways (see the dashed arrows outside residences 14 and 18 in the photograph in *Figure 4.13* below).



Figure 4.13 A street in an inner-city suburb where some residences without driveways (along dashed arrows) have cars parked on the road blocking bin access.

Without driveways and off-street parking residents have no option but to park their vehicles outside their properties. Since operators must then descend from their trucks to move the bins between parked cars, the resulting bin collection proceeds at a comparatively slow rate. With this parking situation, if Josh's estimate is correct he collects bins in the outer suburbs at over twice the rate (bins per hour) of inner-city collectors.

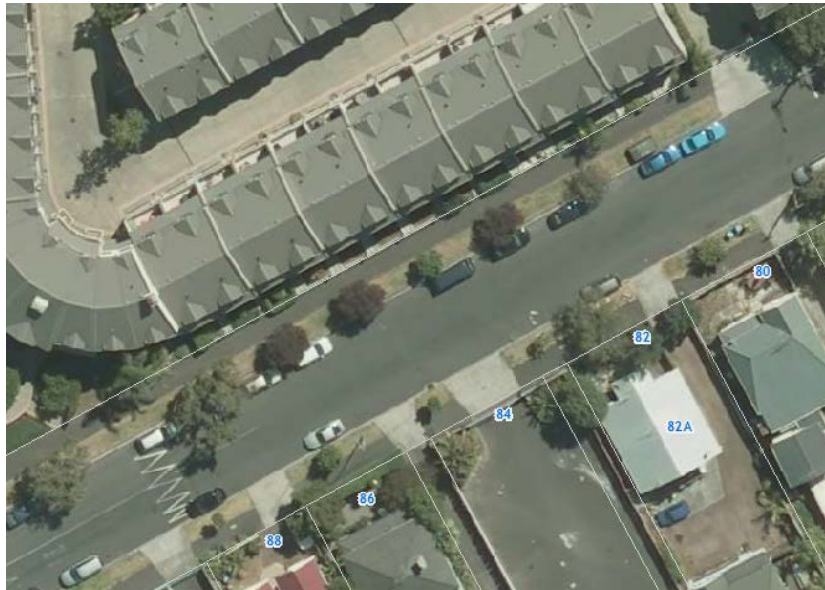


Figure 4.14 Contrasting apartment housing (longer verges) with older housing

The photograph in *Figure 4.14* above is of another inner city suburb with contrasting newer attached housing and apartment styles on one side and older homes on the other. The road frontage outside the apartments has a relatively long berm but almost all the space is taken up by parked cars. The older houses on the opposite side of the road occupy larger sections with driveways and almost individual berms. Again, the berms have vehicles parked along their lengths so on collection days, if the operator has not been able to get to this street between the times when residents' depart for work and when other people arrive for work, he has very little option but to alight from the vehicle and wheel the bins out onto the road for collection.

Some residents and drivers move bins to make them more accessible for the operator. With any narrow street or lane, bottlenecks can sometimes be created due to the nature of the collection operation and the size of the trucks. Although these queues often dissipate in a matter of minutes, some disaffected drivers are an inevitable result. In some suburbs that adjoin the city's commercial areas, narrow lanes abound and the berms often have quite mature well-established trees growing on them. Bins then need to be drawn towards the truck so that tree branches do not interfere with the bin lifting. Also, when vehicles are parked on either side of these narrow lanes this leaves a leeway of just centimetres for large vehicles such as collection trucks to pass through.

Noel works in one of the oldest suburbs and due to the narrow one-way streets with parked cars obstructing his access to bins, he has hired a runner to assist him to shift the bins. Noel pays this person directly since he is contracted and responsible for this

run. The bin runner walks ahead of the truck and wheels all the bins out onto the road. While Noel is emptying the bins on the left side of the street, the runner draws the bins out from the right side of the street. Once Noel reaches the end of the street, he turns to start emptying the bins on the opposite side; meanwhile his runner will be returning the bins to the berms on the first side. Noel only employs the runner on the days he is collecting in the inner city suburbs but he estimates it has saved him perhaps a few collection minutes per street by not having to get out of his truck.

Another feature of inner city suburbs is that some driveways have been recently installed so that off-street parking is now possible for those residents. A result however, is that those new driveway installations shorten the lengths of the berms outside those residences. The consequence is that others who park beside those berms during working hours take the whole space, completely obstructing the bins from the collection vehicle. Bins might then be put in driveways since those are the only spaces available and operators usually return the bins there. This has possibly become more challenging with new housing developed behind older villas and bungalows.

Driveways may then go to the back of these sections and, as Josh states, “instead of one bin there’ll be three bins behind, because there’ll be an old villa at number sixty-seven, and then . . . sixty-seven Alpha, Beta, and Charlie houses down the back”.

4.3.5.2 Construction zones

On or around building sites, extra pressure is placed on access space, especially maintaining entry to and exit from the sites for suppliers’ delivery vehicles and the vehicles of construction staff. Site foremen usually time the arrival of the delivery vehicles so that the nearby street does not become too congested. However, refuse and recycling days may be overlooked initially, thereby creating a collection challenge for the operators. Occasionally operators find trades vehicles parked in between their truck lifting gear and the bins on the verges; this non-consideration of the kerbside access for bin collectors delays the collection operation. The alternatives for operators again are to get out of their trucks to move bins, or to arrive at the site before the construction team in order to empty the bins. Also trucks delivering materials to construction sites may actually be impossible to pass, necessitating the collection operator having to return to that part of the street later in the day.



Figure 4.15 Construction on an inner-city residence impacts on traffic and collecting

The photograph in *Figure 4.15* above shows construction work on a property necessitating the street being partially blocked. The road cones and temporary plastic fencing will often be removed for refuse and recycling access, especially if the operator arrives there early in the morning to perform the collection. Sometimes a member of the construction team will move bins into position for the operator. The operators report that road construction workers seem to be more in tune with the regime of recycling and refuse collectors than private constructors and developers are. All the operators commented how the road construction teams generally move the bins away from their road or berm work and on to the street to make it easier for these to be emptied. Once the bins are emptied, a road construction team member usually returns the bins to the respective berms outside their residences.

4.3.5.3 *Culs-de-sac*

There are other street designs which present challenges to operators. The photograph below (in *Figure 4.16*) is of an industrial cul-de-sac where parked cars occupy the roadside around the arc at the top end of the road. A feature of industrial streets such as this one is that the driveways may lead into multiple business premises – so although there are at least six driveways shown below, there may be three to four times that number of businesses in the street, and consequently the same number of bins vying for position on the footpaths and berms.



Figure 4.16 Cul-de-sac in an industrial area showing limited daytime parking by workers and consequent challenges for operators

This also means that the frequency of vehicles visiting the premises in these driveways will be greater with courier vans and delivery vehicles needing access. So an operator must also be careful not to block any entry into the circle nor its driveways, for more than a few minutes at a time. Also, the arced shape of the curve does not match the straight sides of the collection truck, and therefore tests the reach of the side-loading arm from the side of the truck.

The parked vehicles fill the available kerbside spaces in the cul-de-sac, thus forming a barrier to the operator reaching the bins (along the dashed curve in *Figure 4.16*).

However, an earlier collection before the vehicles arrive is often unsuitable. Dennis points out that empty bins are sometimes stolen in industrial areas such as the one shown in *Figure 4.16*. A compromise is to carry out the collection after 9am when the operator knows that the workforces have arrived and are parked for the day; also staff members are present to retrieve their empty bins. This also means there is no option but to alight from the truck and roll the bins out on to the street for lifting and emptying. The bins are then returned to the footpath behind the parked cars and again that adds time to the collection.

Yet another safety element arises with the decision regarding where an operator can park his truck. In the cul-de-sac shown above there is a relatively narrow ‘neck’ leading into the end circle so the operator has to temporarily park the truck beside the front car (of those shown) ensuring there is enough room to reach bins but far enough away from the cars and to enable other vehicles to pass on the right side of his truck.


Many suburban residential areas also have culs-de-sac which have bins placed around berms shaped as arcs, and these make collecting a challenge. The arrows in *Figure 4.17* below indicate the various manoeuvres needed by the operator as he collects bins (marked ) around the arc of this cul-de-sac. The three bins placed outside residence number 21 at the arc end of the road in particular require more attention than bins along straighter parts of the road.



Figure 4.17 Cul-de-sac in newer residential suburb showing challenges of truck collection angles

The middle bin has to be wheeled out due to it being behind the parked vehicle. If the car had not been parked there the operator would still have needed to reverse to get access to the middle bin. If an operator reverses the truck however, he is careful not to hit any bins he has just emptied. In fact, great care is taken by the operators with any reversing in their vehicles since there are blind spots at the rear of the vehicles. In these newer suburbs, the kerbstones are shaped concrete and gently sloping, set at a lower height than the upright basalt kerbstones in older suburbs. This enables an operator to align the vehicle by sometimes driving closer to some of the berms in order to gain a straighter line of access to those bins placed on an arc (see arrows indicating truck alignment in *Figure 4.17* above). In spite of the bin placements and collecting angles, Noel suggests that driving in places like this is performed with more confidence, knowing that the tyres on his truck will be relatively unscathed if they brush against such low kerbing during a manoeuvre.

Brian also collects in suburban culs-de-sac and recalls how he emptied recyclables in a particular run in a South Auckland subdivision that contained forty-six culs-de-sac. On some of those occasions, Brian would take his truck “the wrong way” (Brian drove around the on the right-hand side of the loop) in order to make collecting easier and complete both sides of the street (see *Figure 4.18* below).



Figure 4.18 Another residential cul-de-sac showing the two approaches taken by the operator

In this cul-de-sac, Brian drives clockwise around an almost triangular- shaped road to collect the bins on the outer side (labelled 1). He then returns to the main road and performs what is known as a *K-turn*, (researcher’s italics) before coming back to the houses in the large island in the middle of the cul-de-sac, driving in the opposite direction to collect their bins (labelled 2).

The K-turn appears to be a common strategy with several operators when their vehicle cannot be turned around in streets due to the length of the truck. Although this turn is similar to the three-point turns used by car drivers, reversing heavily laden trucks into residential driveways is not sanctioned due to the likelihood of damage to the concrete and the footpaths. Several of the operators stated that some residents report their driving to the council so the operators are keen to stay well away from driveways.

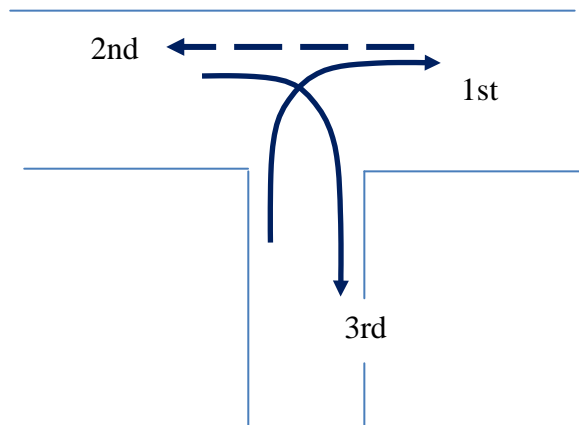


Figure 4.19 Three point turn or K-Turn made by operator when turning at a T-junction

The operator first drives the truck forward, turning right into the top road (see *Figure 4.19* above). Then he reverses the truck (dashed line) so that he passes the opening to the road he has just exited. Finally he moves forward, and turns right again, returning to the original street to start collecting the remaining bins on the other side. Turning a vehicle quickly so that it returns to the street it has just exited before any oncoming traffic arrives is challenging for any driver let alone the operator of a heavy truck. However, it remains a useful strategy when the top road is clear of other traffic for up to twenty seconds, the time an operator usually takes to complete such a manoeuvre.

4.3.5.4 Restarting after returning from emptying a load

When Josh returned from emptying the second load he restarted at the street corner he had departed from. When asked how they knew where to restart a collection after returning from emptying a load the operators suggested various strategies so they could be sure to return to the exact location where they completed the previous load. The consequences of missing a resident's bin by not returning to this place would create work for others. To get around this one recycling operator said that if he reaches the weight limit while in the middle of a street, he would choose a house next to a clearing to stop at as a landmark. Others like Josh try to reach residences on corner sites. Another operator mentions leaving a bin at a slight angle so that he would notice it on his return; however the obvious risk is that the owner may retrieve the bin while the operator is emptying the load, thereby removing the marker. Others mark their locations on the portable maps they carry of the day's run, and return to the marked place on the map. If all else fails the Global Positioning Satellite (GPS) system operated by the company can assist. The uses of this are described in section 4.3.5.7.

4.3.5.5 *Suburban weight differences*

The operators believe that the socio-economic status of an area has an impact on bin weights. They report that around lower-income housing areas, the load weights are generally higher. Dennis suggests one reason is that some households use both bins for refuse and recycling, apparently unconcerned about the contents. As described earlier in 4.3.4.2, some recycling operators find that non-recyclable items like grass clippings or animal waste may be in some bins so this takes extra time at the recycling plant to decontaminate the load. However, some higher-income housing areas occasionally have heavier bins when residents discard periodical magazines and these tend to be printed on heavier paper. Sean has found that some of the heaviest materials are “actually pamphlets; they can be heavy when altogether”. Other people appear to drink more from glass bottles and “they can put three to four dozen in on some fortnights” (Sean).

During the third load, Josh states that he needs to refuel before he empties his truck for the final load. He says that the fuel may last him up to two-and-a-half days and that it will be one less thing to do the next day. Josh also explains that when he began as a recycling operator, he had tried to use an averaging process but came to recognise that seasonal variations upset his predicted bin counts, sometimes the weights, and his attempts at calculating an average for each fortnight of a run:

I went through a period – I’d add up [bin counts] for the last six months and do averaging; but that six months of averaging coming into winter put me on the high side, (then) if you did it six months during winter it put you on the low side.

4.3.5.6 *Planning routes*

With the scales being placed in the truck hoppers as well as operators becoming increasingly familiar with their run localities and particularities, their abilities to estimate the weights of their loads and the seasonal bin number variations have expanded. It also means that operators occasionally vary what they do; as Josh states, “probably nine times out of ten I’ll do it the same, but today I’m doing it slightly differently”, when trying to complete the day’s run in only three loads. One of those variations appears when Josh returns to some streets where he has already collected the bins on one of four blocks.

The researcher observed that Josh needed to work out the shortest (or critical) path to empty all the bins along the sides of the three remaining uncollected blocks, and to use

the least amount of diesel fuel before he went to refuel. After Josh brought his truck to the intersection (see *Figure 4.20* below), he started shortly afterwards, driving along all the sides without retracing any sides of streets he had already completed.

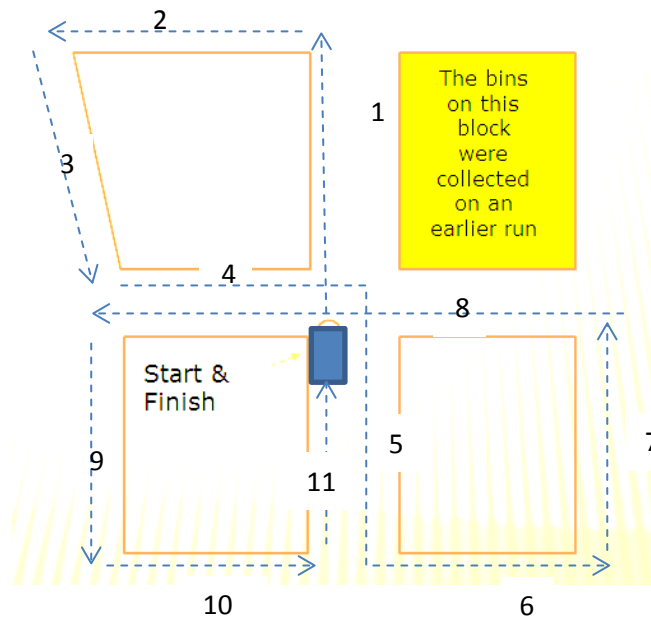


Figure 4.20 Josh's route for emptying the remaining bins without retracing any side

The numbers from 1 to 11 indicate the sequence of the sides of the blocks Josh drives along. This experience with street designs and where blocks start and end appears to become local knowledge with operators. Familiarity with a neighbourhood and its residents is echoed by Sean who adds, “You also get to know which bins will be out and when. [. . .] and whether a resident is late”. This last point is critical and as will be explained in section 4.3.5.7 operators need to be accountable when challenged over whether a bin has or has not been collected. In that instance another truck may be dispatched to empty an uncollected bin.

