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Human behaviour modelling through Human Intelligent Movement Software (HIMs)

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Human Behaviour Modelling through Human Intelligent Movement Software (HIMs)

By

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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the Award of

Doctor of Philosophy of Loughborough University

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Abstract

The concept of sustainable urban environments aims to provide urban facilities including transport interchanges that can accommodate a wide spectrum of the human population irrespective of gender, age or disability. A major objective is to reduce levels of social exclusion which arise from inadequacy in infrastructure that strongly affects certain members of society such as the elderly, disabled and poor.

This research focuses on the particular aspect of crowded public spaces where it is envisaged that improvements in crowd flow could be achieved by a proper consideration of all the users of the space but particularly the elderly and disabled. The ultimate objective would be design tools that provide architects with the means to achieve inclusivity in design for the elderly and disabled with relative ease and speed. Therefore, this research has developed a methodology and a computing tool to implement aspects of human walking behaviour in public spaces.

Human behaviours have been studied using a large-scale video observation involving over 17,000 subjects. The videos have been analysed to determine a number of different behaviours and their relationship to distinguishing characteristics of the subjects such as age, gender and disability. Algorithms for representing these behaviours have been developed and implemented as a simulation tool (HIMs) within commercially available gaming software.

Two case studies, within shopping malls and a bus station, have been carried out to illustrate the feasibility of the work and simple examples of small environmental design changes that significantly affect crowd flow are shown.

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Chapter 1   Introduction to the Research Work

1.0   Introduction

Many aspects of human behaviour have been of considerable interest to researchers for several decades. Much of the work done has been concerned with the psychological characteristics of human behaviour in work and social settings. Recent advances in computer and information technology science have opened up the possibility of simulating the physical behaviour of humans as they interact with each other in social and work settings. Interaction is at its greatest in crowded places and so it is natural to look to human behaviour simulation as a potential aid to the design of crowded public spaces such as shopping malls, railway stations, bus stations and sports stadia.

A majority of the previous research has been conducted on a scalable crowd of human beings. A typical example is the creation of a scene to simulate particular crowds such as those in a shopping malls, sports stadia and bus stations. The simulated scenes can be intended for situations like the breakout of fire (Fraser-Mitchell 1999) where panic can lead to uncontrolled evasive actions in making for the fire exits.

The work reported here is closely related to, but separate from, a major research programme known as AUNT-SUE (Accessibility and Users Needs in Transport – Sustainable Urban Environments)(Marshall et al. 2009)). AUNT-SUE is a 'Design for All' project that seeks inclusivity in the design of the urban transport infrastructure. In particular computer aided ergonomic design methods have been developed to help ensure that the elderly and disabled are considered in design

alongside the young and able-bodied. Accessibility in the AUNT-SUE work is primarily concerned with access onto vehicles such as buses and underground trains whereas the work of this thesis is more concerned with the wider infrastructure including transport interchanges (bus and train stations).

1.1   Aims and Objectives

The aim of the research is to explore and prototype a suitable method for modelling human walking behaviours in a discrete manner which will contribute to the prediction and depiction of how human beings behave in particular situations. This research is deemed important as it provides a stepping-stone for future research on human related designs in surroundings such as workplace, social and travel situations. Two of the foreseen areas to benefit are the fields of ergonomics and human relations. Ergonomics is defined as the *study of the interaction between people and machines and the factors that affect the interaction* (Bridger 2003). This research is particularly focussed on the elderly and disabled as the main aspects of research for human walking behaviour modelling. It is hoped that new findings from this research will act as an in-depth understanding of the elderly and disabled behaving in their social paradigm.

The objectives of the research are:

a)   To study and identify various human behaviours relevant to the area of study. The area of study is focused on the walking characteristics of the elderly and disabled in crowded public spaces and is closely related to research into sustainable urban environments.

b) To develop a prototype simulation program for the modelling of human walking behaviours and characteristics of the elderly and disabled.

c) To verify and validate the effectiveness of the human behaviour models for the elderly and disabled through a relevant case study.

1.2   Problem Statement

Many researchers have published work related to human crowd modelling where the objective is to study how a crowd of humans exhibit behaviours as a single entity rather than as individuals. This could be considered to be similar to the behaviour of a flock of birds or a shoal of fish responding to external stimuli. However, the main point of this study is to focus on the behaviour of individual human beings in crowded situations.

A substantial part of the research is concerned with gaining knowledge of some of the characteristics of human behaviour that can be modelled in a virtual environment. The important aspect of this is that human behaviour is a significant issue when for example understanding how a disabled person in a wheelchair reacts to a platform while boarding a bus or how an elderly man manoeuvres himself while balancing his walk with a walking cane.

This approach applies to the design of common facilities for ordinary people in their everyday life. Citing elderly people as an example, there is a need to know how they respond to the facilities offered such as disability toilets and lifts, procedures for boarding and alighting from public

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transport, access to shops and climbing staircases (Figure 1.1). In this way, it will be possible to gather information on the difficulties that they are facing and to investigate how the design of facilities might be undertaken to minimize these difficulties.

Figure 1.1   A Tram Stop With Various Individuals Interacting in Budapest

(http://www.acclaimimages.com/).

In terms of the public transport system, the research work hopes to find better solutions for everyone and to establish design evaluation methods to achieve it. Realistically, the research aims to not only provide for the elderly and disabled but to encompass the following users:

- Those who are permanently mobility impaired due to physical, mental or sensory disability;
- Those travelling with heavy luggage;
- Those accompanying young children and;
- Children travelling alone.

1.3   Problem Identification

The problems stated in Section 1.2 have been identified in a manner which takes into account the various needs of human beings in their everyday life. The problems faced by humans are actually the real problems that all of us have encountered during everyday observations of human life. Therefore, the problems are identified in various ways such as:

- Visual observations;

- Data from reports on transport facilities and other sources deemed relevant;

- Relevant journals and conference proceedings and;

- Reported accounts of various events from the International Crowd Safety Consultants (Crowd Dynamics Limited which can be found in their http://www.crowddynamics.com/ website.

1.4   Research Novelty

The research has the purpose of producing a viable prototype simulation software capable of modelling human behaviour in a virtual environment. With the introduction of such a software to any field of research into human behaviour, it is hoped that much can be done to understand humans when interacting with their environment. This is especially true when ergonomics is concerned for the elderly and disabled human beings.