At the end of the third load, while the truck is refuelling at a nearby service station, Josh shows the area his run has covered by referring to a map of the relevant suburbs. These enlarged maps of the collection territories are usually kept in a folder on the dashboard in each truck cab. Each map is almost all of an A4 page with its borders to adjacent collection areas clearly marked. Operators informed the researcher that they were quite familiar with their assigned collection areas, so the maps were used mainly to ensure that every street or side of a street had been completely collected.

Two of the operators would trace a line (with a highlighter pen) along the sides of streets they had completed. Another use of the map was to occasionally mark a

stopping point when a load was full and thus to have a designated place to restart at the next load. One of the operators also used the map to explain how he was intending to exit a road (and the collection territory) so that the load on board which was almost full, could be taken to the recycling plant after the bins on the next street had been emptied. Each truck cab has a radio telephone for contacting the depot administrator and other operators who may need assistance. Maps are useful resources for this as is access to the GPS system as a back-up location system.

4.3.5.7 *Using GPS*

Global Positioning Satellite imagery, or GPS, has some useful roles in the work of the collection operators. Firstly, when trying to trace where each operator is during a day's run, the depot administrator can locate a truck in a matter of seconds. This was particularly useful for the researcher attempting to intercept and accompany operators who were research participants, but who were also working in a mobile environment.

Secondly, the GPS system is also used by operators who return from emptying their loads, and on rare occasions they may not recall whether or not they have completed the collection of bins on part of a street. With the GPS system maintaining a record of each operator's entire driving movements, a quick call to the administrator will apprise the operator of the information. This is particularly useful if an operator has omitted to mark on the map where he collected the last bin.

Thirdly, the GPS provides historical evidence that an operator has actually visited a road in an area. These records are kept for some time if something needs to be queried. On several occasions residents have complained that their bin has been missed by the operator; operators believe the resident is likely to have been too late in taking their bin out onto the road. However, as customers it is even likelier that if the same person complains to the city council, the administrator at the depot will have to despatch an operator to collect it anyway. As Brian explains, "our KPI's (Key Performance Indicators – in this case all bins collected and minimal complaints) are always under scrutiny, so we do it".

Lastly, the GPS system enables the administrator to locate where truck breakdowns are and to then send out mechanical assistance if required. Also, the administrator will ask operators in neighbouring areas to then finish the collections in and around the breakdown. These operators will be asked if they appear to be close to completing their own runs; again this may be confirmed by the administration team as they can refer to

the GPS or can ask the other nearby operators. Those closer operators will normally estimate when they will be free to do this. Noel for instance knew that he would be 20 minutes away from completing his last load before being able to go to his neighbour's run to assist him. Noel's estimate of his third (and final) load, to complete his own run before starting his neighbour's run, is of 205 to 210 bins. Accordingly, Noel was cautiously optimistic that he could also accommodate his neighbour's bins from the remaining streets in the adjacent run, although he was careful to check his map to see which blocks and streets were involved.

4.3.5.8 *Making room for other collectors*

In some parts of Auckland operators share the collection territory with other companies. In most instances operators report on the existence of a road and collection courtesy. Noel notes that "if I am first I make sure that I return my bins and not make it in his way". Josh explains that since the refuse driver comes here every week while he only returns fortnightly, he tries to accommodate the refuse operator and looks for passing opportunities along the road:

There's a bit of a relationship you have with the rubbish truck drivers (both have the same collection day). If bins are too close together, if I'm going in with my grab arm or he's going in with his you tend to knock one another's bins over so ... he has to do this run every week so I'm encroaching on his turf really by doing it once a fortnight. So yeah I'll move a bin you know, maybe move it a couple of metres out of the way.

On the run Sean operated in South Auckland during the study, most residences still use bags for refuse although the recyclables are in bins. Sean suggests that residents need to be cautious how they place their refuse bags near the bins. But he appears to have a working relationship with the refuse truck operator and the runners:

When I've been in the street and I've seen them, because they're faster than me, with the guy who drives and the guys who throw the rubbish (bags) in, I'll pull over. We can't compete with them. When I pick my bins up I try to put them down away from their rubbish bags out of their way. When I've gone further along, I've seen one of my bins down, and I see them pick it up for me. Works both ways.

The researcher as a participant assisted on just a few occasions by shifting some bins, thereby helping the operator maintain his collection momentum through streets. However, in spite of several offers of assistance, the operators were mainly content to do this outside work themselves. As one operator observed, when descending from a

cab an inexperienced person is at far greater risk of falling from that height. Also, large slow-moving noisy vehicles may attract very young (but mobile) children to footpaths. Operators are on full alert when these children are observing the truck. At least four of the five operators revealed that they are parents and health and safety remains a priority in their working environment as one of the critical aspects of their work.

4.4 Distilling the Numeracy Events and Practices

The preceding sections have described typical activities of the collection operation so now the workplace practices will be excavated for numeracy events. Borrowing from literacy as a set of social practices (Barton & Hamilton, 2000), a numeracy practice is “what people do with numeracy” (p. 8) while an event is any observable episode arising from a practice in which numeracy has a role. Several numeracy events and practices are embedded in the workplace practices above and are summarised below. The events emanated principally from the observations of the operators’ work. The practices emerged from interviews with the operators and managers from decisions and observations following workplace activities.

Dowling (1998, p.2) states these workplace decisions are situated “in real time and ... are often highly localised”. Though number and measurement are evident in the operators’ work, both also underpin estimation while measurement is also embedded in spatial awareness. It was clear that the operators’ workplace practices unfold as they collect; the associated numeracy keeps surfacing throughout a run *within those workplace practices* in spite of these seemingly being invisible at times to the operators.

To describe the numeracy in workplace practices of refuse and recyclables operators, several examples of the numeracy activities are listed in Table 4.5 which carries over on to the next two pages. The numeracy in this table has been arranged into four strands for convenience – *Numbers*, *Estimation*, *Measures*, and *Spatial Awareness*. Other than *Estimation*, each has sub-categories; for instance *Number* is sub-categorised into *Counting*, *Calculating*, and *Costing*. Listed in each sub-category are predominantly observable numeracy events that the operators use in their everyday work. However, some of the lines between categories are blurred; this supports a position that these activities often resist being categorised or mathematized into one category.

Table 4.5 *Numeracy activities of refuse and recyclables collection operators*

NUMBER			ESTIMATION	MEASURES			SPATIAL AWARENESS	
COUNTING	CALCULATING	COSTING	Often taken for granted	TIMING	WEIGHT & VOLUME	LENGTH	SPACE & SHAPE	LOCATING
Bins counted realising 4 loads versus 3 loads	(850 to 900) total bins, divided by 3 indicates possible load numbers.	Owner-operators pay all costs; employees' costs are met by company	Time to get to places, e.g. tip off loads at plants, returning to run	7am start residential; elsewhere earlier starts	More weight in bins over summer due to many more outdoor events and functions	8m truck on continuous stop-start motion	Straight-side truck parallel to berm side unless arced as with circular culs-de-sac	Route planning known esp. for exit strategy to tip off
"Push" the amount in the first load to as near to 300 as possible	989-850 \approx 150 bin difference in consecutive fortnights so one less load	Compliance costs if load overweight, fined \$100's met by owner-op's or pd. by co.	Always thinking how much more to fit in the load; when to go and empty the load	School holiday traffic is less congested than term time traffic	Excess weight in load is more critical for recyclers (see compliance)	Length of chain-arm-claws extend to 2.5m	Tight areas - narrow lanes in inner-city, with parked cars on both sides and entry to culs-de-sac	Often critical paths taken so fuel & mileage saved when planning route and exiting strategies
Refuse bins 1000 before lunch; 1400 on full day	Averaging runs is unwise due to seasonal variation with bin numbers	Maintenance costs brakes & tyres esp. (\$600 ea.), met by owner-op's, paid by co.	Recyclers vigilant when they get to $\frac{2}{3}$ or 70% of their load (or near the 3t weight on their scales) – this signals a need to keep weighing	Seasonal timing – 4 loads each daily run during summer	Compaction ratio agreed on for weight /cubic metre	Monthly distance driven is around 2000km	Access to bins is blocked by school parents, cars of workers, and building contractors	New houses at rear of existing homes increase bin numbers on the same berm
Subitizing bin numbers (i.e. knowing 4 bins here, or about 10 bins there) in small bunches	Metric mass conversions in 4.32t as being 320kg over 4t	4 loads v 3 loads saves fuel, and wear & tear on truck	Recognise 10 min here & there and rough bin numbers expected in roads	Public holidays so collect on Saturdays less traffic, but every bin is out	Refuse bins take more weight since everything can be discarded, so arms can lift ~ 110kg	Height of seat in cab above ground requires safe descent, advise three points held.	Mirror use has reverse view for operators as they lift, so clockwise seems anti-clockwise, etc.	Familiarity with road layouts & traffic-density opportunities, with timing to enact K-Turns

Table 4.5 (continued)

NUMBER			ESTIMATION	MEASURES			SPATIAL AWARENESS	
COUNTING	CALCULATING	COSTING	Often taken for granted	TIMING	WEIGHT & VOLUME	LENGTH	SPACE & SHAPE	LOCATING
Saturday collection is almost 100%	Recyclable bins average weight of 12-14kg, but refuse bins are heavier.	Accounting & GST costs for owner-operators, who are small business owners	Anticipate more bins around new housing developments	Suburban collecting at least twice as fast (bins/h) as inner-city	Overfull bins, so operators juggle when lifting so as not to spill contents	Reversing truck to tip out at Visy plant must allow room for tipped load to extend beyond rear of truck	Only use scales when truck is on level areas – knowledge of location of these level areas	Recognise approx. numbers of bins will be on certain roads, and when to collect there depends on load status (weight).
Recognises that 10% more bins probably adds an extra 30min to the overall collection time	Bin collection rates are not truly accounted for with spreadsheets – operators can typically lift, empty and return a bin every 15s, though monthly figures suggest only 120 bins/h	Owner-operators refuel when they get the opportunity, whereas employed operators refuel on their return each evening	First load often indicates the way a run will unfold in bin numbers & weight; however operators still monitor scales	Bin runner saves time in inner-city, where previously operator needed to alight from cab several times	Bin capacities: - Refuse 120L bin - 240L for recycling (Auckland Council is reviewing these)	Claws need about 100mm space on each side of a bin to enable the claws to grab	Courtesy with space - other company's operators	Use of maps to mark off streets completed, or stopping points. GPS records routes as a record of runs completed
Compare loads, weight 294 < 310 but 4.12t > 3.78t 16 extra bins but $\frac{1}{3}$ t less	Gross weight – Tare weight (10,070kg) = Net weight on weighbridge		Time lost when having to get out to shift bins, clean up spills ~ 10 min	In normal situation operators can empty a bin in 15s	Operators can sense how heavy a bin is if the joystick strains	Claws grab tapered bins approx. halfway up the sides	Truck lifting gear extends perpendicular to bins, often to square up	Returning empty (lighter) bin to an uneven verge has them toppling on windier days

A very broad sub-category is *Calculating* which has links to the *Estimation* category. *Calculating* includes instances of addition and subtraction being used when deciding bin numbers needed to complete a load, or when a result of fewer bins might mean that one less load is needed to complete the day's run. The *Calculating* sub-category also merges proportional reasoning with estimation and measuring when an operator recognises that his truckload may be two-thirds or almost 70 per cent full, thereby alerting him to monitor the weight during the rest of the load.

There are instances of numeracy transcending boundaries and residing in more than one category. In one case, Dennis suggested that on a busy day, a further 10 per cent more bins would add another 30 minutes to his overall run time. This practice features in the *Number - Counting* sub-category, and in the *Measures – Timing* sub-category. Both also fall within the *Estimation* category.

A second case which challenges categorising is when operators plan an exit strategy with a load that is almost full. Not only does an operator consider *Location*, but also draws on what he recalls of the bin *counts* along any planned exit streets, as well as being mindful (if recycling operators) of the *weight* of the load which he cannot exceed. Again these examples cross category boundaries and draw in *Estimation*. Therefore, Table 4.5 above should be viewed more as a convenient list rather than a definitive summary of some key numeracy activities by the collection operators.

With the interrelated nature of the numeracy activities largely unaddressed in Table 4.5, there is an opportunity to have the four categories of *Number*, *Estimation*, *Measures*, and *Spatial Awareness*, together in a more integrated diagram (*Figure 4.21* below). Without appearing overly simplistic, the key area of overlap appears to be the *Estimation* category. It is therefore appropriate that this category should be made central. It also suggests that *Estimation* is a derived category, owing its substance to *Number*, *Measures*, and *Spatial Awareness*.

Three numeracy events have been inserted along the “borders” between categories to illustrate boundary blurring with each event eligible to reside in either the *Estimation* or the category occupying the other side of the border. Although the sub-categories and lists of events in the original *Table 4.5* have not been displayed due to constraints of space, these are expected to remain in their original categories.

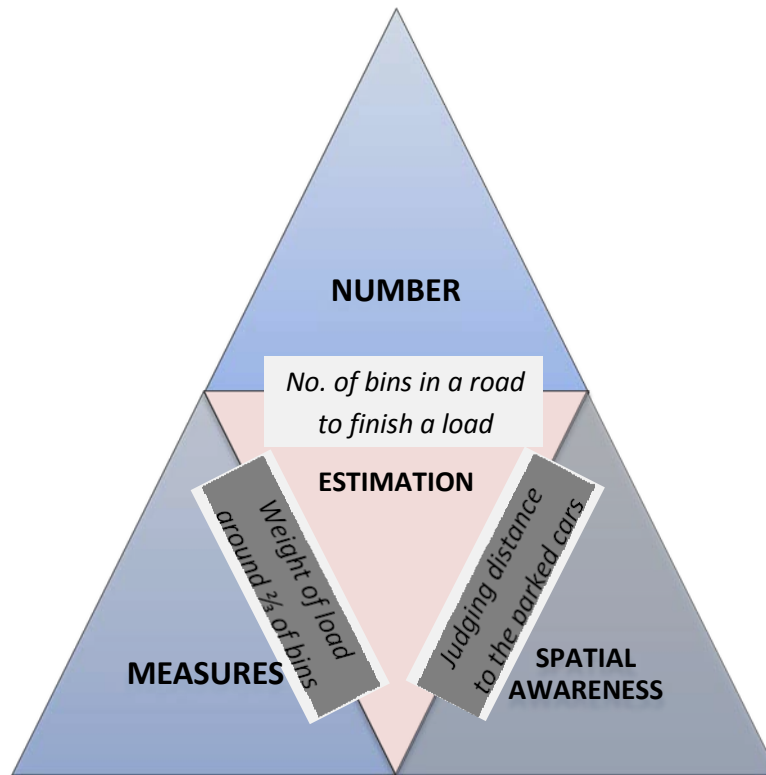


Figure 4.21 Representing the interrelated numeracy categories and examples of events

Numeracy categories and practices however, are part of a larger set of workplace practices. Accordingly, a circular model of the five major workplace practices follows in *Figure 4.22*. The sectors identified as workplace practices (or sectors) are *Collecting (bins)*, *Driving*, *Emptying (loads)* at a refuse transfer station or at the Visy recycling plant, *Maintenance*, and *Administration* making up the circle of workplace practices. As with the categories in *Figure 4.21*, the edges of the workplace sectors may sometimes be blurred, for instance along the border of *Driving* and *Collecting*. A sixth practice, *Safety*, weaves across the three operational practice sectors of *Collecting*, *Driving*, and *Emptying*, and also nudges *Maintenance*. When each operator was asked about the major piece of advice he would give a new operator, all nominated safety practices as their first priority.