The study of human behaviour with the elderly and disabled in mind will enhance the credibility and performance of designs dedicated as a user-friendly product or surroundings. As for the designs of public amenities, such public transport, stations, pedestrian walkways, and others, this can be improved overall with the elderly, disabled, children and pregnant mothers in mind. The important thing here is to find the best options for everyone to benefit and enjoy life for years to come.

1.5   Scope of Research

This research spans the subjects of human behaviour modelling and sustainable urban design that covers personal space, age, gender, human physical ability, spatial behaviours and software development.

The research was limited to studying the different types of movement pattern in human beings based on video observations carried out in Loughborough town centre. The research looks only into the entities' age, gender and their physical abilities (limited to those with waking aids, mobility scooters and wheel chairs), when interacting within a public space. Many other factors such as anthropometry details, joint constraints, cognitive capabilities and body strength have not been considered.

An attempt was made to find a better solution for the layout of a shopping mall's walkway and a bus interchange hub's barrier and seating orientation for better human walking flow patterns especially for the elderly and disabled. Theoretically the software development should include walking

objectives and walking speeds that affect the software's simulation area, cost of change to layouts, unlimited number of entities, etc but these aspects were not tested practically. The practical work was limited to the video observations and the redesigning of the placements and re-orientation of barriers in several layout designs covered in the research. The research also does not concern services or other facilities provided in both areas of simulation.

1.6   Thesis Structure

The thesis consists of eight chapters including this introductory chapter. The contents of the chapters are as below:

Chapter 2: An Introduction to Human Walking Behaviour Modelling

This chapter consists of a literature review focussed on previous research in human behaviour modelling. It includes human behaviour modelling and related research on the representation and parameterisation of the behaviours of entities and the personal space for individuals. The chapter concludes by putting the research in perspective relative to the analysis of simple human body movement.

Chapter 3: Review of the Application of Gaming Software and Human Behaviour for Simulation Purposes

This chapter considers the use of gaming tools that have been the driving force in the programming of video games, especially those that need high quality graphics and sound effects. During the

course of this review, a programming language that has been considered for the simulation purposes of the research work is introduced.

Chapter 4: Human Behaviour Observational Studies

This chapter covers the use of video technology to record, analyse and collect essential data to be interpreted and used as a tool to learn more about human walking behaviour in public spaces. The different characteristics of those involved in the survey are also discussed.

Chapter 5: The Human Walking Behaviour Mechanism

This chapter includes a discussion based on the video observations of Chapter 4. The most important feature that needs attention in this chapter is how human beings react towards each other when they are in crowded public places such as shopping malls and public transport facilities.

Chapter 6: Software Design and Modelling

This chapter covers the use of DarkBASIC Professional as the tool for the simulation aspects of the research work. The simulation work is carried out to demonstrate that a simple program is able to simulate certain human walking behaviours in public places. The program acts as a platform to show how human beings work as entities in an artificial environment. The environment or world is modelled from the previously recorded videos of human beings interacting in a crowded walkway of a shopping mall in Loughborough's town centre.

Chapter 7: Case Study and Evaluation

This chapter describes the use of a mock up of a place of interest as a case study. The introduction to the case study is based on the selection of the location on the assumption that the program simulates a situation that involves all the entities in the previous chapter. Subsequently, validation work based on the assumptions of the case study is carried out to show the feasibility for the program in a typical public transport situation. The two main case studies are the simulation of a shopping mall walkway and a bus station departure hall.

Chapter 8: Discussion and Conclusion

This chapter provides a summary of the research and results. Conclusions are drawn confirming the contributions made to knowledge. Further research opportunities originating from this work are also suggested.

Chapter 2   An Introduction to Human Walking Behaviour Modelling

2.0   Chapter Overview

In this chapter, the focus of the review is on previous research in human behaviour modelling. Human behaviour modelling and related research includes the representation and parameterisation of the behaviours of entities and study of the personal space for individuals. The review is concluded by putting the research work in perspective relative to the analysis of simple human body movement.

2.1   Introduction to the Concept and History of Human Behaviour Modelling

The discussion of previous work involving human behaviour modelling is, in part, aimed at identifying the gap in the research. Firstly, the work on human behaviour modelling is more concerned with the involvement of human characters or entities that are general in concept rather than the identification of human entities with specific characteristics such as disabilities or being elderly. Most of the previous research concentrated on queuing aspects and crowd control as the objective was often the idea of controlling crowds at a macro level where the entities are examined in groups based on their movement within a crowd. The gap in the research involves the micro level of determining the walking behaviour of individuals with varying characteristics arising perhaps from age or disability.

The research is also focused on the concept of sustainable urban environments where the usual practice of having to sustain all lifestyles will be the determining factor in finding a good solution for

the design of public spaces. There has been a considerable amount of research that is related to human behaviour modelling in this context and this is described in the subsequent paragraphs.

At the lowest level of abstraction, this research is an instance of the application of human behaviour modelling as an aid to understanding and providing for human participation in public open spaces. This approach involves constructing simple dynamic models that represent human entities of all lifestyles irrespective of age and ability. There are similarities with previous work on human behaviour modelling but here the focus is on the impact of the simulation of specific human walking behaviours for the elderly and disabled.

2.1.1   Physical Contact and Spatial Behaviour in Human Behaviour Modelling

This section refers to the action of human beings in a crowded place or scene which is the main focus of the research. An absence of focus on sustainable urban environments is shown as the call for user-friendly surroundings, especially for the elderly and disabled, has not been addressed by the authors covered in this sub-chapter. The area of interest of the research of this thesis is mainly concerned with human walking behaviour that is coupled with human personal space.

Whenever a human is in a crowded situation, such as a group of football supporters in a stadium watching a match, the physical and close contacts between individuals is always an important factor. Physical contacts can be divided into two categories, namely, self-focused and other-focused (Badler and Allbeck 2001). They defined self-focused contact as *it may reflect a person's cognitive state or a habit and include nervous mannerisms;* meanwhile other-focused contact *includes irritating,*

condescending, comforting and electric. The current research is mainly focused on how humans react spatially in particular situations and it will be interesting to know how they react as conditions become more crowded or get sparser rather than being in actual physical contact.

The same authors (Badler and Allbeck 2001) tried to use spatial human behaviour as a new area of research interest. Their research on spatial human behaviour is based on using age, gender, status, roles, culture, personality and context in trying to tackle the issue of human behaviour modelling. Looking at previous work done in physical contact and spatial behaviour shows that these aspects can be replicated immaculately by actors and animation artists, but embodied human model researchers have not yet focussed on the specific detail. This is the main area that needs addressing in this research where human walking behaviours are concerned.

One interesting work on human behaviour modelling (Burgess 1983) suggested that the interpersonal characteristics change with age and one finding was that the acceptable personal distance increases with age, but is always less with peers than with those that are younger or older. Another finding was that physical contact changes with age and status as older people are more likely to touch those younger than themselves than vice versa. This will form the basis for the current research in human walking behaviour where personal distance is concerned.

2.1.2   Status Modelling in Human Behaviour Modelling

Status modelling is a field of research that is based on the status of entities in the form of a master-slave relationship (Hayes-Roth et al. 1996). They discovered that changes happen to postures and actions as the slave becomes the dominant character in the environment and then returns to his submissive role. Another model using status (Poggi and Pelachaud 2000) is based on the concept of *performatives,* which means facial expressions that accompany and add interpersonal relationship information to speech. In another related work (Musse and Thalmann 1997) introduced the *dominance* factor into the simulation work where dominance is defined as *the state that exists when one person or group has power over another*.

However the status of an entity does not account for the movement pattern of anyone in a public space from the experience of the author. The agility of the entity in a public domain affects the movement and subsequent response from others nearby. Likewise, the movement of neighbouring entities has a similar effect. Human beings do not normally observe status as the main feature affecting walking behaviour or movement patterns as observed personally by the author in the current research work. Although status is considered in this section only a small portion of master-slave relationship and dominance can be used for the current research work.

The author feels that more emphasis should be given to the actions or walking behaviours of focus groups such as the elderly and disabled in public spaces. The degree of understanding in human walking behaviours must be studied so that their behaviours can be incorporated in the design of current or future public spaces or buildings that practice sustainable urban environment design.

2.1.3 Human Behaviour Modelling in Gender Research

A study (Exline 1963) stated that physical appearance is an obvious channel for communication between different genders, but gender should also be consistent with the other channels of communication. Exline suggested that a clear example was where pairs of women tend to engage in more eye contact than pairs of men. In another study (Burgoon et al. 1989) many gender differences that effect the channels of nonverbal communication were discussed. These include postures in which males tend to have more dominant, less affiliative, and less intimate postures than women, and spatial behaviour in which in small groups and interpersonal interactions, women require less personal space than men. Though both men and women have been modelled in virtual environments, there is currently no implementation that models gender as a component of the cognitive state of entities.

This area of research that focuses on gender has been studied by many researchers but it seems that gender can be an important consideration or otherwise. The absence or presence of gender in human behaviour modelling or human walking behaviour is acceptable depending on the cultural origins of the individual. For instance, if a subject comes from the West the affect of gender is very minimal as far as the closeness of distances between different genders is concerned. A different situation happens for those from the East as they are very concerned with whom their neighbours are. Different genders mean that they must distance themselves but for the same gender closer rapport is possible.

A simple observation like this means that gender may or may not play an important part in human behaviour modelling because when a crowded situation happens the entities may just forget about

the gender issue in order to pass through promptly without much hassle. This research work considers different age groups but not gender as significant parameters in walking behaviour.

2.1.4   Using Character Roles in Human Behaviour Modelling

Characterisation of human beings is a basic tool to identify various categories of humans in the physical research area. Character is a very general topic to report but some researchers have been able to identify certain characters that belong to certain age groups.

A study (Danzinger 1976) stated that every character has a role to play in the simulated runs of virtual environments. The roles involve expectations; both from the individual characters in the role and from those interacting with the individual playing the role. In order for a character in a virtual environment to be consistent, it must meet the expectations of the role it is playing. Roles are known to be learned, generalized guidelines for behaviours. The author agrees with Danzinger (1976) who stated that *a human's behaviour originates from an individual's occupation, kinship, age, sex, prestige, wealth, or associational grouping.*

Meanwhile, (Isbister and Hayes-Roth 1998) have studied roles in relation to intelligent interface entities. They found that making the role of an interface entity clear helps to constrain the actions users will take in their corresponding role in public. This section will be another tool to support the research work based on video observation work carried out in Chapter 4. The characters of human beings as stated by Danzinger (1976) in the first paragraph of this section will be scrutinised.

2.1.5 Individuality in Human Behaviour Modelling

Individuality of human beings is another field of research that needs to be considered in human behaviour modelling. Individuality can be described as *a distinct personality of an individual regarded as a persisting entity*. In this field of research, what is important to people, what they value, and what they desire are important aspects of their individuality. Conducting research in this area is constrained by the programming power of the software and depends on how dynamic software can be simulating individual human behaviours. At any moment, a person's actions are motivated by their goals and the interactions and conflicts of their goals. This approach is possible by knowing the needs of the goal and resolving conflicts between goals. A study (Russell and Norvig 1995) indicated that Artificial Intelligence (AI) research has studied many aspects of planning and conflict resolution in planning, but what is more important for consistent communication is the manifestation of these processes in human walking behaviour such as for the elderly and disabled.

For example, if we were to imagine a young child whose mother asks if he scribbled on a newly-painted wall in their new house, then the child values being honest with his mother, but also values the dessert that will be taken away as punishment. He will express confusion and anxiety as he decides what to do. The results of his cognitive processes will transmit valuable information to his mother where she has fulfilled her objectives of teaching her child to be more responsible.

This section shows that the study of individuality of human beings will determine what values are to be considered for this research especially after the video observation carried out in Chapter 4. The next sub-chapter will determine whether the work on the behaviour of entities is viable for research work based on a suitable computing tool.

2.2   Computational Software in Representing and Parameterising Entities' Behaviours

This section looks into the use of computing tools in behavioural research of human beings and design of public spaces or places. The use of computer graphics technology has evolved greatly during the last few years. The portrayal of 3D embodied characters or virtual humans has been intensified with the introduction of more powerful supercomputers that simulate at a speed never imagined before. Apart from the offline, animator-intensive methods used in the special effects industry, real-time embodied entities are expected to exist and react with users "live". They can represent other people or functions as autonomous helpers, team mates or tutors enabling novel interactive educational and training applications (Badler, et al. 2002). We should be able to interact and communicate with them through modalities we have in our everyday lives, such as language, facial expressions and gestures. This seems to be an ideal situation to relate to our everyday life but in terms of human interaction in a public space, there is a need to consider it in its entirety especially considering the needs of the elderly and disabled.