The three major operational practices, *Collecting*, *Driving* and *Emptying* take operators comparatively more time than *Administration* and *Maintenance* do. However, it is important to note that the reporting responsibilities (taxation and ACC levies, on-road costs such as fuel, diesel road-user charges, vehicle registration, insurance, tyres, and other business costs) of the contractor-operators suggest the two latter sectors are larger for them than for the employed operators, who do not have the same responsibilities or have to meet the individual compliance costs.

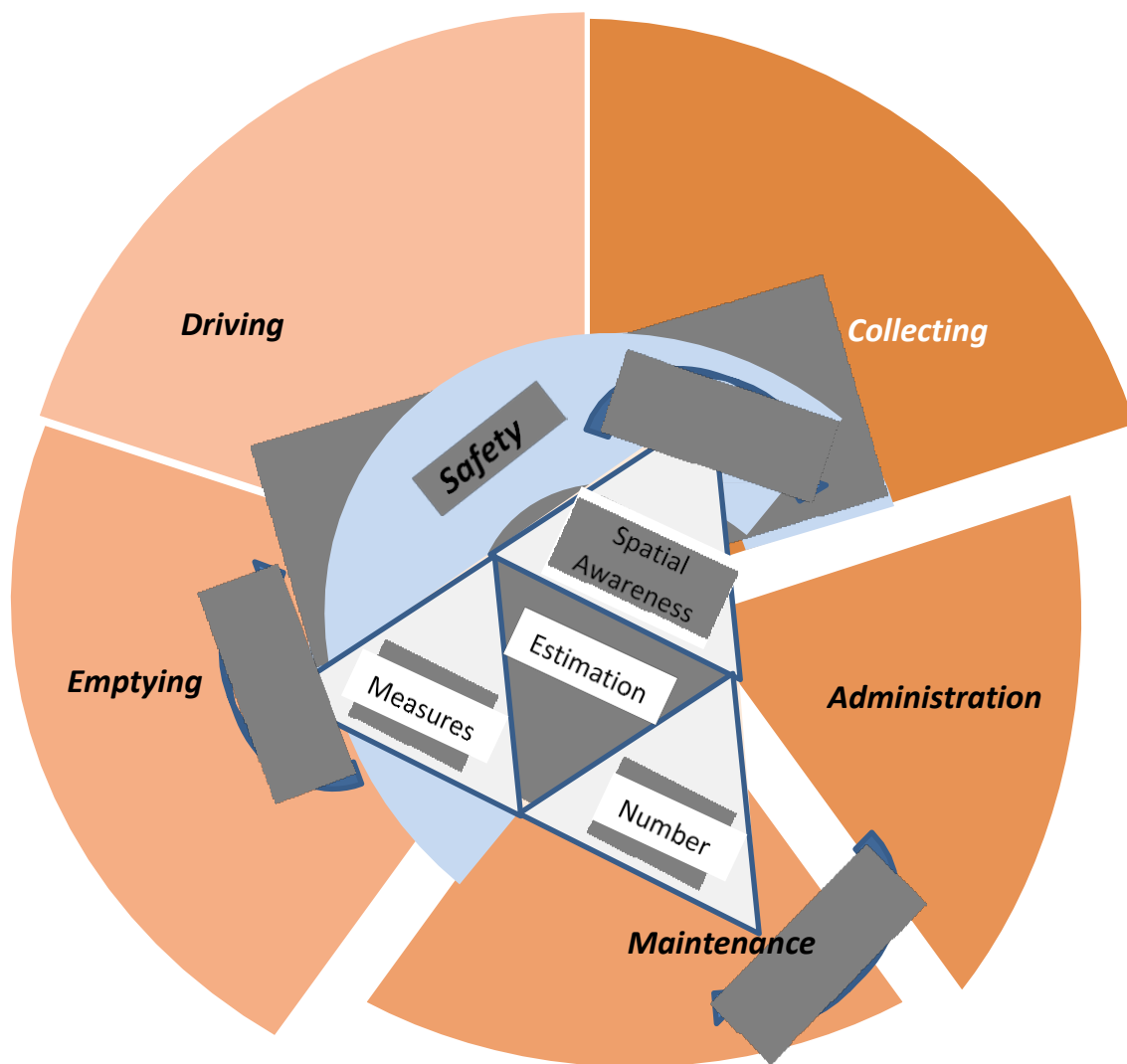


Figure 4.22 Workplace Practices and Numeracy Practices of Collection Operators

Within this ‘circle’ of workplace practices lie the revised set of numeracy categories, *Numbers*, *Estimation*, *Measures*, and *Spatial Awareness* (originally formulated in Table 4.5, then condensed in *Figure 4.21*). These numeracy categories are not exclusive to one workplace sector, rather these engage with the workplace practices in a manner similar to a ‘lazy Susan’ on a dining table, rotating until drawn on by a particular workplace practice.

If for instance a recycling operator returned to the Visy plant with an overweight load, the *Emptying* practice and the *Administration* practice could draw on *Measures* (to see what the load weighs and whether it is compliant) and then on to the *Numbers* category to reveal how many kilograms over and what the fine could be for that overweight load.

These models have taken some time to formulate and reform. The terms *strand* and *category* have been used deliberately for the four numeracy components since these are typical content descriptors in syllabi (Ministry of Education, 1992). When values, beliefs, attitudes, behaviours and social interactions are bound with the numeracy contents, practices emerge. Not all of the numeracy strands in *Figure 4.22* will be drawn on equally, nor will the workplace practices use the same amount(s) of numeracy. What the model in *Figure 4.22* does reveal however, is the complexity of workplace practices and how these tend to cloak other practices such as numeracy and literacy. Up to this point, literacy has only been mentioned in the discussion around social practices; literacy coexists with the numeracy which has unfolded within the operators' work. The rich instances of communication involving literacy practices are a possible site of further research.

4.5 Reflections of the Researcher

Lincoln and Guba (1990) suggest that researchers of case studies are obliged to share their values, experiences and contexts that are "rooted in the construction" (p.54) of their studies. Therefore within the description of the observations, visits, and interviews of the operators' practices described in the previous sections, there are several reflections by the researcher arising from the data that are suitable to communicate.

At the beginning of the pilot study by Chana and Kane (2010), both researchers were provided with a brief insight into the capping (covering with rock and earth) and winding down of the Greenmount Landfill facility. That first encounter opened doors to refuse and recycling companies where contacts were made with other site-managers, and finally access was provided to staff. In this study, those managerial contacts were remade and familiarity with these people proved to be an advantage for the researcher in gaining momentum for this study. Not only did it save time in initiating contacts but it also meant that the managers were dealing with someone who was partly familiar with their *modus operandi*. The converse was also positive in that the site offices and trucking environment were also partly familiar, as were the reception staff in each company. The only unknown participants were the operators who would be visited and interviewed.

The site-managers at each company were open and frank in their dealings and the researcher understood that because the company's operators were visited on-the-job, they recognised that the work of their operators would not be disrupted, and safety standards would be maintained. On one occasion the researcher visited the operators of Company X as a group at a 'tailgate' meeting, held after all the operators had returned to the depot from their daily

runs. At this meeting the research was explained briefly and volunteers were asked to participate. On departure, forms and information sheets as approved by the AUTECH Ethics Committee were left. Near the end of the study, the researcher returned and provided the two site managers at Company X with a brief executive summary (Appendix G) of the numeracy practices that had been uncovered so far.

One new operator volunteered while others were approached by managers to see if they wanted to take part. When the operators were visited in situ the researcher was not completely certain how receptive they would be; it was possible they might view a researcher as someone sent in by management. Also, although linked by radio-telephone to their administrators and other operators these people work in a solo environment. Hence the researcher was aware of the possibility that the operators would be wary of someone invading their solitary workspaces. However, in each case this potential wariness seemed to be dispelled reasonably swiftly and instead the researcher found that the cohort of operators was genuinely interested, even curious that someone might be interested in what they do and how they do their jobs.

There were several commonalities with the operators' and the researcher's experiences. First, the operators were all males of a similar age or slightly younger than the researcher. Second, most of the operators being interviewed have older children and when they found out where the researcher was working they offered thoughts about the education of their children along with some of the challenges of their children's learning. Third, the researcher had some experiences in the past driving fork-hoist trucks, courier vans, cars with trailers, and on one occasion a truck, so these provided some minor insights into commercial driving. Driving experiences in particular, provided the researcher with the most background knowledge while observing and conversing with the operators, and provided a starting perspective on some of the driver decisions; the collection operation and stop-start driving were however, completely new to the researcher.

Even considering the prior driving experiences of the researcher, the complex coordination of the operators' driving and operating work was never underestimated. Rather the detail of what these operators do is perhaps masked by the apparent expertise and speed with which they carry this out. The sheer volume of the repeated actions (up to 7000 lifting and emptying actions for refuse operators per week) also provides them with time to inspect their surroundings and some of their customers' habits. They notice human behaviours such as residents behind slightly shifting curtains, or sometimes waiting near their bins.

Consequently, one of the first instincts with some operators is that the resident may have put

material in to a recyclable bin which is not permitted, so their observations of residents' behaviours around their bins often acts as an informal barometer of loading infringements and follow-up work.

One health and safety factor during interviewing was when to recognise where there were locations and roads with limited room to manoeuvre the large vehicle, or that queuing traffic was attempting to pass. This meant that the interviewing needed to pause since operating such a large vehicle required greater concentration by the operator, and continuing an interview would have been a distraction. The reward was that in some instances the operators would break the silence with a question themselves by asking whether the researcher had noticed something such as a resident's overfilled bin, some suspicious contents in a bin, or the bin placement on a berm.

During the final meeting where the executive summary was discussed the two managers in Company X commented on company changes (outlined in the Background section of this chapter) and ownership. On the practices around spatial awareness, one of the managers suggested that their team of operators were predominantly forty-to-fifty-year olds; as a consequence, their taking part in outdoor activities during their younger years may have had more of an impact on their sense of space than any formal education. This was in response to one of the questions inquiring whether any of the operators had experience with electronic games such as 'space invaders'. Only two of the operators replied in the affirmative to this question – the other three had not spent much time on arcade or electronic games in their youths.

4.6 Summary

This chapter began with some background information about the companies, the operators, and the large vehicles used to collect refuse and recycling in and around Central, South and East Auckland. There are descriptions of the operators' experiences from interviews with the researcher. Observations of their work have also provoked questions and other insights. One operator in particular, Josh, and his work experiences, have been outlined to represent the various duties an operator performs. Another operator, Brian, was observed and interviewed after the others, and he confirmed many of the previous observations and interview points of the earlier interviewees.

Returning to the research questions which were first posed in chapter two, the first question targets the numeracy practices that these refuse and recycling operators use in their workplace practice:

- Which numeracy practices, in particular with regard to spatial reasoning and estimation, do these recycling and refuse operators use in their workplaces?

Table 4.5 and *Figure 4.21* above provide several categories of these numeracy events and practices and critically, integration between several categories during the course of their workplace practices (*Figure 4.22* above), such as *Collecting*, *Driving*, and *Emptying*.

The second research question enquires how these recycling and refuse operators learned these numeracy practices:

- How have these operators learned these situated numeracy practices?

During interviews, the backgrounds of respective operators were provided by each, particularly regarding mathematical experiences at school. All but one of the operators was satisfied with his own mathematical ability; however, the invisibility of the subject in their current work, along with expertise gained from previous workplace practices, made it challenging for them to recognise what was mathematical and what was not. This will be discussed in greater depth in the next chapter.

There are also differences in how recycling operators and refuse operators must comply with load weights, and there are differences between how employed operators and owner-operators respond to the business operation. There are many similarities however, especially during the acts of driving these large vehicles, and in the amounts of estimating and sense of space that each operator needs. These will be commented on more fully in the Discussion chapter which follows.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

The previous chapter opened with a discussion of the evolving ownership of the two collection companies, the details of their collection territories around Auckland, and the refuse or recycling operators who participated in this research study. The relevant features of a standard collection vehicle were also described before the procedures carried out by an operator in one of these vehicles was provided. The participants' accounts gave a broader context to the background. Photographs, diagrams, and tables were included, to assist in presenting a rich, thick description (Geertz, 1973) of the workplace practices, along with the environments and neighbourhoods the operators work in. Finally, workplace events and practices established from observations and interviews were in turn examined to uncover the respective numeracy events and practices lying within the workplace activities, which were condensed to Driving, Collecting, Emptying, Maintenance and Administration.

The data provided by the operators and described in the previous chapter is now drawn on to answer the two research questions which are:

- Which situated numeracy practices, in particular involving spatial reasoning and estimation, do these recycling and refuse operators use in their mobile workplaces?
- How have these operators learned these situated numeracy practices?

In this chapter, the workplace and numeracy events and practices of the operators are reintroduced and the particular practices around estimation and spatial awareness are expanded on within the workplace practices in order to answer the first research question. To make a comparison with refuse and recycling operations in the discussion around estimation and spatial practices, another mobile workplace involving heavy transport will be referred to. Also relevant evidence of situatedness and social practices of the recycling and refuse operators will be considered. The second question will be answered by returning to what the operators have said about their earliest days of collecting, as well as their reflections on schooling, induction and prior work experiences. Again, other relevant work experiences about learning will be compared with the operators' experiences.

In addressing the first question, the three major workplace operational practices (or sectors of Table 4.22 in Chapter Four), *Collecting*, *Driving* and *Emptying*, were the primary foci of the observations and interviews with the operators. The *Administration*, *Maintenance* and *Safety* practices (or sectors) were also interspersed throughout the other practices. It is important to note that the reporting responsibilities (taxation and ACC levies, on-road costs such as fuel, vehicle registration, insurance, tyres and other costs) of the contractor-operators suggest the two latter sectors are more significant for them than for the employed operators who do not have the same responsibilities or individual compliances. However, employed operators are well aware that although the company covers compliance costs it will not continue to do so for repeat infringements. Instances will be provided of particular workplace activities and decisions in order to delve into the sectors and illustrate how numeracy, in particular estimation and spatial awareness, are situated within the sector. The boundaries may be blurred between sectors so it is likely that several numeracy events will occupy more than one sector. Section 5.2.4 on roles and controls is used to revisit power issues, while section 5.2.5 on geometrical practices looks at whether the operators recognise when they use geometrical thinking. A brief comparison will also be made between bus operators and collection operators to ascertain if there are other events and practices which are shared.

The second question is addressed by first revisiting the situated nature of the workplace roles of the operators, and their initial training and enculturation into their new roles. The discussion will move briefly to the operators' formal school learning before reconsidering their prior experiences as truck drivers. The operators' learning in their current roles is discussed next.

This chapter concludes with a brief discussion of possible future impacts on the workplace of the refuse and recyclables operators, before summarising the salient points of the answers to the two research questions from the discussions.

5.2 The situated numeracy practices within the workplace practices

The first research question asks:

Which situated numeracy practices, in particular involving spatial reasoning and estimation, do these recycling and refuse operators use in their mobile workplaces?