Various aspects and issues of real-time virtual humans have been discussed in Badler's work such as consistent parameterizations for gesture and facial actions using movement observation principles, and the representational basis for character believability, personality, and affect. They also discussed using Parameterized Action Representation (PAR) that allows an entity to act, plan, and reason about its actions or actions of others. Besides embodying the semantics of human action, the PAR is designed for building future behaviours into autonomous entities and controlling the animation parameters that portray personality, mood, and affect in an embodied entity. In this work Badler, was more interested in the individualisation of physical reaction to its surrounding and he did not look into the effect of public space design.

We are used to seeing films at cinemas and being amazed by the special effects used by the special effects masters. They are given extraordinary appearance and achievements of various special effects and interactive games, but the creation of real-time autonomous embodied entities remains one of the last remaining frontiers in computer animation. Cartoon characters and fictional personalities have been used with the greatest visual success. They are either developed with relatively low level techniques such as parametric key interpolation or edited from motion captured with live performers (Badler et al. 2002).

However, such activities are iterative, off-line, and subject to the technical and aesthetic skills of the animator. The important aspect to be exploited is that the autonomous entities are supposed to be entities that respond to human interaction in real-time and with behaviours that are perceived to be appropriate to the interaction and needs of the participants. Generally, these needs are constrained by the application so that the behavioural repertoire of the entity can be created in advance, recalled, and modified in real-time as needed. Thus, in games the movements and choice of the game entities are restricted so that the user is really only exploring a finite game space.

Now, let us try to compare games and interactions between real people. The interactions with real people seem to appear infinite. They are at least real-time, not predetermined, broad in content, highly contextual, communicative and behaviourally subtle even to the extent of being subliminal. The communication modes between entities are multi-modal and encode multiple levels of meaning. The entities can either communicate with speech or other verbalizations, facial expressions, eye movements, head movements, limb gestures, body postures and even gait. In reality, as an example human beings are relatively unaware of the acts their bodies are performing while they are talking.

However, an observer picks up the details of additional non-verbal signals or language from the speaker's "body language". Both parties are attempting to obtain or convey some sort of information via the communication, and therefore are exposing and manifesting some aspects of their internal knowledge, desires, beliefs, intentions, emotions and feelings to the other (Badler, et al. 2002). Apart from the work done by Badler and Allbeck (2001), which consists of communications with arms and torso, facial expressions, and eye movements; another work of equal importance concerns the gait of human beings (Ashida et al. 2001).

From the previous paragraph, the interactivity between entities and the specific design of a public space is missing from the two mentioned works by Badler and Ashida. Neither mentions the level of interactivity especially when concerning the study of the elderly and disabled.

2.3   Study on Personal Space for Individuals

Personal distance is defined as *the distance that non-contact species, such as humans, will create between each other; a spacing to avoid contact*. This essentially acts as an invisible bubble that surrounds the entity. When two bubbles overlap, the two entities are very much more involved in each other's actions, than when they are not overlapping. The size of the invisible bubble is determined by many factors, which can include fear, social standing and dominance.

Human beings are born to be distinctive entities in their own right. Humans, as they grow older, lead independent lives. However, to what extent is the human being able to tolerate others around him? It is a proven fact that each of us has personal space boundaries that influence our comfort in certain

social situations. A researcher in the 60s, (Sommer 1969) referred to it as *an invisible boundary surrounding the person's body into which intruders may not come, like the porcupines in Schopenhauers fable, people like to be close enough to obtain warmth and comradeship but far enough away to avoid pricking one.*

These boundaries have been defined by (Hall 1966) who explored the science of *proxemics*, the study of man's use of space as a communication vehicle. He produced four different spatial distances around the body, which are described below:

a) **Intimate distance** (0 - 0.2 metres)

This distance can be seen in both wrestling and comforting someone and reveals much about the other person involved through body heat, smell and breathing.

b) **Personal distance** (0.45 - 1.2 metres)

This is a transitional distance between the intimate contact provided by intimate distance and the more formal contact seen in social distances. This distance is seen by (Hall 1966) as a *small protective sphere or bubble that an organism maintains between itself and others*. He therefore sees this as the most important distance in terms of personal space.

c) **Social distance** (2 - 3.6 metres)

(Altman 1975) felt that this distance is the basis for public seating such as reception rooms where people who do not know each other can feel comfortable with their personal space unthreatened.

d) **Public distance** (3.6 – 7.5 metres)

This distance is used when either talking to a group or walking alone. (Hall 1966) describes it as *a position where the individual has enough time to either take evasive or defensive action if threatened.*

These definitions are not set in stone for every person and as Hall (1966) describes they can change because of nationality, social standing and the environment the individual is used to as well as many other social factors. One example is the difference between age groups and this is mentioned by Altman (1975). A study was carried out on children ranging from 6 to 12 years old who had to pick a circle of a particular size to represent them. These sizes not only increased with age, but with self esteem in relation to how they compared themselves to others and dependency in their perception of the symbol being part of a group. He also mentioned a presentation given by Hall (1966) which demonstrated how parents actually position their children, subconsciously teaching them their own personal space.

A simpler form of the definition of personal space is re-iterated by Forsyth (2006) from Hall's (1966) list of personal spaces into a simpler form as shown in Table 2.1. The table has characteristically redefined the various personal zones or spaces that can be used as the reference for this research work.

Zone	Distance	Activities	Zone Characteristics
Intimate	Touching to 0.2 metres	Procreation, massage, comforting, accidental jostling, handshake, slow dancing	Sensory information concerning other is detailed and diverse; stimulus person dominates perceptual field.
Personal	0.45 – 1.2 metres	Friendly discussions, conversation, car travel, watching television	Other person can be touched if desired, but also avoided; gaze can be directed away from the other person with ease.
Social	1.2 – 3.6 metres	Dining, meetings with business colleagues, interacting with a receptionist	Visual inputs begin to dominate other senses; voice levels are normal; appropriate distance for many informal social gatherings.
Public	3.6 – 7.5 metres	Lectures, addresses, plays, dance recitals	All sensory inputs beginning to become less effective; voice may require amplification; facial expressions unclear.

Table 2.1   Personal Space as Re-defined by Forsyth (2006).

2.4   Analysis of Simple Body Movement

In attempting to analyse the bodily actions, (Laban 1960) found it may be helpful to consider several sequences which contain typical movement ideas. Each of the following six examples contains a characteristic action mood which may be lyric, solemn, dramatic, jocular, grotesque, serious, or such-like. The interpretations of the sequences are left to the reader's own imagination. It need only be mentioned that the created action-moods will become obvious through the particular way the instrument (body) is used; the directions the movements take and what shapes they create; the

rhythmical developments of the whole sequence and the tempo in which it is executed and rely on placement of accents and the organisation of phrases (Laban 1960).

Listed here are six examples of movement sequences, namely:

a) running – tossing – crouching – whirling – standing.

b) bowing – lifting – closing – opening.

c) swaying – circling – spreading – hovering.

d) trembling – shrinking – precipitating – sprawling.

e) Waving – drooping – perching – pouncing – creeping.

f) Walking – reclining – turning – jumping – up rearing.

Laban stated that it is possible to determine and to describe any bodily actions by answering four questions, namely:

a) Which part of the body moves?

b) In which direction or directions of space is the movement exerted?

c) At what speed does the movement progress?

d) What degree of muscular energy is spent on the movement?

An example that Laban used in explaining the above questions is:

a) The moving part of the body is – *the right leg*.

b) The region of space to which the movement is directed is forwards. The movement is *straight*.

c) The muscular energy spent on the movement is relatively great. The movement is – *strong*.

d) The speed of the movement is rapid. The relative pace is – *quick*.

The conclusion from the above is that the movement described is not a step but a thrusting kick of the right leg in a forward direction. Yet, this conclusion depends on the imagination of the user in this instance. Figure 2.1 shows the basic subdivisions needed for the observation of bodily actions.

Left Side   Right Side

Head

Shoulder   Shoulder

Elbow   Elbow

Wrist   Wrist

Hand   Hand
(fingers   (fingers

Trunk
upper part
(centre of

Trunk
upper part
(centre of gravity)

Hip   Hip

Knee   Knee

Ankle   Ankle

Foot   Foot
(toes)   (toes)
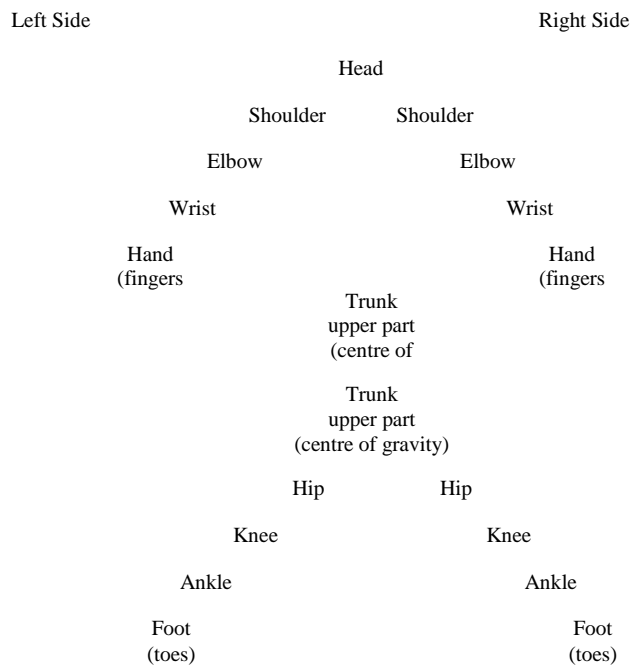
Figure 2.1   The Body: Basic Subdivisions Needed For The Observation of Bodily Actions (Laban 1960).

To conclude the research by Laban, he had shown that body actions do play a role in determining the movement of entities which is directly associated with human behaviours. However, his research should be supported by other behavioural traits such as walking behaviours for human beings especially ones that involve the elderly and disabled.

2.5 Studies on Human Anthropometry

Another field of study that involves human beings is anthropometry. The word *anthropometry* relates to a branch of study in the field of ergonomics that deals with body shape and size (Worthy 2005). Anthropometry is important in the field of human behaviour modelling because the study of human beings recognises that humans come in all shapes and sizes. This drives the need to take these physical human characteristics into account whenever someone designs anything that somebody will use, from something simple such as a writing pen to a more complex concept such as comfort during driving and handling a car.

From anthropometry, we can deduce what might be the main characteristics of human beings as entities in simulations. As stated by Worthy (2005), we can make use of the anthropometric study as a reference for the research work. This research is carried out by following the stated criteria below:

a. Decide Who You Are Designing for

The use of anthropometric data (Worthy 2005) determines which characters are suitable for research purposes. Typically they are divided into groups based on different nationalities and age groups. On this basis, various age groups of entities suitable for observation purposes were defined and can be found in Chapter 4.

b. Decide Which Body Measurements Are Relevant For Research Purposes

From video observation, it will be possible to determine the size of the entities that are going to be simulated by referring to the data provided by Worthy (2005). From the data, it is deduced that the types of entities can be sub-divided into various groups such the elderly, the disabled, the normal adult, teenagers, children and toddlers. This is true in the sense that we have more information on the entities being simulated. This is where it is possible to predict by knowing exactly who is being designed for and this is termed as the *user population*.

c. Decide Whether The Design Is for the Able-bodied, Elderly or Disabled

The variation in the design of products for human beings must include the needs of everyone including the elderly, disabled and also children. Worthy (2005) has stated that nobody is average in his or her body dimensions. Someone may be average in height but have a longer than average hand length. This shows that the research work to be done in this area must be diversified when looking at the carefully selected entities.

Therefore, it is important that research work be in accordance with the needs of the particular set of entities intended for any particular design. Subsequently these guidelines are useful in determining whether any design is suitable for the elderly and disabled. By using the human walking behaviour models incorporated into the designs, it is hoped that the designs can benefit the elderly and disabled in particular and society as a whole. In the real design work, it is sometimes difficult to accommodate all users due to the fact that there are bound to be conflicting solutions to the design.

Therefore, any designer will have to make a judgement about what are the most important features to be incorporated in a particular design.