In the Findings chapter, the operators' workplace practices were investigated and revealed several numeracy events and strands. The workplace practices were

summarised in Figure 4.22 in Chapter Four. The researcher drew on the literacy perspective (Barton, 2006; Street, 1995) to approach the data collection. Numeracy events became visible by using observations, field notes, sketches and photographs during the site visits, and were detailed in Table 4.5 in the previous chapter. These mainly observable events form part of the situated numeracy practices which are not as overt as the numeracy events, and are dependent on the operators' ways of thinking about their work and how they have structured their daily collection routines and strategies.

5.2.1 Administration and Maintenance Practices and related Numeracy practices

Every operator is aware of the major practices of *Driving*, *Collecting*, *Emptying*, and *Health and Safety* (see Figure 4.22) since they engage with these on a daily basis, and there are key performance indicators amongst these practices. In one example, Sean illustrated how the Health and Safety practice was important by walking around the truck during a meal break, inspecting tyres and other moving parts for wear and tear. Truck inspections are something that Sean had always done throughout the duration of his prior commercial driving experiences and, as Stein (1998) mentions in the literature review, Sean transferred that practice with him to his new role. Employed operators such as Sean acknowledge *Administration* and *Maintenance* although most of the paper work and scheduled vehicle maintenance are organised around them. Tyre repair trucks are in regular attendance at the Company X depot, either repairing damage to a truck's tyres or replacing them. Tyre replacement is a part of planned maintenance and the depot managers insist it should be done every three months. The managers have also contracted an electrician with electronics experience who works on the trucks at the depot every Saturday.

Contracted operators are first and foremost running small businesses; they own their collection vehicles so they must meet legal compliance factors. They have bought into the enterprise and have vested interests in its successful operation. They therefore must also meet legal and accountancy fees, insurance, registration and compliance costs, as well as depreciation of their vehicles. As the operator Josh explained, Company Y had not wanted "out and out drivers" (Josh's interview) but people with skills interested in running an individual business. Accordingly, these operators have a broader engagement in *Administration* and *Maintenance* practices. Although every operator has an interest in the "understanding of the enterprise of the community of practice, and contribute(s) to its pursuit" (Wenger, 1998, p.137), the contracted operators in particular

have an “*accountability to the enterprise*” (*ibid.*, original italics) and to external agencies such as Inland Revenue and Land Transport New Zealand (LTNZ who were previously NZTA). Conversely, the Company X employed operators have none of these responsibilities and as one employed operator commented, “the office takes care of that stuff”; also the aforementioned authorities deal directly with their employers. There appears to be a continuum of financial responsibility then, with contracted operators at one end and employed operators at the other. As such, the numeracy practices for those with greater financial responsibilities are by necessity broader and more complex.

To best illustrate this part of the discussion around administrative and maintenance workplace practices, an example of an estimation numeracy practice is drawn around *optimising resources* (researcher’s italics). Although every operator, employed or contracted, is looking to take the most direct route in the least possible time, efficiency is more of a cost centre issue for the contracted operators. Not only are the contracted recyclables operators heeding distances, weights and times, they are also estimating when they need to refuel if at all, where the most suitable fuel stop is located and whether it is on their way, if there is enough money in the account to fill the tank with diesel, and if their rear tyres will last one more month before they are too worn or illegal. They might also be considering their next two-monthly Goods and Services Tax (GST) payment and the front wheel brake job they have been delaying.

Further, Josh explained that each of the small business operators brings in prior experiences and some of these are shared among the group of thirteen operators in their community of practice (Lave & Wenger, 1991). Josh’s experiences in driving large machines had provided him with sufficient mechanical knowledge to assist other operators with minor equipment failures and vehicle maintenance. Josh would at least inspect the issue with the vehicle and feel he could advise his fellow operator of the next steps to take. It also meant he could receive something in return, for instance help with completing a run on a day he was going to finish early. This numeracy practice will also involve a discussion about the relative worth of each side of the ‘deal’ and whether one party needs to do more (e.g. carry out two loads) in order to keep their side of the deal. The bartering of relevant skill sets based on experience (e.g. in run experience, how much time, the numbers of bins, which sides of the streets) illustrates that in spite of the mainly solo working environments of the operators, they are still part of a wider community of practice, assisting each other when required.

5.2.2 Collection Practices and related Numeracy practices

The collection practices encompass many activities such as counting, weighing and locating.

5.2.2.1 *Counting and Subitizing*

For the operators, keeping a count of bins collected is an ongoing necessity. Not only does it provide an operator with a feeling of their progress in a certain area on their usual collection day, but it also signals when to check loads for weights as the count increases. Fortunately, the on-board bin counter and set of electronic scales keep the count and monitors the weight for operators; however there are always times when they are nearing a full load and a quick estimate is needed. Estimates of bin counts have been described several times in the previous chapter, particularly with regard to when operators were looking ahead to estimate the number of bins in a street and whether these could be accommodated in their current load. The operators are always mindful that what is not collected now must be collected sometime in their run.

A mental tool which may assist to count very small numbers of bins is subitizing. Subitizing appears to involve a different process than estimating (Siegler & Booth, 2005; Revkin, Piazza, Izard, Cohen, & Dehaene, 2008), and emerges where users recognize relatively small numerosities compared with estimating larger sets of objects. Balakrishnan and Ashby (1992) suggest that after rapidly recognizing a set of four objects, there is a “continuous increase in the mental effort required enumerating displays up to 6 elements” (p.89). Piazza, Mechelli, Butterworth, and Price (2002) claim that “no brain area is specific for subitizing or counting” (p.444), suggesting that perhaps the processes of subitizing and counting lie on the same continuum of pattern recognition.

These operators appear to use subitizing-based judgements to recognise clusters of bins, usually up to four at any time, without needing to count them and this is likely to assist them with estimating bin numbers. Nowhere is this more critical than when a truck's load is almost full and decisions need to be made in the next few minutes when to leave the area and unload. While the truck is in motion, the decision of an operator to collect further bins is reliant on load weight and bin counting. As mentioned in the previous chapter, for recyclables operators this counting and weighing require more accuracy since there are penalties for non-compliance at the recycling plant.

Although there is research on the abilities of children and adults to subitize (Revkin *et al.*, 2008), the application of subitizing in workplace settings does not seem to be as evident. The practice of bin counting and estimating appears to be usefully supported by the ability to subitize in two main ways. First, recognising that there may be a dozen or so bins between the truck and the next corner or behind some parked cars would be supported by seeing clusters of four bins, then three bins, then another four bins, and so on. Therefore subitizing enables the operator to chunk small numbers of bins then quickly combine these chunks to determine whether there is room in the load for the extra weight. Second, subitizing may be used by an operator who notices that the number of bins on a particular berm does not correspond to the number of residential letter boxes. For clusters of three to four letter boxes at the start of a right-of-way, recognizing that one bin is missing may signal a defence to a later claim from a resident that their bin was missed. Alternatively, an extra bin arouses the suspicion of an operator that a resident across the road has brought their missed bin across, or has refilled an already emptied bin from the other side of the road which was completed earlier in the run. Subitizing in this operation is an event that is carried out several times informally during the same run to support on-the-spot estimates. Further, it means that if there is one less or one more bin, operators need to anticipate possible future actions and responses.

In comparison, another workplace example where subitizing is carried out was at a winery warehouse where the researcher was employed. For monthly stocktaking at this warehouse, cartons were counted as one dozen bottles and these cartons were stacked on wooden pallets. Occasionally, bottles were removed from cartons for promotional events during a particular month. When a recorder found a carton with bottles removed, he or she could tell quickly (due to the 3×4 layout of a carton) how many bottles remained, without the need to count.

For example, in Figure 5.1a below, it is easy to check that ten bottles remain in the case because there are two empty spaces within the standard dozen.

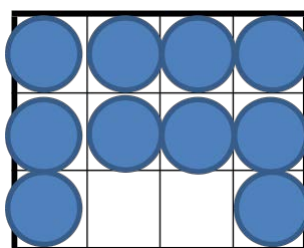


Figure 5.1a – two adjacent bottles missing

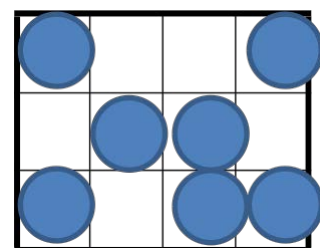


Figure 5.1b – five bottles missing in an uneven layout

Usually a recorder would not go through the calculation; it is more likely the layout of the case would be familiar so a ‘count’ of ten would be virtually automatic, or more likely the recognition of two missed bottles (see Figure 5.1a), thereby subitized by the recorder. It also means that people removing bottles of stock leave a case balance to enable a quick ‘count’ of the stock. In figure 5.1b, a recorder would have been delayed by a less accessible layout such as this since one-to-one counting would be required.

Both workplace examples use counting events to support different numeracy practices; however the precision of the count differs. In the winery warehouse the counting goes towards an overall total number of bottles leading to a valuation of the wine product that is eventually included in the business’s monthly assets. This figure needs to be accurate since it is destined for a monthly balance sheet and perhaps later auditing. The use of subitizing on recycling collection runs is to provide an operator with estimates of bin numbers and eventually to see if their current load can potentially take on more weight. A compliance decision awaits and as Josh explained, the scales on the truck will give some indication of the current load – is there space for any more weight, and what does this translate to in bin numbers? As described by Adams and Harrell (2010) in the literature review, people who estimate accurately have spent a lot of time getting to that level of expertise.

Although there is imprecision with the collection estimates there is extra estimation complexity in aligning weights and bin numbers for a near full load, while also taking into account whether one more load will complete the day’s run. This may be threatened if a call is sent from an operator with a vehicle breakdown who requires assistance to complete their run. These calls cannot be ignored and adjacent operators usually split the balance of the bins and streets in order to finish the run. The operators would also require street locations, which sides of streets to collect along, and approximate numbers of remaining bins in those assigned streets. However, recyclables operators need to re-estimate their loads as the consequences are expensive if a load ends up being too heavy.

5.2.3 Driving and Emptying Practices and related Numeracy practices

Operators work in places where spontaneous decisions need not only to be made with bin numbers but also with measurements, space and time, particularly if there is other traffic building up around and behind them. Hogan and Brezinski (2003) define measurement estimation as the ability of a person to “provide estimates of length, height, weight, liquid capacity, and similar measures, usually for common objects in the

environment” (p.260). However, this description undersells what operators do and in particular, the estimations being carried out by contracted operators during their runs.

5.2.3.1 *Refuelling practices*

On one occasion, Josh needed to refill his truck’s diesel fuel tank. Josh recognised that the current level of fuel in his tank would last him for the rest of the run, but he was already planning the next day and the more accessible fuel stop was at the service station three blocks from where he was working. He also estimated that filling the tank now would ensure he had another two and a half days of uninterrupted work, without the need to refuel. The teachers who visited workplaces described in section 2.3.5 of the literature review mentioned how these kinds of idiosyncratic strategies were common (Hogan & Morony, 2000)

There are several variables running through Josh’s mind including time and opportunity, distance before running empty, fuel tank volumes, and locations of other possible service stations. The financial variables were also evident and Josh was contemplating how to apply these. As it eventuated, the fuel station he stopped at also accepted his supermarket fuel voucher with a discount, and his credit card where he was on a rewards scheme. This illustrates how “estimation goes beyond rote applications of procedures” (Siegler & Booth, 2005, p.197). All of these events combined to create a numeracy practice for refuelling, heavily dependent on optimising cost, convenience of location and time for Josh. Although working on foot, the warehouse staff of Scribner’s (1985) research from section 2.5.3 were like Josh, also seeking the least distance in the fastest time to complete their order assemblies. When viewed singularly, each event is not high-level mathematics but when combined these events illustrate the complexity of everyday workplace practices, and the almost invisible numeracy that supports the decisions needing to be juggled. The invisibility of numeracy is mentioned several times in chapter two (Cuban, 2001; Coben, 2002; Williams & Wake, 2007) and is often passed off by adults as common sense.

The need to estimate is most evident with operators when they must respond to various situations along the runs. For example, estimating the time remaining before the current load needs to be emptied, thereby necessitating an exit from the area; or judging the space and time an operator has to K-turn the truck into another street, in order to have enough time to return to the first street and finish collecting the bins along the other side. Gal (1999) states that a “chosen plan of action may deliberately involve sacrificing precision for convenience (e.g., by estimating rather than calculating)” (p.11); Josh

provided a further example of this when he described previously how he had made “a dash for cash”, where even though his current load was not full he’d estimated that returning to the recycling plant before the traffic peaked would save him travelling time later. In the literature review, Gal (1999) described this as managing the situation, not solving it as if this were a school maths problem. By the time of Josh’s next load, the traffic would probably have normalised and he would not then spend valuable collecting time locked in queues of vehicles and exhausting his fuel.

5.2.3.2 *Planning routes*

Having local knowledge of road layouts, where the pressure points are located, and the times when those points are congested or not, provides an operator like Josh with windows of opportunity to save time, and trucking costs, since as a contractor he is liable for these. This is an illustration of estimation not being confined to numerical practices. Josh’s “dash for cash” not only involved financial considerations, but there is also a non-numerical estimation (Siegler & Booth, 2005) with the judgement about how much time is being saved. This resonates with Coben’s (2003) definition of a numerate person as Josh was comfortable and confident enough to estimate he had enough time to empty the load and return before the traffic became too busy. Dennis also managed his schedule by deciding to begin collecting on a ‘tricky’ street since the residences there traditionally produce the heaviest bins. Once completed he knew the adjacent streets had comparatively lighter bins. Dennis’ planning illustrates the messiness of numeracy in authentic and local situations, an occasion where Kell’s (2001) and Coben’s (2002) Domain Two is visible. By recognising and then planning to address the pressure points of his run earlier it is evident that Dennis is using both estimation practices and locating practices to manage his loads.

In the previous chapter, Josh described how he worked his way around a neighbourhood in order to recognise where he could leave, then restart, and also to find an efficient route to the recycling depot. Scribner’s (1985) description of a group of warehouse order pickers or assemblers from section 2.5 and their approach to filling orders, is another instance of people being aware of the layout of their working environment. She describes how when given orders of dairy products to be filled, the assemblers did not waste any of their time studying the load-out forms. Nor did they need to ask each other who would be doing what; instead there was an innate understanding of the division of labour. Scribner (1985) describes this sense of space where:

Each assembler needed to have some internally represented knowledge of the spatial arrangement of the warehouse that could be used flexibly to organise the items on hand. Each also needed to have some knowledge of the customary sequence of items, and recurring chunks of items, on the load-out order forms. With such knowledge ... they elegantly mapped one organisation onto another – the symbolic onto the spatial – to meet their own needs and to satisfy externally imposed task requirements (p.206).

This appreciation for layout or location aligns with one of Bishop's (1988) six pan-cultural mathematical activities as described in section 2.3.1.2, and is shared with operators of collection vehicles or with others who drive commercial vehicles – such as bus operators, taxi drivers and courier drivers. It could be argued that bus drivers know where the bus stops are located en route, and depending on the time of day they will have a sense which bus stops will be busier than others. Courier drivers (the researcher has some delivery work experience) will have a similar sense of the locations of 5-minute vehicle loading zones where they can park when making inner city deliveries. In Chapter Two, Chase's (1983) studies of taxi drivers show how drivers with over ten years' experience know how to use lesser known streets through cities much more efficiently than novice taxi drivers. Although the dairy company assemblers (Scribner, 1985) recognise the layout of their warehouse, in contrast the collection operators must recall five routes (weekly refuse collections) or ten routes (fortnightly recyclables collections). The drivers may refer to maps for their zones, or when planning a route. The dairy company assemblers may well have a warehouse plan available, at least for emergency exits and evacuations.