Some of the design work by Worthy (2005) that incorporates the needs of a particular set of entities is shown in Table 2.2, and it is noted that the use of 'average' dimensions is not recommended and instead there is a need to consider the 5% or 95% percentiles as in Figure 2.2. For this research, the focus group will be the elderly and disabled human entities. The disabled are confined to those in a wheelchair or those using other walking aids (inclusive of those on mobility scooter).
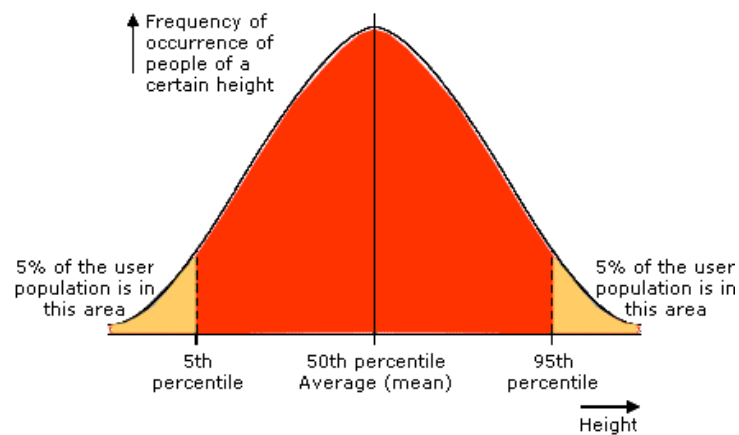
Figure 2.2   Graph of Height against frequency of occurrence (Worthy 2005).

What is that you are aiming for with your design?	Design examples	Examples of measurements to consider	Users that your design should accommodate
Easy reach	Vehicle dashboards, Shelving	Arm length, Shoulder height	Smallest user: 5th percentile
Adequate clearance to avoid unwanted contact or trapping	Manholes, Cinema seats	Shoulder or hip width, Thigh length	Largest user: 95th percentile
A good match between the user and the product	Seats, Cycle helmets Pushchairs	Knee-floor height, Head circumference, Weight	Maximum range: 5th to 95th percentile
A comfortable and safe posture	Lawnmowers, Monitor positions, Work surface heights	Elbow height, Sitting eye height, Elbow height (sitting or standing?)	Maximum range: 5th to 95th percentile
Easy operation	Screw bottle tops, Door handles, Light switches	Grip strength, Hand width, Height	Smallest or weakest user: 5th percentile
To ensure that an item cannot be reached or Operated	Machine guarding mesh, Distance of railings from hazard	Finger width, Arm length	Smallest user: 5th percentile Largest user: 95th percentile

Table 2.2   Examples of Situations That Involve Particular Design Projects (Worthy, 2005).

2.6   Recent Research on Human Movement Patterns

During the last ten years, research has been focussed on several issues such as rendering the virtual environment and population of entities, controlling and designing the content of the simulation world and simulating the behaviours of virtual entities and their navigational features. The need for full interaction between the entities is vital for progress in human being simulation techniques. This is where the current research to tackle the problem of interaction between entities.

In rendering a large crowd situation, or virtual environment, it is possible to organise a particular scene by applying level-of-detail strategies (Hamill and O'Sullivan 2003). Human entities can be depicted as highly detailed 3D models through a range of intermediate techniques to simple 2D pre-computed images. This method is based on the use of a virtual camera to cover the distance of the image to the user (Tecchia et al. 2002; Dobbyn et al. 2005). The 2D rendition of human entities which are pre-computed is found to be highly restrictive due the limited range of possible motions in the content of the image itself. This fact (Shao and Terzopoulos 2005) has made it difficult for interactive environments with various rich human entity behaviours to have a very large population size.

Loscos et al. (2003), modelled the environment using cell-automaton methods based on 2D rendition. A pedestrian's global motion results from successive local motions from one cell to another. The cells are guided by probabilistic rules that are frequently used for evacuation simulation techniques. However, this method failed in synthesizing high quality smooth movement patterns due to the effect of discretization. Another possible way is the use of circles of varying radii for different entities (Pettre et al. 2006). Triangulation methods can also be used (Lamarche and

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Donikian 2004). In the case of large virtual environments, a hierarchical representation preserves fast path search times (Shao and Terzopoulos 2005; Paris et al. 2006).

In another development, researchers have tried to use Voronoi diagrams to solve the various path planning problems and entity-to-entity neighbouring problems (Sud et al. 2007). The use of both cell-decomposition and Voronoi diagram-based techniques have demonstrated an ability to handle large crowds, but this is not enough as there is still the question as to whether the simulation is able to handle the large numbers over a period of time. Presently, the introduction of high speed computers has made it possible to increase the numbers of entities in the population. It is sometimes illogical to put large numbers of entities in a public space as it should be possible to estimate a suitable number of entities for the analysis being undertaken. The introduction of path planning has enabled the user to have even more control over the simulated population by equally distributing prescribed points of interest to individual entities composing the crowd.

Looking at the traversing level, most of the current software movement mode is controlled by steering methods. This is the main concern when trying to put realism into the simulation work. One example is using a set of rules for interaction purposes (Reynolds 1987). A social forces model (Helbing et al. 2005) is based on the laws of physics and mimics a working magnet. In this case, the interaction between pedestrians is represented by two conditions, namely, entity acceleration resulting from a set of attractive (goal, friend and family) and repulsive (obstacles, danger, enemy and other people) forces. The work of (Helbing et al. 2005) was eventually improved in order to avoid artefacts such as oscillations in trajectories (Pelechano et al. 2005).

An analogy (Treuille et al. 2006) was made with potential fields where people move against the gradient resulting from a static field (goal, objective, family or interest) or dynamic field (other people or enemy). In other research based on robotics, the concept of velocity obstacle is adapted to solve human interactions (van Den Berg et al. 2008). The most recent work (Yersin et al. 2008) is on the possibility of steering or manoeuvring with a level-of-detail approach that makes it possible to simulate a large-scale population. Other recent work solves interactions from examples of other simulation works (Lerner et al. 2007), (Lee et al. 2007) but their results are below the recommended performance level for applications in interactive virtual worlds. The latest work by (Yersin et al. 2009) is based on motion patches in the form of building blocks annotated with motions but it still needs to be proved that it can simulate different age levels especially the elderly and disabled.

In this section, although different techniques are available to simulate human walking behaviours, there is still a need to give full autonomy to users in determining the best solution in providing motion and action autonomy to a virtual world population; action decisions need to be provided for behavioural simulation, or defined directly during the design or start-up stage. From the above works, it can be seen that the possibility of navigation globally is determined from path planning prior to simulation. The limitations involved include the difficulty of mixing various behaviours including walking behaviours with real-time rendering techniques; secondly, online generated simulations cannot be easily controlled, because movements in simulators are pre-planned, world size is limited and the level of complexity is also limited. With the complexity increasing, the number of mathematical interactions to be solved increases and this slows down the program defeating the purpose of simulation in the first place.

This research hopes to create a new awareness of walking behaviours for the elderly and disabled in an area concerned with both primary usage and artificial intelligence incorporated together. It is hoped that designers in the future could control the composition and behaviours of virtual populations

2.7   Incorporation and Modelling of Human Walking Behaviours into Software

In the following sections, five common human walking behaviours that are potentially suited to simulation are described. The order of appearance is in order of their importance in simulating human walking behaviour as determined from the observational videos on human walking behaviours. These behaviours should be able to show how humans interact in different kinds of situations. In choosing the behaviours, careful attention is taken to ensure their suitability for the simulation process. An important feature of all the behaviours is that they are compatible with all age groups of people in the neighbourhood. They will play an important role in determining the feasibility of focusing on human walking behaviour for the elderly and disabled.

2.7.1   Adaptation

This represents the ability of the entity to adapt to their current state or surroundings. This process is necessary in order to overcome any problems encountered prior to entering any state or surrounding. An example of adaptation is when an entity called Entity A suddenly meets a large group of other entities moving towards it in a chaotic manner like those happily moving around

without any specific goal. Therefore, entity A must try to either change the way it moves by reducing its speed or by changing the walking direction in order not to hit the oncoming group. Adaptation is a critical ability for entities to master as failure to adapt can result in accidents happening. This will also result in the failure of the simulation system.

2.7.2   Altruism

Altruism literally represents an unselfish concern for the welfare of others (selflessness). This type of behaviour is instinctive in nature where cooperation proves not to favour the entity but contributes to the well-being of the entire set of entities within a certain space. For example an entity, Entity C will help a disabled person (Entity B) to board a bus that has a ramp that is not high enough for easy access. By receiving a helping hand, Entity B is able to board the bus with ease.

2.7.3   Attention (Interest)

This behaviour defines the concentration of an entity upon an object with a close or careful observation or listening. This level of behaviour can also be termed as an observant consideration where courtesy is involved by giving some attention to others' feelings. Gallantry (heroic courage) behaviour is always observed when this kind of attention (interest) is observed. The level of attention is based itself on the ability of an entity to concentrate on the things that interest it such as window shopping at a shopping mall or looking at train timetables at a railway station. Another example is the stop-look-go behaviour where an entity would stop at a point of interest and spend

some time there to analyse and evaluate a situation before proceeding to the next point of interest or just moving away without having any further interest of things to come.

For this behaviour, the act of being interested towards another entity is always shown to be the focus when the elderly or disabled are involved in a public place. There seems to be an interest in knowing or predict what is happening next for the elderly or disabled as other parties spot them in the crowd. The latter will try to either avoid them or help them by whatever means they can. Most of the time, avoidance will be the dominant behaviour. Altruism will be next in line as this is only applicable when an entity spots that another entity needs help in a current situation like in a state of distress.

2.7.4 Avoidance

Avoidance means shunning or avoiding an object or person. The most evident feature of this behaviour is the ability of an entity to detect what is going on in front of or to the rear. It is of particular interest when an elderly or disabled entity tries to manoeuvre in a crowded space or dangerous situations. An elderly person is vulnerable to becoming a *victim* in a crowd as he or she moves slowly with a high tendency of being hit by or colliding with another person. Therefore, they will have to *devise* a suitable mechanism to avoid any of these undesirable situations.

2.7.5   Excitatory Potential

Excitatory Potential refers to the act or potential of being excited whether by an external stimulus or personal space intrusion (increased or decreased space). In this behaviour, the presence of an external stimulus will be the deciding factor on whether this benefits the entity in terms of a manoeuvre procedure that will ease movement in any type of surrounding. The surroundings can be a highly crowded scene, a small crowd or just moving alone in a space. An example of this behaviour is when a low excitatory level exists the entities are freely moving without any disturbances from other entities in the vicinity. Speed of movement is erratic and no personal space is fully adhered. This is more evident when many entities are involved.

At high excitatory levels, the whole set of entities have the maximum potential of excitation and react instantaneously towards any intrusion of their personal space. The movement of each entity will be restricted to a small space that is smaller than its personal space. This is similar to a crowded space with excitation potential being at its maximum, which shows every entity is aware of other entities in the vicinity.

At intermediate levels the excitatory potential is at its average functionality where the entities are acting in a moderate manner as their exact personal space is used. Now, the entities seem to be acting normally but with certain restrictions towards other. Hesitation in movement is restricted to using only personal space (not larger or a smaller than the former's space).

2.8   Summary

From this chapter, it can be said that the use of human walking behaviour modelling will be an important feature in incorporating human interactive ability into simulations. Based on the different areas of research described in this chapter, this research makes use of human personal space, age, human physical ability and human movement patterns to produce a simple computing tool or software to tackle the issue of human behaviour modelling of the elderly and disabled in public areas such as a transportation hub.

The walking behaviour of the elderly and disabled will be analysed in order to find a suitable solution on the effects of a crowd, other human entities and other related objects found in a typical public environment. The related works in this research will be further discussed in the next chapter in terms of their current application by other researchers.

Chapter 3   Review of the Application of Gaming Software and Human Behaviour for Simulation Purposes

3.0   Chapter Overview

This chapter considers the use of gaming tools that have been the driving force in the programming of video games, especially those that need high quality graphics and sound effects. During the course of this review, a programming language that has been considered for the simulation purposes of the research work is introduced.

3.1   Introduction to Programming Language and Computer Software Review

The programming languages which were reviewed are:

a) DarkBASIC;

b) DarkBASIC Professional;

The selection of the programming language and graphics software was based on criteria such as:

a) Ease of programming;

b) Cost effectiveness;

c) Ability to accept plug-ins or DLLs in the case of a programming language from the same software manufacturer;

d) Durability (able to run long and nested programs);

e) Compatible with any programming language compiler and;

f) Most importantly versatility of the programming must be taken into account.

DarkBASIC Professional has been chosen as the main programming language. DarkBASIC Professional originates from Game Creators Limited located in Warrington, Merseyside.