Taylor (2005) discusses how maps are used differently by someone interested in planning a route to someone else “pulling out the map to just get the ‘lay of the land’” (p.323). Taylor claims that there is configural information when using a map so that the big picture of the area in focus becomes arranged in the user's memory. This is in contrast with navigation which is more dependent on the user's memory of landmarks along a route (see Tversky, 2005, section 2.7.1). One instance of that is when an operator is planning to stop along the way to mark the end of a load, and a place to restart for the next load. There are many situations which contribute to an operator's spatial numeracy practices around location and optimal route planning; their times spent in their collection neighbourhoods are major sources of their experiences and whether they even need to refer to maps once the respective run layouts become known.

5.2.3.3 *Spatial Courtesy*

As described previously, spatial courtesy occurs when operators are collecting in the same street at different collection speeds. There will be some point of intersection between their two activities where one will need to give way to the other. This point of intersection may be earlier if the operator in the front and whose truck is moving slower can stop at a place which can accommodate a passing manoeuvre by the other vehicle. If the other vehicle collects refuse bags (at the time of this research, this is the case in both South and East Auckland), the two runners at the back of the vehicle can lift several rubbish bags and carry these bags to their truck as it creeps forward. Their collection is usually quicker since the runners can carry bags from more than one residence.

On the other hand, if each truck is equipped with an automatic side-loading arm (as shown in the photographs of *Figure 4.3* and *Figure 4.4* in Chapter Four) and if one truck moves quicker, the other will wait at a convenient space where neither has bins to pick up and wait for the other to pass. Not only is the operator in the front truck aware of the possible spaces in the street where he can temporarily park his vehicle for the passing move, but he is also familiar with the residences in the street so that neither operator misses any of his designated bins. This example shows how there is a relatively fluid boundary between locating and counting practices.

5.2.4 Roles and controls

Engeström (1999) states that work practices such as this may be regarded as emancipatory in that a key impression of the research has been to expose the scope and to appreciate the complexity of what these operators achieve on their daily runs. If this exposition is at one end of the spectrum, then at the other end, Engeström asserts that the operators' visibilities for managers are primarily for control. Employed operators are at the more controlled end of the spectrum but contracted operators who are small business owners in their own right, lie further toward the less controlled end of the spectrum. When the contracted operators were with Company Y, they viewed their site manager more as a facilitator. A researcher needs to then be aware of these positions, but also to recognise that access to any of the operators is always through key people (Merriam, 2009), or "community gatekeepers" (Hennink, Hutter, & Bailey, 2011, p.92) such as site managers. These managers lead the organisation at the worksite hence the perceived need for some form of supervisory control. In the previous chapter, GPS technology was discussed and this is another possible means of control by making the operators 'visible' to the administration staff from a distance.

There are many subtleties within the work practices of these operators so it is hardly surprising then that some numeracy cues are overlooked. The practices of the operators “include all the implicit relations, tacit conventions, subtle cues, untold rules of thumb, recognizable intuitions, specific perceptions, well-tuned sensitivities, embodied understandings, underlying assumptions, and shared world views” (Wenger, 1998, p.47). As suggested by Fenwick and Tennant (2004) in chapter two, this tacit knowledge is often difficult to articulate or even for workers to justify. From the observations of the operators’ working environment it is clear that they often do not recognise these subtleties, or if they do, it is not regarded as important. This is not unusual; their major focus is to complete the work task.

There are several instances in the previous chapter, where Josh recognised that there were mathematical events within his workplace practices, such as reading digital scales for weighing (numeracy of compliance), estimating and averaging bin numbers (as he was closing in on a full load), and using metric conversions (adding our weights in kg to the load weight in tonnes before entry to the weighbridge). As Fischbein (1982) explained in Chapter Two, some mathematics is self-evident or intuitive and only through questioning did Josh see what he considered was self-evident. However, there was one occasion when Josh did not recognise any mathematical ideas, and yet there were several numerical and geometrical references. Josh was explaining whether he would attempt a figure-eight manoeuvre with many left-turns, in order to collect enough bins to approach his target of 300. He did not identify the estimation spurring his decision on how much to collect and where to stop, stating that “there is no mathematics involved in that at all”. Josh appeared to move in and out of seeing the mathematics in his work, even with numbers such as ‘eight’, ‘300’ and ‘half’ all appearing in the same quote (see section 4.3.2). This is another instance of the invisibility of mathematics in the workplace (Cuban, 2001; Coben, 2002; Wake, 2014).

As Williams and Wake (2007) note, “it may not be recognized as mathematics if it is sufficiently embedded in or fused with the workplace culture” (p.321). When considering an ethno-mathematical perspective however, at least five of Bishop’s (1988) six fundamental pan-cultural mathematical activities, “counting, locating, measuring, designing, playing, and explaining” (pp.182-83), have some spatial connections (locating, measuring, designing, playing, and explaining), while all six have links to estimation. Perhaps *ethno-mathematizing* (researcher’s italics) as discussed in

Chapter Two is a more appropriate model to work with when considering what mathematics resides in workplace practices.

5.2.5 Geometrical practices

With geometry occupying one of the traditional cores of mathematics, it became one of the initial influences on the researcher when considering which ideas of the mathematics of space were being observed. As a consequence, the foundational geometry of very young learners, and the van Hiele theory (van Hiele, 1986) of geometrical thinking (see Table 2.1) were early references to see if there was some alignment with the spatial practices of the refuse and recyclables collection operators. As discussed in the literature review, the van Hiele theory identifies levels of thinking as a person develops their own geometric reasoning, and hypothesises that learners make progress through increasingly complex levels of geometrical thought. Although the van Hiele model of increasing sophistication of geometrical thinking and reasoning may be appropriate for geometry learners, its place as a reference for ordering the spatial awareness of the collection operators seems limited and limiting. The theory allows for progressively more complex geometrical thinking to develop but it does not seem to accommodate the complexity of blended numeracy practices, and the mobile nature of the collection operation with changing angles and widths to compensate for. And as shown with the example in the literature review of the arborist's use of similar triangles and tree felling, the geometrical concepts have very specific contexts while generalising is not practised nor in fact perceived as a need.

In Chapter Two, it was seen that there is evidence of very young children having a greater sense of spatial thinking before they learn to count or enumerate (Clements, 1999). It is possible that workplace activities are similarly placed, with spatial thinking so well-ensconced and experienced, that other numeracy practices stand out more because numbers (e.g. barcodes), quantities (e.g. numbers of cartons to be filled), measures (e.g. number of litres of fuel), and time (e.g. deadline for the courier or the delivery truck), all appear to be more critical to the completion of the operation. This perception of the unevenness of numeracy events and practices means that arithmetic concepts are more visible and thus are noted by researchers in the literature review. However, the spatial requisites such as placing the barcode so it can be read, packing the cartons on a pallet symmetrically (Harris, 1991) so that it is stable and maximises the number stacked, arranging the pallet squarely on pallet racking or in location, and ensuring that older stock is arranged so that it is first-in-first-out (especially if pallets

have to be returned since they are a cost centre), are all spatial considerations and configurations. These illustrate the pervasive nature of spatial thinking and almost seem like a cartilage that holds together more prominent numeracy bones.

5.2.6 Comparing mobile workplaces

Refuse and recycling operators are not unique when it comes to having spatial awareness and a sense of estimation in large moving vehicles. When using public transport, the researcher has observed bus-driving situations where timing and a sense of space and estimation converge. On one occasion a bus operator recognised that the queue his bus was joining had a short green traffic light phase at the intersection relative to the other directions. A large truck in front of his bus had four cars ahead of it in the same queue. The operator noticed another bus was edging its way into the same queue although it was ahead of the truck. Spatial courtesy appears to be such that bus operators usually 'let other buses in' so the second bus would likely complete the lane entry in front of the truck. However, by waiting for the second bus to join the queue and try to drive through the traffic lights would probably delay the passage of the first bus through the intersection, and it would miss the green light phase when 'trapped' behind the slow-moving truck. What was about to unfold was an example of a non-routine problem as discussed in the literature review.

The operator of the first bus then angled his bus into the next (right) lane anticipating vehicles to his right would allow him entry into their queue. When the light turned green and traffic started edging forward, the vehicle on his right hesitated long enough for the bus to move into the gap, drawing alongside the truck as it began to move. The traffic queues in each lane moved forward and the bus was abreast of the truck as each approached the intersection. Both large vehicles crossed the line as the traffic lights turned amber, although having forward momentum they kept moving. With the relative lengths of the truck and the bus, and the time each consequently took to drive across the intersection, it meant that none of the other vehicles behind them had time to reach the line into the intersection.

Once both large vehicles arrived at the other side of the intersection, the bus operator decelerated allowing the truck to move ahead in the left lane, while recognising there was temporary space behind both vehicles. As the truck drew ahead, the bus now re-joined the queue on the left behind the truck. The operator then shifted even further left (into the dedicated bus lane) so that he could let a passenger exit at the next bus stop, and also to align his bus to take a left turn at the next major intersection to continue his

route. This short scenario has parallels with McMurchy-Pilkington's (1995) IF-THEN inference as discussed in the literature review. Once the light turned green the whole procedure took less than 20 seconds but the spatial practice of the first bus driver enabled or even coerced drivers of other vehicles to 'play their parts' so his bus could pass through the intersection without delay.

When meeting with the depot managers at Company X with an executive summary of the findings, the nature of bus driving was broached during the discussion. Both managers asserted that bus driving did not have the same challenges as refuse and recyclables collecting. One stated that bus driving was less complex than collecting with trucks especially when comparing the stop-start motion of trucks as they carry out their collection work. The other stated that "buses only go through the one route, stopping occasionally" and buses also enjoyed the almost exclusive use of dedicated bus lanes with special 'B' traffic lights at some intersections. Further, buses "did not have to align perfectly 1400 times a day" in order to get into position to lift a bin.

The manager's final point was around the nature of routes and bus stops which are dedicated bus-only spaces, clearly marked with dashed lines on the road at which other vehicles are forbidden to stop or park. He added that the collection vehicles operate along both sides of each street on the same run whereas buses only need to go in one direction on each run. Furthermore, the need for buses to 'leapfrog' each other depends on one bus picking up passengers while the other bus catches up and passes. Refuse and recyclables trucks on the other hand usually stop at every residence so leapfrogging manoeuvres with other collection vehicles would likely lead to bins being missed. The manager finished with "every bin had to be lifted, (not) every bus stop had to be visited".

However, bus operators must also contend with work which involves time, space, speed, and estimation while interacting with members of the public. This is another Doman Two situation as discussed in the literature review with the often temporary messiness of the numeracy being used (as in the bus manoeuvring example described above). Buses do have a longer wheel base and therefore need to allow more room to turn their rear wheels. Buses must also at times be driven through major arterial routes during peak times, whereas collection vehicles often collect along those roads much earlier in the day to avoid the same traffic. Bus drivers do not have this option, instead they drive their vehicles through all kinds of traffic conditions often driving split shifts (when operators drive for two separate four-hour shifts). What is common to both

workplaces as mentioned in Chapter Two, is that the collection and bus operators work in situated social practices, with the numeracy strategies employed drawing on operator knowledge of local settings and particularities.

Though obtaining agreement from the managers about similarities of bus operators with collection operators was perhaps optimistic, each set of operators (collectors and bus drivers) does appear to have a number of inventive manoeuvres that they can employ in their large vehicles. Eliot & Hauptman (1981) suggest that spatial ability is a most underrated capacity, including ironically by the people who actually *have the capacity*. The consequences of its misuse are probably a better way to alert its users:

we may underrate the significance of spatial ability to scientific or mathematical thought because we may not have been made aware of the role that it plays in our thinking, and because we tend to be most conscious of spatial ability when we find that our estimations, predictions, or judgements are inadequate (pp. 45-46).

As mentioned in the literature review, adults' funds of knowledge provide them with background knowledge and experiences. The bus driving manoeuvre described above would have failed if the car driver in the right lane had not given way to the bus. The green traffic light phase would have been lost no matter how much spatial planning and local funds of knowledge the bus driver had. The social practice does not mean that it is an amicable situation.

5.2.7 Black boxes in the practices of the operators

Although many numeracy users may not be privy to, or even interested in, the learning of advanced level mathematics as mentioned in section 2.3.3, they are at times beneficiaries of that mathematics. For instance, the collection vehicles have electronic scales, cameras and a monitor, a mechanical drive chain, and a hydraulic system for grabbing and lifting bins. Buses have friendlier traffic signalling, dedicated bus lanes, and now a city-wide transport card which may be used in buses, trains, and ferries. Though each operator engages with these instruments every day, they are not expected to understand how each works let alone the calculations behind their calibrations. This use of an instrument, whose workings or advanced mathematical and technical practices are not fully understood, though the benefits from using them are recognised, is described as a 'black box' (Latour 1999, Williams & Wake, 2007; Damlamian, Rodrigues, & Sträßer, 2013). Users understand the inputs and the outputs but the internal workings are left to those who create them. The advanced mathematics which

supports the technology mentioned above thereby creating the black boxes, is unrecognisable to many who operate it. With a view of school mathematics curricula, Noss (1998) suggests that “the mathematics in working practices becomes less visible, so the mathematical knowledge of the school curriculum becomes less applicable” (p. 3). Curriculum writers may also be caught out with the pace of the technological changes.

Another black box seems to be created by those in service industries, where customers accept the service of the collection operator or the bus operator although may have very little idea of the work going on around them or the decisions being made. As long as the transport takes a passenger from start to destination, or a resident wheels out a full bin in the morning and retrieves an empty bin in the evening, then there is an acknowledgement of what has been paid for by fare or by rates respectively. What the passenger or the resident may not notice is the amount of technology on board, or more particularly with this study, the kinds of workplace and numeracy practices including estimating and spatial which place collection vehicles at their doorsteps to efficiently remove their waste or recycling to places far away from their residences. As discussed in the literature review, new technologies have changed workplace practices, particularly with side-loading collection trucks operated by one person replacing a traditional refuse truck having one driver and two rubbish bag runner-collectors. These ‘service black boxes’ which conceal not only the technology but also the practices, could be added to the technological black boxes suggested above.

In closing this section, several things are worth revisiting. First, the numeracy practices such as optimisation, refuelling options, and almost-full-load estimation are usually challenging to observe, as noted in section 2.5.2, although their respective numeracy events are visible. Each is embedded in workplace practices which at times are complex and often appear to have a mosaic of activities being carried out. That mosaic often obscures the numeracy being used although some mathematics is tied in with technology which is accessible to just a few.

Secondly, the embedded estimation and spatial awareness in the workplace activities often intersect and always lead to decisions needing to be made. For instance, in the loading compliance practice the scales in the truck cab provide the operator with enough information about how many more kilograms of capacity are available, and whether he can empty the bins in the next cul-de-sac or not. Finally, the social practices of the collection operators are situated within a power structure where each operator is

responsible to residents, their employer, and the local municipal council. For recyclers, there is the added pressure of load weight compliance at the Visy Recycling plant, and for the contracted recyclers, as small business owners, there is the extra compliance responsibility with agencies.

5.3 Learning the workplace practices and numeracy practices

The second research question asks:

How have these operators learned these situated numeracy practices?

From their first day each operator is situated in the authentic practices of the collection workplace culture. Each company expects its new operators to bridge the gap between being a novice and an experienced operator. For most of their working day refuse and recycling operators work unaccompanied. As mentioned in the literature review, at some stage the community of practice of operators will trust a newcomer to work independently in their own collection vehicle. Though the environment appears to be that of a solo operator the collection workplace is still socially situated since operators maintain communications with other operators in their trucks on adjacent runs, as well as with administration staff at the depot, and occasionally with residents. Each new operator will start to build his or her own effective workplace experiences during their early legitimate peripheral participation as discussed in Chapter Two. This participation benefits from their working with the collection vehicle (and its artefacts), from informal discussions with others in the workplace, attending their community of practice including site management or ‘tailgate’ meetings, and from the behaviours of the residents and other service contractors in the neighbourhoods they visit.

According to Wenger (1998), “a community establishes what it is to be a competent participant, an outsider, or somewhere in between [...] *a community of practice acts as a locally negotiated regime of competence*” (author’s italics, p137). As discussed, the competence of operators is judged not only by the recycling or rubbish depot managers, but also by the local authority or council who initially awarded the collection tender to each company, the staff at either the recycling plant or the refuse station where trucks are unloaded, and of course the residents and commercial customers whose bins are being collected. As Clancy (2005) observes, “people visibly demonstrate competency in how they make interpretations, conduct business, and produce results that are of an agreeable quality to institutions and public audiences” (p. 16). Competence in the

operators' case is cast much wider than what may appear when observing from a distance.

As discussed in section 2.2, in a situated learning approach people learn the knowledge and practices of their trades by participating with others in everyday contexts and by using the tools (in this case a purpose-built truck with dual driving and steering controls, an electronic monitor with bin-counter, cameras, and a hydraulic bin-lifting system) associated with their particular work roles. In situated learning "knowledge is not just a static mental structure inside the learner's head" (Sawyer, 2006, p.5), although people do reflect on their actions and what to watch for in their workplace environments. Before even beginning their work in collections each new operator must have truck-driving experience in order to assimilate, or to link their existing (Billett, 1999) trucking skills to the new challenges of driving *and* collecting (researcher's italics).

For this learning or training to happen in the recycling and refuse collection workplace, new team members are familiarised with the collection practices of their organisation. Accordingly, the two companies train their new operators by sending them to urban situations. Company Y engaged contractors and sent them to Melbourne for training, initially to observe workplace practices first-hand from recycling operators in a large city. As Noel described, after two days of observation he was given the steering wheel and he took over the run. Company X also arranges for each new employee to first accompany a senior experienced operator in Auckland, using an 'old-timer to a novice' arrangement (Lave & Wenger, 1991). At some stage in the training each novice employee is 'given the wheel' and invited to experience the collecting and driving operations in trucks similar to what they will operate. The transfer of knowledge during operator training was by observation, questioning, and then participation in the practice; there was no dedicated classroom time in their training model. So relatively early in the training of an operator, each company situates new operators in the driving and collection activities that will be their major roles. New operators are expected to work within the operational culture using the supporting lines of more experienced fellow operators and maintaining the reporting lines to depot managers and administrative staff. As described in the literature review, a trainee may eventually become a coach or mentor to other newcomers so the operational culture recycles and evolves.

While the operators are learning to drive and also to operate the collection instruments on board their vehicles, they are also becoming familiar with the layouts of five neighbourhoods (if weekly refuse collectors) or ten neighbourhoods (if fortnightly

recycling collectors). Although the collection sequence in a neighbourhood is usually provided for operators who are starting, there is scope for them to reconfigure a schedule if they find a more efficient order of collecting. This sequencing relates to Taylor's (2005) point in the literature review about the temporal being related to personal landmarks and how people relate the two. For operators, other factors contributing to their decision making around their collection areas are bin numbers and how bins are distributed on each street.

5.3.1 Previous formal learning experiences

Three of the five operators in the research study believed that they were competent in mathematics. The operator Josh was typical of the three operators in that he recognised some uses for mathematics in his current role, although his major interest was as a parent of a daughter in her exam year. He struggled to maintain interest once he was in the sixth form and when he knew he was already assured of a military position. Transferring knowledge from formal educational situations to workplace situations is contentious (Wedge, 2002; Evans & Tsatsaroni, 2000) and like many so adults the operators believed mathematics was something they only studied at school. Josh however, used a lot of mental arithmetic to quickly calculate, estimate and locate on the road.

Another operator mentioned that his mathematics and his geometry were quite good although he did not use them much. A third operator was not confident in his mathematical background, though in his previous work he also had completed time and distance calculations when completing his statutory log book for truck driving. The remaining operator believed that mathematics is important but did not proceed beyond this statement.

5.3.2 Prior work experiences

Although none of the participants in the study had worked as collections operators previously, four of the five had truck or heavy machinery driving backgrounds prior to becoming collection operators. Brian had driven trucks carrying shipping containers; Sean had driven car transporters, while both Dennis and Josh had military transport experiences. Those prior experiences of driving larger vehicles than those they use in their current collection operations is still drawn on in their current work. With the contractors, Josh believed a majority was more interested in becoming business owners who happened to be driving and operating their largest asset. There were a few such as

Neil who had not driven any large vehicles prior to becoming operators; accordingly these men and women had to not only learn to drive the vehicles and acquire the spatial awareness that comes with a larger vehicle, but they also had to learn how to operate the machinery. For the employed operators however, their driving experiences provided them with entry to becoming operators.

There is an advantage to having earlier experiences as drivers of large commercial or industrial vehicles. This experience underpins the capability and the confidence to undertake any new driving role, in particular recognising whether your vehicle can fit in position. Particularly for Brian and Sean, the trucks they had driven previously were much longer than their current collection vehicles and each had to contend with hydraulic systems in those respective instances. Therefore, the experienced drivers all believed that driving a vehicle with new instruments (lifting gear, tipping mechanisms) can be learned and then operated in a relatively short time. The driving is never an issue for them although that is a difficult thing for them to describe (Wenger, 1998). Schön (1983) writes about people's abilities to internalize something they have learned, to the point where they are unaware of their own expertise, and are unable to explain what it is they know. This resonates with the carpet layer in the literature review where he intuitively knew the conversion factor but initially struggled to explain why. The experienced drivers could describe what they had driven in the past but explaining their expertise, other than suggesting it was down to experience, was not so easily conveyed.

The operators were therefore familiar with many of the spatial demands which truck driving introduces. For instance, operators have both geometrical and measurement senses including the use of angles (mirror driving), truck cab dual steering and gear controls, and reverse viewing sense (reflections in mirrors). All were familiar with lengths and widths (edging through gaps between parked cars, or estimating the reach of the hydraulic arm and claws (in reaching a bin). It is difficult then to align what the operators know with the van Hiele levels in Table 2.1 of the literature review. Their novice or newcomer status (Lave and Wenger, 1991) seems inappropriate when describing the complexities of what they already know with their entry into the collection workforce. Clearly the amount of time spent in that 'legitimate peripheral participation' zone is relatively short as the operators then work alone and are literally on the road without much delay. They are trusted with equipment worth tens of thousands of dollars so the 'novice' status for people with previous driving experience is very temporary. Rather, operators begin their work in this setting more at an

‘intermediate’ level since they start out on the road as soon as possible aiming to become independent operators.

Lave and Wenger (1991) discuss how a newcomer has “conferred legitimacy” (p.92) with the gain in experience and dependability in their workplace. In the case of solo practitioners such as waste and recyclables operators, or bus drivers, conferring legitimacy is in a way similar to transferring independence to the new operator. There is a subtle shift in trust and power with the new operator expected to fulfil the collection obligations in the daily designated run. There are still clear reporting lines but the on-the-spot decision making must be made by an operator.

5.3.3 Learning on the road

Other than Sean the operators who participated in the study were already experienced practitioners, experienced in their collection and driving roles and very aware of any health and safety responsibilities. They were also familiar with the characteristics, and some of the residential behaviours in their collections areas. The growing expertise of each operator has an important and obvious implication in terms of repeat experiences. Reviewing location and loci, Schulman (1983) suggests that people “record the spatiality of experience for future use” (p.360). Not only do people remember places they have previously visited, but they connect the location with other events such as who they met there, what they did there, and perhaps what they were thinking at the time. In chapter two Gardner (1993) and Pinxten (1991) provided examples from other cultures about how people can recall particular locations in spite of what seem barely noticeable details to an outsider. Considering the runs of refuse and recycling operators, their familiarity with locations such as bends in certain roads, the level areas for weighing loads accurately, the challenging intersections to get through, or parked vehicles in front of bins at the same residence, is described as “ ‘whatnesses’ entail(ing) ‘wherenesses’ ” (Schulman 1983, p.360). Consequently, they also notice changes and potential impacts in their territories such as new subdivisions meaning an increase in the number of bins.

Neisser (1983) suggests how experience contributes to the improvement in a person’s practice in several ways. Firstly, in the case of the operators, they have worked in the medium for some time and now recognise the local landmarks, street features, rights-of-way, and where difficult householders reside. Neisser describes these as the “affordances . . . where skilled action becomes increasingly economical” (p.4). Secondly, the operators take less time to carry out their work, and therefore use less

energy than when they began. Neil recounted in the previous chapter how he struggled to empty ten bins in his very first hour as an operator, and now he can complete this in three to four minutes. Thirdly, time in the role has armed them with knowledge about how to do their work in the most efficient way possible. An example of this is Sean who even as the newest operator of the participants, had quickly learned that when his truck was almost fully laden and he only needed a few more bins to top it off, there were certain long streets that he should avoid. Lastly, the practice time that each operator has undergone has meant that their movements, driving and collecting are more fluid than when they began. As Neisser (1983) notes, “where the novice is awkward and clumsy, the movements of the skilled practitioner have become graceful and continuous, coherent and unhesitating” (p.5). As the literature review notes, over time the gain in experience leading to the smoother operation has possibly gone unnoticed even by the operators themselves. Wenger (1998) describes the “tacit is what we take for granted [...] it tends to be relegated to the individual subconscious, to what we all know instinctively, to what comes naturally” (p.47). It has only become common sense or natural because each operator performs that operation or a comparatively similar action and no one perhaps thinks it is worth mentioning.

Although the operators’ strategies may vary from truck to truck, their collection practices are all much more effective and efficient than when they started. Eraut (2004) suggests in his workplace studies that there are four kinds of activities which promote learning. First, he suggests participating in group activities such as tailgate meetings held monthly for the operators. One of the depot managers leads these and every operator is expected to attend. Second, Eraut suggests working with another person; in the solo environment of the collection operators that is not always possible, unless like Brian they are occasionally involved in training new operators. However, each operator is linked electronically to the others, and by the GPS system to their depot.

Eraut’s (2004) third point is “tackling challenging tasks” (p. 267). The discussion of the bus operator and his non-routine manoeuvring was a good example of an unusual but challenging task. Although the operators do not go out to actively seek extra challenges in what is an already challenging role, they do on occasion come to road works, parental parking around schools, or traffic obstacles which then force them to decide whether to come back later or to proceed as usual. Operators will also make a note to be alert at this site on their next weekly or fortnightly visit. The fourth point is to work with their customers, in this case residents. As seen in the previous chapter, contact with residents

is often due to providing cautions or warning cards on offending bins. Operators do however, meet difficult residents and that cannot help but influence their actions and add to their situated social practices as discussed in section 2.4. These kinds of episodes take some measure of control in order to keep to their schedule. Most operators look forward to ‘normal days’ although most remember the ‘difficult spots’.

5.4 Future Challenges and Opportunities for the Operators’ Practices

Change in this sector is inevitable as urban authorities wrestle with the waste generated by an increasing population. As mentioned in Section 4.2 of the previous chapter, the presence of recycling collection companies in Auckland and their corporate ownership has changed since the start of this study. Change has also occurred in the destinations of recyclables and refuse. When the pilot study began, the first visit of the researchers was to the Greenmount Landfill, the previous facility where waste from Auckland City and Manukau City had been sent for many years. The 53 hectare facility was closing however (no more refuse accepted), and is in the process of being “capped”, where the existing compacted refuse is being covered with several metres-thick layers of rock, clay, and soil. An agreed deadline for final closure in 2012 has already passed, and it is likely that 2015 will be the new closing date.

Several years before, municipal authorities had begun to look for a new modern landfill facility and as has already been noted in the previous chapter, Hampton Downs in the North Waikato was opened for refuse in 2005. This site met the critical geological soundness criteria for a new landfill (Envirowaste, 2013) and it now receives waste material from Auckland and Hamilton. The landfill will eventually occupy an area of 87 hectares, and will have several stages (or cells). The owners of the landfill, Envirowaste, state that although the new facility has an initial resource consent for up to 35 years, the “life expectancy of the landfill is approximately 100 years” (p.1). There will be other pressures on residents and ratepayers within that lifespan. The Auckland Council has advised that the “short to medium-term target is to reduce domestic kerbside refuse by 30 per cent from 160kg to 110kg per capita per year by 2018” (Auckland Council, 2012, p.16). If this leads to a change in bin sizes and volumes, less for refuse and more for recycling, that will impact on the collection operators, their vehicles, and perhaps their practices also. However, the Auckland Council (2012) has also announced that householders are not the only part of the chain who are ‘on notice’. The council statement below may pressure the existing collection agencies such as Company X and its operators, and the Visy recycling plant:

After analysing current waste services, and the nature of the industry and waste management infrastructure, the Auckland Council Waste Assessment concluded that it will be challenging for the council to achieve a significant reduction in waste to landfill under present ownership, governance and operational arrangements. This will need further consideration over time (p. 5).

The Auckland Council acknowledges that although there is a wish to throw out less and to recycle more, the market for “diverted materials is extremely variable” (p. 31) so the transforming of recycled materials into raw reusable product, including the energy required to enable that transformation, is contingent on the economic conditions at the time.

5.5 Summary

Workplace numeracy has been shown to occupy an increasingly large domain with many practices and capabilities in evidence, some local and others global. Research visits to workplaces and their participants have captured what some of these work practices and capabilities are. One issue with these inspections is that although estimation has often been noticed at work, spatial awareness of workers has not enjoyed similar attention (Marr & Hagston, 2007). This is not unusual when one considers that for many people, mathematics was what they did in school and it seems invisible to them outside the school gates (Williams & Wake, 2007). Researchers have investigated how learning and working simultaneously occur in workplace spaces (Kersh, Waite, & Evans, 2011) although what the learners actually do spatially is often overlooked. Any mathematics performed outside of formal learning is often considered to be just common sense (Coben, 2000) and is part of completing a much broader task.

5.5.1 Situated Events and Practices

The concealed nature of the numeracy within the workplace practices of the collection operators is not out of the ordinary. What separates this workplace from others is the mobile nature and solo environment in which the refuse and recycling operators work in. Further, the operators’ workplace is replete with estimating, spatial and temporal events and practices within the workplace practices of driving, collecting and emptying bins, and health and safety. Other workplace practices around administration and maintenance have more impact on the contracted operators and their small businesses than for employed operators.

Examples are given above of refuelling practices and loading practices, each typically invoking a number of numeracy events and decisions. As these decisions are unfolding,

the truck is still in motion and the operator is likely to be thinking about the next load on his return. The need for sound estimation is paramount since there are compliance penalties for overloading. While all these decisions are being made, each operator uses his sense of estimation and his spatial awareness to drive efficiently and courteously

5.5.2 Learning

The spatial and temporal numeracy practices outlined above are expected of each operator, required by the collection companies, the city council, the residents, and their peer operators. However, those spatial and temporal numeracy practices are almost invisible, submerged not only from a casual observer, but also from the operators themselves. It is unfortunate that so many adults believe that “formal academic mathematics is the only valid representation of people’s mathematical ideas” (Millroy, 1991, p.6) and do not appreciate the mathematics they carry out and learn for themselves.

CHAPTER SIX

CONCLUSIONS

6.1 Introduction

This thesis has used the workplace of refuse and recycling operators to target numeracy practices around estimation and spatial awareness. This numeracy has been situated in and around the mobile workplaces of collection trucks as these are driven through urban settings. It has described what is an often overlooked and perhaps incomplete aspect of numeracy – adults’ awareness of how they use space at work. From a very early age we use and occupy space and it is only our arrival at school that “requires restraint and immobility never asked ... before” (Bruner, 1966, p.114). The research participants, the refuse and recycling operators, are the reverse in terms of mobility, and ample evidence has been provided to describe how they apply spatial awareness practices throughout their mobile workplaces. The elements of spatial awareness include being able to manoeuvre large trucks through narrow city streets, locating various features in their collection areas, including places where these large vehicles can be turned, having an appreciation for the numbers of bins in certain streets, planning routes in and out and around the areas, using side mirrors to assist with bin lifting and safety, recognising the capacity of the side-arm extensions on their trucks, and accommodating other collectors and vehicles.

Importantly, these elements of spatial awareness are not stand-alone features of this workplace. There are close links with measurement and a sense of estimation, the other focus of this thesis. Estimation is also pervasive throughout the workplace practices of the collection operation. Operators are frequently judging distances, estimating bin numbers, deciding which route to take, and working out how much more weight can fit in their trucks. Further, operators are continually assessing their options such as when to exit an area in order to reach destinations outside of rush hour traffic. Each of these estimates within situations is evidence of seemingly ingrained practices which may only be uncovered using ethnographic means. It is clear that traditional assessment instruments would struggle to uncover the complex and tacit numeracy that these operators practise, especially considering that there are several situations where the operators themselves do not recognise the numeracy aspects.

Although each operator has had school-based learning experiences, their learning of their work practices is mostly due to their current working experiences. For some who started without any truck driving history, the journey has been longer as they first have had to acclimatise to the spatial environment in and around a heavy machine, and also learn to operate hydraulic lifting and tipping, and extending and retracting equipment. However, all appear now to be competent operators, although they will be mindful of the revolving ownership of the company that employs and contracts them as well as the changing landscape for the Auckland region's refuse and recycling.

While numeracy has been variously described as slippery (Coben, 2003) and elastic (Doig, 2001), the estimation and spatial practices of the operators in this study might not be defined as 'slippery' so much, rather as neglected elements of numeracy. The operators' mobile workplace is a mosaic of civic, environmental and commercial practices. The scale of their spatial awareness is impressive as is the way it merges with estimation within their workplace practices. This is due in part to the operators being so proficient at these practices that they do not acknowledge their own expertise with spatial awareness and estimation, or how mathematical these are.

There is little evidence that previous education settings have made major contributions to their current work. Other workplaces described in chapter two were similarly situated with on-the-job learning, initially having newcomers working beside more experienced staff.

6.2 Responses to the research questions

This thesis posed the two research questions:

- Which situated numeracy practices, in particular involving spatial reasoning and estimation, do these recycling and refuse operators use in their workplaces?
- How have these operators learned these situated numeracy practices?

This research study was a case study drawing on ethnographic methods of semi-structured interviews, observations, field notes and examining artefacts such as workplace documents and truck cab machinery. Five refuse and recycling operators were accompanied on their daily runs through Auckland suburbs to investigate how each carried out his role.

In answering the first research question it was found that the workplace activities of the collection operators may be separated into six overlapping sectors – Collecting,

Driving, Emptying, Administration, Maintenance, and Health and Safety. Within these workplace sectors, several numeracy events and practices surfaced; for convenience these were categorized into mathematical strands such as Number, Estimation, Measurement and Spatial Awareness. Practices such as refuelling, compliance, loading and route planning drew on various strands such as estimation and spatial awareness illustrating that the numeracy also overlaps and is not necessarily tidy.

The second research question was addressed by asking the operators about their school mathematics learning experiences and their training for the current role. Although four of the five thought that mathematics in school had some value, it is fair to say that they were unconvinced as to whether mathematics had any presence in their work. Four of the five operators had driven other large vehicles prior to working in the collection roles. This previous driving expertise has been augmented by being trained (for up to two weeks beside a more experienced operator). Each operator then developed his own strategies to meet the demands of the daily collection routines.

The findings of this research tend to support the literature of numeracy research in other workplaces suggesting that on-the-job learning appears to be the major training resource for the people in those workplaces. There is also a further appreciation, not only of the complexity of people's working lives, but also of the momentum to keep learning informally as situations evolve around them. The findings endorse the separate domains (Coben, 2002) of numeracy and mathematics, related yes, but situated by their respective participants who occasionally make one or other visible in their respective practices. Few adults acknowledge the presence of maths in their everyday work practices but fewer still acknowledge the contribution of spatial awareness (Marr & Hagston, 2007) even though it is very clearly present when one observes people at work. Finally, the cultural influences and tacit knowledge of people at work is masked by their expertise and familiarity with process, thereby promoting ethnographic approaches as the best means of visiting these people's contexts and concepts.

These findings could be of interest to numeracy educators who may recognise that estimation is indeed important but may not appreciate the innate sense of space that workers may already possess. Alternatively, workplace trainers may need to be concerned if their staff do not have spatial awareness where use of location, direction giving, and space and shape are standard workplace expectations. Also, assessors of

numeracy may need to rethink how they might fairly examine these hidden but critical elements.

Although estimation and spatial awareness have been mentioned in workplace numeracy literature, this thesis hopefully adds to the understanding that numeracy in mobile workplaces occupies a different niche than in less dynamic environments. Every movement in the operators' collection vehicles draws on numeracy events. Whatever activity they are engaged in, it is simply non-stop whether or not the operators are aware of the ongoing numeracy around them.

As a result of this study, further research might well be conducted in other mobile workplaces (e.g. buses which were mentioned in chapter five), courier drivers, or any of the operators of mobile selling franchises, to look for commonalities and contrasts with the refuse and recycling operators. Further research could be also be around proposed council changes to the waste minimising plans and the effects these might have on the roles and the employment of the operators. Another research project could investigate the recyclables industry, the eventual destinations of the materials that are collected, and what kinds of cost-benefits are evident. Finally, research could also follow the progress of the remaining contracted owner-operators who will be approaching their seven-year timeframe, and whether continuance is possible under the current regime.

6.3 Limitations of this study

Although this thesis describes how estimation and spatial awareness are used in a particular workplace, the researcher acknowledges that with a sample of five operators interviewed and observed, it would be unwise to generalise beyond this case study. This research remains a snapshot of the workplace of the refuse and recycling operators and their particular localised practices.

There is a large body of literature from neuroscience and psychology which draws on functional magnetic resonance imaging (fMRI) and other experimental work to describe how humans and others behave with respect to both estimation and spatial awareness. This work is beyond the scope of this thesis although is referred to briefly.

Although the audiotaped interviews provided the richest vein of information, the transcription of those conversations was at times made difficult by the volume of noise in the truck cab. In several instances it took up to six attempts to ascertain what one of

the interviewees had said, such was the noise made by the hydraulic lifting gear and the low gear driving. Also operators frequently had to turn their heads away to concentrate on the lifting and placing of bins so the audio-sound was at times inconsistent. So the researcher found he became almost as reliant on the field notes and sketches where neatness and subsequent legibility of handwriting were also challenged by the frequent lurching movement of the truck.

Spatial awareness in particular crosses subject boundaries such as mathematics, art, physical education, and geography. In the interests of numeracy, which as Steen (2001) suggests is “essentially inter-disciplinary” (p. 115), this thesis has confined itself to the mathematical domain, although other domains are also clearly visible.

As mentioned in Chapter Three, although the researcher provided information to prospective participants, the managers or ‘gatekeepers’ were involved in inviting most of the operators who participated. Although one of the newer operators had attended the tailgate meeting and volunteered, most of the others were asked if they would take part. Fortunately, these operators appeared very knowledgeable about their roles. The operators did have the right of refusal if they did not want to take part.

Finally, there is also the acknowledgement of researcher subjectivity that no matter how earnestly the researcher has tried to be objective, there are always “preconceived notions” (Yin, 2009, p. 69) that surface and need to be put to one side. To the best of the researcher’s ability, this objectivity has been pursued so hopefully this thesis has fairly and accurately described what each participant has shared.

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GLOSSARY

- *Bins* – wheeled out by residents on their dedicated collection days,
 - a weekly 120 litre bin for refuse and
 - a fortnightly 240 litre bin for recyclables.
- *Commingled material* – mixed raw recyclable material such as glass, paper, and most plastic containers, separated at Visy recycling plant
- *Compaction factor* – a weight to volume ratio (commercially sensitive) agreed to by Auckland Council and Visy when the collection system was first set up; truck loads have a maximum compliance weight for recyclables based on this compaction factor.
- *Dual controls* – each side of the truck cab has a steering wheel and foot pedals so the vehicle may be driven from either side.
- *Load* – the amount that a truck is carrying at any one time; the recyclables loads are more restricted than refuse loads.
- *Run* – normally one day's work for an operator and it is usually carried out in the same suburb on the same day each week or fortnight; so refuse operators will have five runs to complete every week whereas recyclables operators will have ten runs per fortnight. Each run will have three to four loads each collection day depending on the season.

Participant Information Sheet

Project Title : **How do Recycling / Refuse collector/ drivers' use Numeracy (estimate, spatial perception, other) in their everyday work?**

An Invitation

My name is Phil Kane and I am researching the Numeracy demands of certain occupations, as part of my MPhil programme at AUT University. I want to research through the eyes and experiences of operators some of the main numeracy practices used when collecting refuse and recyclables. By numeracy practices I mean the ways you use numbers to calculate things, how you estimate space and work out locations when doing your work. I am inviting you to be one of the operators who will contribute to this discussion. I would like to stress that this research is not trying to determine 'good' or 'bad' practices - I am simply interested in how the job is done.

Your participation in this project is voluntary you can withdraw at any time, prior to the completion of the data collection, without consequence. If you agree to take part, I would like to observe your work practices and interview you around the numeracy involved.

What is the purpose of this research?

As a refuse or recyclables operator you would have significant knowledge and experience in collecting waste in the Auckland and Manukau areas. In particular I am interested in your perspectives on the numeracy (*number use, measuring, space, location*, etc) which you work with every day. I realise that there are many occasions when you may use numeracy in your work, some of it visible and some not. Your overview of the industry, and your expertise, will contribute to the research report I plan to write. This report would be available to you and your manager if you wish. The report will be used as the basis for my thesis study and also for conference presentations and/or journal articles. It is important to note that this research project will focus on your insights about numeracy in your workplaces so that an overall view of the industry is provided; it is not a focus on you as an individual.

How was I chosen for this invitation?

You will have read the notice which I posted in your staff/lunch room and attended the brief meeting which was held after that. You will then have contacted me to say that you are interested in taking part in the research. You are volunteers who have expertise in your industry, and no pressure to participate will be placed on you. You will have ample opportunity to ask any questions and be free to withdraw at any stage before the completion of the data collection. The work that you do may inform us of future numeracy insights into this industry.

What will happen in this research?

If, after discussing this Information Sheet and project with me, you agree to participate, arrangements will be made to observe your work practices. Then I will make a time which suits you, to discuss your insights and knowledge about the numeracy you use in your work. When observing your work I would also like to take photographs of the collection operation, though not of you, the operator. I also want to interview you about the work you do. In the interview I will use the notes, sketches and photos to jog your memory of the work you do and the numeracy you use in doing this work. Before the interview you will be given a copy of the interview schedule and the main questions I plan to ask, although some questions may come from the notes, drawings and photos. The interview should take up to forty-five minutes. To enable the interview to be recorded accurately, I would like to use audiotape. Transcripts of your interview will be forwarded to you for checking.

What are the discomforts and risks?

It is highly unlikely that any questions asked will cause you discomfort but, if it does, as voluntary participants you are free to terminate the interview at any time. Copies of the Indicative Questions **will be given to you** well in advance of the observation and interview.

There are several waste collection operations in the Auckland and Manukau areas, and it is unlikely that it will be possible to identify you in the finalised research project as volunteers are being recruited from a number of sites. Although your manager will not be informed that you are participating it is, however, possible that he will become aware of this. However, **no** information about you will be passed on to him. Managers will receive a summary of the finalised report..This research is exploring how numeracy impacts on your collection practices. This has nothing to do with how the company is being run, nor how their staff is progressing.

How will these discomforts and risks be alleviated?

These questions have been designed so as not to cause you any embarrassment or to upset you in any way.

What are the benefits?

The numeracy aspects in collecting waste may possibly benefit from your industry insights. Importantly the summary report may also provide you with feedback about numeracy uses in your field, and potential training issues to be met.

How will my privacy be protected?

Protecting your privacy cannot be guaranteed since there is a possibility that as individuals you may be identified. That is, however, unlikely as this research is interested in identifying patterns and trends and will not focus on individual opinions. Although your manager may be aware that you have participated in the research he will not be given any information about your work practices or anything you say in the interview. If a photograph which contains a human figure is used, all facial features will be digitalized out.

What are the costs of participating in this research?

In terms of time, a brief meeting with me to answer any questions around the contents of this sheet, and if you agree to participate in the project, an interview of up to forty-five minutes. My observation of your work practices will be unobtrusive and will not interfere with you in any way.

What opportunity do I have to consider this invitation?

Approximately a week.

How do I agree to participate in this research?

If you agree to participate, please phone me on the number provided or contact me at the email address.

Will I receive feedback on the results of this research?

Your interview will be transcribed and returned to you to verify that it is a true and accurate record of **our** discussion. This is an opportunity for you to check that I have written down what you have said and your use of numeracy. You will also be able to make any changes you like to the transcript, including taking out any material. Once the transcripts have been verified, the information from these will be made into a report, and summary feedback will be sent back to you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor. Associate Professor Pat Strauss (09) 921 9999 ext 6847 or pat.strauss@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTECH, Madeline Banda, madeline.banda@aut.ac.nz, 921 9999 ext 8044.

Whom do I contact for further information about this research?

Any questions or suggestions you might have about the research should be directed to the researchers,

Phil Kane: (09) 9688765, ext 8162 or phil.kane@manukau.ac.nz

Associate Professor Pat Strauss (09) 921 9999 ext 6847 or pat.strauss@aut.ac.nz

Thank you

APPROVED BY AUTECH

on Thursday 21 July 2011 for a period of two years, from 01 August 2011

Reference: 11/162

PARTICIPANT

Project Researcher: **Phil Kane**

- Yes ☐ No ☐

signature:

name:

.....

.....

.....

Approved by AUTC

Reference: 11 / 162

Note: The Participant should retain a copy of this form.

APPENDIX C - Indicative set of semi-structured questions

INDICATIVE QUESTION SET – WASTE AND RECYCLABLES COLLECTING

1. Background information

- How did you come into this (refuse/recycling) collection industry?
- What experience and/or qualifications were required when you became a waste collector?
- Are there any skills you learnt from past work experience that help you in this job?
- Were there any assessments for things like reading, numeracy, and driving, operating machinery?

2. The roles which you (and other drivers) carry out in your daily routines . . .

- What skills do you think one needs in order to do your job efficiently?
- If there were three major tasks as a waste collector could you list these in order of importance?
- Are there any other roles?
- (Prompts: accuracy, following schedules, road transport compliance, maintenance, safety, . . .)

3. Thinking about the numeracy demands of your job, and the kinds of numbers you are involved with:

Can you provide any examples (using these prompts)?

- Number work:
 - Counting/ checking – e.g. *have I collected them all?*
 - How do you keep track of the number of bins you've cleared?
 - Calculating ... are there any additions, subtractions, multiplying, etc to be done?
 - Estimating – e.g. *I should be at the transfer station in about 25 min?*
 - Proportion concepts such as percentages, ratios, rates (e.g. *bins per hour, met our KPIs?*)
 - Optimums – what is the most number of bins that you collected in an hour?
- Measuring & Locating:
 - weighing (e.g. *bins overkg?, transport loads, weigh-in at the recycling / transfer station*)
 - Can you tell when a bin is heavier than it should be and how can you tell?
 - How do you know when the truck is full?
 - measuring length (or width between parked vehicles, distance travelled/day)
 - What cues do you use on your mirror to help you with getting into position/ check for potential hazards? - How do you know when you're in the best position to lift the bin?
 - How do you do collections on bends, cul-de-sacs, one-way streets though both sides occupied? Is there anything you do differently with your truck in these spaces?

- Is there any positioning or gauging you have to do at the recycling/transfer station?
- any volumes? (*cubic metres to compact*)
- Climate & temperatures (*wet conditions – slippery bins*)?
- time scheduling? (*near schools, hospitals, main roads*)
- What strategy do you use to get your job completed in the quickest time?
- How do you time it so as not to overlap with other collectors from other companies?
- using maps or GPS or following directions? (*reducing number of right turns*)
- Is there counting or measuring skill/s you know from your past /culture, that helps in work?
- Are there any skill/s you learned in school maths (calculations, geometry, proportions, measuring) that helps in your work?
- Data and information processing:
 - comparing other weeks, months, season, years? (*increase over last year*)
 - collecting data . . . new dwellings, mileage, road works, different areas of the city, etc?
- Other?

4. Working with new staff and their training

- Is there any numeracy requirement of a potential waste collector before they are hired?
- Can you think of an example where you had to teach a new member of your team about an aspect of numeracy (number, shape, locating, etc), and if so what was the circumstance and what did this entail?
- Think of something involving numbers or measurement in the collecting industry that you had to learn
 - in what way(s) did you learn that?

5. Your perspectives on changes and trends in this industry, possibly requiring alterations to numeracy procedures (including numeracy):

- In your time in this industry have you noticed changes in technology which require more or less numeracy actions from you and the other drivers?
- In your time in this industry have you noticed changes which impact on your planning and scheduling,
- or other numeracy actions from you and your team?
- Do you believe that driver/collectors will need to have the same levels of numeracy, or have more numeracy, for their work in the future? Why?
- What do you know about where all this stuff goes? Have you heard of times (how many years) when maximum capacities at the landfill might occur?

APPENDIX D - Examples of residential warning cards

What to do to ensure your recycling is collected.

1	The recycling bin lid must be able to close - excess recycling needs to be removed. • Recycling items falling from an overfull bin can be a safety hazard and possibly harm people or damage vehicles.	4	Bins full of glass or magazines can be too heavy to lift. • Some items will need to be removed and put into the next collection.
2	Telephone Council on (09) 301 0101 to arrange for repair.	5	Recycling will only be collected from the Wheelie bin. • Excess recycling items can be taken to a Drop-off point. Telephone Council on (09) 301 0101 for locations.
3	Please ensure cardboard is folded flat. Do not pack too tightly in the bin. • Large amounts of cardboard and paper can be taken to a drop-off point. Telephone Council on (09) 301 0101 for locations.	6	Handles of the bin must face the house (face away from the road). • Place away from trees or lamppost • Leave a space between bins • Place clear of footpath

Please phone Auckland Council on (09) 301 0101 for help or more information if you do not understand the information on this tag.

Faamolemole, telefoni i le Pulega a Aukilani i le (09) 301 0101 mo se fesoasoani poo nisi faamatalaga, pe afai e te lē malamalama i faamatalaga i lenei pepa (tag)

Fakamolemole 'o telefoni ki he Auckland Council fika (09) 301 0101 ke nau tokoni pe fakaikiiki atu 'o kapau 'oku 'ikai ke mahino kiate koe 'a e tu'utu'uni 'oku fakapipiki atu heni.

如果您看不懂标签上的内容而需要帮助或更多信息，请致电奥克兰市政府，电话：(09) 301 0101

अगर इस लेबल पर दी गई सूचना आपको समझ में नहीं आती तो सहायता या अधिक जानकारी के लिए ऑकलैंड काउंसिल को (09) 301 0101 नम्बर पर फोन करें।

Thank you for recycling

www.aucklandcouncil.govt.nz

We have emptied your recycling bin this time.

Your bin will be checked on your next collection day.

If any wrong items are in your recycling bin again it will not be emptied.

If there continues to be wrong items in your bin council may remove your recycling bin.

The items that can and cannot be put into the recycling bin are shown on the sticker under the bin lid



Please phone Auckland Council on (09) 301 0101 for help or more information if you do not understand the information on this tag.

Faamolemole, telefoni i le Pulega a Aukilani i le (09) 301 0101 mo se fesoasoani poo nisi faamatalaga, pe afai e te lē malamalama i faamatalaga i lenei pepa (tag)

Fakamolemole 'o telefoni ki he Auckland Council fika (09) 301 0101 ke nau tokoni pe fakaikiiki atu 'o kapau 'oku 'ikai ke mahino kiate koe 'a e tu'utu'uni 'oku fakapipiki atu heni.

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Thank you for recycling

www.aucklandcouncil.govt.nz

APPENDIX E - Spreadsheet of Josh’s collection history in the preceding month

THIESS SERVICES - AUCKLAND NZ

MONTHLY TRUCK RUNNING SHEET

DRIVER: JasonW

TRUCK No: 30

COMPANY: 57 October Limited

MONTH- June 2010

REGISTRATION- ENU890

DAY	DATE	TIME			FUEL UTRES	ENGINE HOURS	KILOMETRES	TOTAL BIN COUNT	TOTAL WEIGHT	LOAD1		LOAD 2		LOAD 3		LOAD4		LOADS	
		START	FINISH	Hrs:Mins						BINS	WEIGHT	BINS	WEIGHT	BINS	WEIGHT	BINS	WEIGHT	BINS	WEIGHT
"Enter Previous Months last Engine Hr & Kilometre					j,623		49,209												
E	Tuesday	01 Jun 10	5:30	14:30	9:00		3,636	49,387	894		310		294		290				
A	Wednesday	02 Jun 10	5:30	11:00	5:30				783		313		297		173				
S	Thursday	03Jun 10	5:30	14:00	8:30				900		307		313		200				
T	Friday	04 Jun 10	6:00	13:30	7:30	157.6			828		275		273		280				
	Tu6\$day	08Jun 10	6:00	13:15	7:15	160.06			984		346		318		320				
	Wednesday	09 Jun 10	6:00	13:30	730				793		281		261		251				
W	Thursday	10 Jun10	6:00	15:45	9:45				989		226		234		247		282		
E	Friday	11 Jun10	5:30	13:00	7:30	170.29			780		256		271		253				
S	Saturday	12Jun 10	6:00	13:30	7:30				812		240		256		156		160		
T	Monday	14Jun 10	6:00	13:00	7:00	156			820		269		268		283				
	Tuesday	15Jun 10	6:00	13:00	7:00				844		230		261		104		249		
E	Wednesday	16Jun 10	6:00	11:30	5:30	138.05			716		272		255		188				
A	Thursday	17 Jun 10	5:30	14:00	8:30				850		245		229		241		135		
\$	Friclay	18 Jun10	5:30	13:30	8:00	150			785		222		220		204		139		
T	Monday	21 Jun 10	5:30	11:30	6:00				939		338		334		267				
	Tuesday	22 Jun 10	6:00	12:30	6:30				803		273		277		253				
W	Wednesday	23Jun 10	5:30	14:00	830	163			841		183		275		227		155		
E	Thursday	24 Jun 10	6:00	14:30	830				768		282		262		224				
\$	Friday	25 Jun 10	6:00	11:45	5:45				838		310		262		265				
T	Monday	28 Jun 10	5:30	12:15	6:45	140			854		287		282		285				
	Tuesday	29 Jun 10	5:30	13:30	8:00				927		291		313		323				
	Wednesday	30 Jun 10	530	13:15	7:45	166.5	3,776	51,305	815		277		270		268				
'Enter End of Month Engine Hrs & Kilometres:					3,776		51,305												

163.45	1,402	153	2,096	18,563	234.44	6,033	6,026	5,383	1,121				
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APPENDIX F - Spreadsheet of Company Y owner-operators' collection histories in the preceding month

MONTHLY SUMMARY OF TRUCK STATISTICS

AUCKLAND RECYCLING

MONTH: JUNE 2010

Name	Rego	Fuel	Truck Hours	Lt's/hour	Km's	k/100 L	Km's/hr	Bins	Bins/hour	Total Weight	Kg/bin	Loads	Weight / load
	886	1185.00	155	7.65	1810	152.74	11.88	17807	114	229.30	13.02	70	3.28
	890	1402.00	153	9.16	2096	149.50	13.70	18563	121	234.44	12.63	72	3.28
	881	1490.00	164	9.09	2050	137.58	12.80	17408	106	241.46	13.87	75	3.22
	883	1557.00	174	8.95	2098	134.75	12.06	17873	103	230.20	13.42	73	3.29
	884	1269.00	163	7.79	1748	137.75	10.72	17639	108	230.58	13.07	69	3.34
	889	1350.00	161	8.39	1741	128.96	10.81	18167	113	237.68	13.08	72	3.30
	887	1285.00	155	8.29	1955	152.14	12.61	17390	112	236.38	13.59	72	3.28
	882	1435.00	140	10.25	2269	158.12	16.21	17406	124	234.44	13.47	74	3.17
	970	1237.00	142	9.30	1956	158.12	13.52	17161	118	236.20	13.76	71	3.33
	885	1331.00	156	8.53	2164	162.58	13.87	17346	111	239.64	13.63	75	3.20
	969	1371.00	180	8.57	2098	153.03	13.11	17808	110	232.54	13.21	72	3.23
	888	1321.00	146	9.05	1885	142.69	12.91	17973	123	241.18	13.42	75	3.22
	972	1610.00	141	11.42	2294	142.48	16.27	17081	121	236.02	13.82	75	3.15

Total:

17843	2010	116	26164	1910	170	229222	1485	3060.26	174	945	42
1372.54	154.62	8.96	2012.62	146.96	13.08	17632.46	114.22	235.40	13.40	72.69	3.25

COMPANY VEHICLES

Name	Rego	Fuel	Truck Hours	Lt's/hour	Km's	k/100 L	Km's/hr	Bins	Bins/hour	Total Weight	Kg/bin	Loads	Weight/ load
ENZ 974 - Sideloader	974	307	45	6.82	643	209.45	14.29	2782	G2	39.78	14.30	14	2.84
EPU 281 - Rear End Loader	281	981	134	7.32	1447	147.50	10.80	9998	75	156.34	156.34	41	3.81
Total:		1288	179	14	2090	357	25	12780	136	196.12	171	55	7
Averages:		644.00	89.50	7.07	1045.00	178.47	12.54	6390.00	68.22	98.06	85.32	27.50	3.33

APPENDIX G - Executive summary discussed with managers before
final operator interview (Brian)

OBSERVATIONS OF SPATIAL AWARENESS AND ESTIMATION WITH RECYCLING AND REFUSE OPERATORS IN AUCKLAND URBAN AREAS EXECUTIVE SUMMARY

Introduction

A preliminary (pilot) study of numeracy practices of refuse and recycling operators was carried out in mid-2010. Four operators (two recyclers and two refuse) from the (then) two South Auckland collection companies were observed and interviewed by two researchers during their usual collection runs. This was followed 18 – 24 months later with a fuller research project, where different recycling and refuse operators (from the now amalgamated company) were observed and interviewed during their collection work; the set of interview questions used in the second project had been revised following the exploratory study. Though findings were similar, other numeracy questions surfaced during the interview transcribing.

Findings

The key targets of the researcher were still an appreciation of each operator's spatial awareness when driving their dual controlled trucks (on the side opposite every other right-hand driven vehicle), alongside the lifting and placing of bins, along with the estimating skills (though there is considerable overlap here), as well as competence and safety in driving dual controlled trucks.

Similar themes for all driver operators:

- Competence in truck driving (a working knowledge of the capabilities and limits of their machines, use of mirrors) and the responsibility for their and the residents' safety
- Turning and timing when dealing with traffic – esp. intersections and roundabouts
- Estimation – particularly being able to think 'on their feet' and to anticipate others' (re)actions when their trucks were working
 - expected bin numbers, e.g. how many could be left in this day's run,
 - occasional locations and map reading (knowing suburb, street, school, etc.) layouts or whether public or private construction is going on, (e.g. where contractors might park their vehicles on collection days), one way systems, narrow streets and trees with low overhanging branches, school parking behaviours at the start or at the end of a day. Also used if they must collect for a colleague, & need directions about where to begin.
 - time (to start collecting - e.g. residential after 7am, main roads before, then after 9am)
 - timing, esp. seasonal, school holidays, rush hours, weekends in a holiday week
- ... all converging, alongside the operators' driving experiences on those local runs.
- Understanding variations in bin weights if collecting across different socio-economic areas.
- Recognising pacing of bin collections in different suburbs – e.g. slower in inner city suburbs with narrower streets and more kerb side parking, versus suburban streets.
- Normal street sequence seems almost to be 'stored' away in the operator's memory – (e.g. a bin suddenly appears, or a resident misses the collection, or a bin from the opposite side of the road suddenly reappears on this side of the street on the way back); also phoning in serial numbers of bins which somehow have offensive loads/to be stickered
- Also having to return if a claim/complaint is made – customer service is important, getting the odd disgruntled resident, but operators also have empathy with older less fit residents.
- Knowing where a load has finished during a run so on the return, they restart it there by looking for cues at that location
- Variation in berms and how residents place their bins, can be challenging to align claws
- Can usually tell when a bin is really heavy with the response on the stick.
- Sense of exiting busy/congested street asap, esp. when other drivers oblivious to schedule

Recyclers in particular

- Focussing when the recycling load in the hopper is almost 4t (3.96t) using their cab scales, then deciding when to return to (Visy) in Onehunga
 - usually depends on where they are (which suburb, which street – exit strategy usually already planned earlier in the run); depending on the season, this could force that decision earlier or later in their run - constant monitoring of weight is critical as load rises.
- Awareness of possible financial penalty if an individual load > 3.96t. Some uncertainty about how this is calculated though knowledge of difficulty for Visy to untangle load if it is too compact?

Other themes or questions arising from the interviews

- Operators seemed to have learned main practices through experience with trucks (or other industrial vehicles), then picked up the other elements of the work by spending time on the same route (situatedness), and from conversations with other operators in the team re strategies (in tailgate meetings?).
- Unsure whether secondary schooling has been useful in preparing them for this work – more needs to be confirmed here; for instance, could map reading in social studies or geography assist, and number sense when thinking about remaining bins, time calculations, weight margins in a load, etc. What about a sense of distance or perspective from physical education or art. What is studied in geometry and does it assist at all?
- There is always the practice of counting going on, but what about *Subitisation*, that ability to recognise a set number of objects (say bins) before having to start to count them?
- Education in the early years (formal and informal) might hold the key for some people in terms of the construction of their own spatial awareness – what did they specifically do, and how much time did they spend with things that gave them a sense of space?
- Games played, electronic or otherwise? Some people have a flair for these, but has their practice or use been a contributing factor to developing the sense of space?

Some people's thoughts on what a sense of space, or possessing spatial ability, might be:

Brennan, Jackson, and Reeves (1972)

- spatial perception does not consist of a single skill or ability, includes attributes such as “hand-eye coordination, visual discrimination, figure-ground relationships, and language and perception”

Sorby (2003)

- spatial skills are not simply “a unitary construct . . . spatial ability consists of mental rotation, spatial perception, and spatial visualization”.

Sutton and Williams (2007)

- spatial ability does involve “mental rotation of objects” . . . plus two other aspects - that an understanding is needed to see how “objects appear at different angles . . . (and) how objects relate to each other in space”

Donohue (2010)

- includes a fourth aspect, an understanding of three dimensions (or 3D).

While some others believe that geometry is a bit underdone in secondary school mathematics, there is another consideration – not everyone has the same sense of space, and for those who need to somehow apply it, there is the dual need that they need some deliberate training. The collection operators appear to pick this up through practice so that it becomes almost second nature to them . . . but is this experience their only learning?

Phil Kane