3.2   What are DarkBASIC and DarkBASIC Professional?

DarkBASIC is essentially *a scripting language sitting on top of a powerful 3D game engine* (Harbour et al. 2003). The language can be thought of as the "wrapper" of the game engine. Low-level functions in DarkBASIC interface with DirectX 9.0 below the scripting language. This language tells the game engine what to do, and the result is a running game.

Because DarkBASIC was designed for creating games, it contains none of the complexity of languages such as Microsoft Visual C++ (the language most commonly used for commercial games). DarkBASIC is a scripted game engine somewhat at the level of commercial games engines. DarkBASIC can be thought of as being one step ahead of DirectX, which is the case with the computer games such as *Quake III Arena, Unreal Warfare* and *Half-Life* engines. DarkBASIC is not optimised like those other engines for a specific purpose (such as first-person shooters); rather, it provides a general-purpose game engine for multiple genres.

DarkBASIC includes all the commands needed to create 2D and 3D games, and it comes with a range of 3D models, textures, bitmaps, sound effects and music that can be used freely and distributed in the computer games invented. DarkBASIC includes all of the following 2D graphics features:

- Support for the bitmap graphics format;

- Mirror, stretch, blur and fade bitmaps;

- Huge number of animated sprites;

- Transparency and;

- Fast collision detection.

It also includes all of the following 3D graphics features:

- XOF (file extension by RenderMorphics™) and 3DS (file extension for 3D Studio scene in mesh file form) model files;

- Landscape transformation;

- Built-in 3D objects;

- 3D object collision detection:

- Full model animation and manipulation;

- Ambient and directional lighting;

- Texture filtering;

- Alpha blending and;

- Translucent textures and fog.

After a short trial period of using DarkBASIC, its capabilities were very impressive and proved to be very powerful, but it was learned that there was a better version that possesses a much greater programming power and ease of use; it also has an interface designed for use in Windows whereas

the original did not. The improved version of the program is named DarkBASIC Professional. This program is a total re-creation of the original DarkBASIC programming language that gives the programmer a lot more freedom in the creation of the programs.

Key advantages of the software are the speed increases over the earlier version, greater support for media software such as the ability to import 3D models directly from programs such as 3D Studio MAX and similar, the ability to create new functions by creating C or C++ code to be imported into the compiler giving virtually unlimited capabilities, a Windows compatible IDE for easy code generation and also greater 3D support. Support for this program is good through both the owner's website and also fan-based sites with forums where the authors, other professionals and amateur programmers are willing to help solve certain problems with code and regular update patches.

As shown in Figure 3.1, DarkBASIC Professional is able to produce a viable game testing interface that can be created at all levels of expertise. The screenshot enables users to benchmark (approximately) the performance of DarkBASIC Professional on their existing PC.
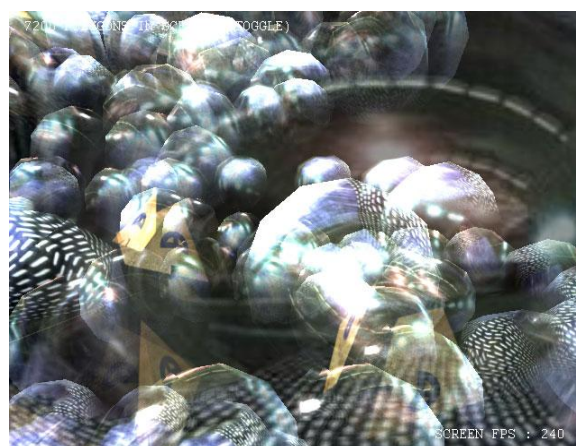
Figure 3.1   Screen Shot of *Lots of Fast 3D* on DarkBASIC Professional
(http://darkbasicpro.thegamecreators.com/)

DarkBASIC Professional has one main feature that is of interest in that it has the ability to import 3D worlds created in BSP format. This allows a world to be created in a different program, of which many are available freely on the internet, and then imported directly into the simulation to be created. Therefore the worlds will not have to be programmed into the simulation. This would give greater flexibility to the users by allowing them to design any world, add various items to represent the physical aspects of the world, and make progressive changes to the world, then directly import it into the simulation and view how the crowds would behave.

One example of using DarkBASIC Professional is the simulation of a simple demonstration program called Waterslide (Figure 3.2). In this demo, from the Real Game Tools website, notice their mascot (Scorch the ant) flying down a waterslide in a rubber ring.

Figure 3.2   Screen Shot of the Waterslide Program Written in DarkBASIC Professional (http://darkbasicpro.thegamecreators.com/)

A second example of simulation work done by the Game Creators animation team is the creation of a virtual terrain in which there are two motorcyclists on their big bikes travelling on an open road with a virtual mountainous background as shown in Figure 3.3. The simulation comes complete with

the revving sound of the motorcycles that adds a more realistic feel. The complete scenario of the

road terrain shows two motorcyclists riding their bikes complete with the mountainous background.

Figure 3.3   **Screen Sho***t of the Road Terrain Program.*
(http://darkbasicpro.thegamecreators.com/)

3.3   An Example of Research Work in DarkBASIC Professional

An example of research work using DarkBASIC Professional is shown in Figure 3.4 where Houlton

(2003), modelled human behaviour in a simplistic manner where humans were modelled as dots on

a predetermined floor plan.
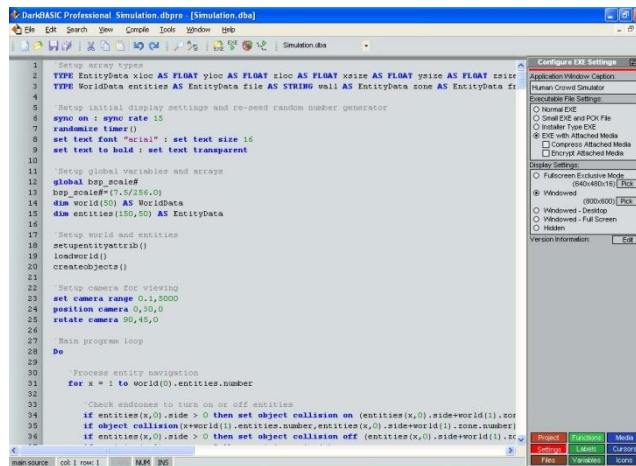
Figure 3.4   DarkBASIC Professional Screen Shot (Houlton 2003).

The procedure to calculate which direction to turn should a predicted collision be detected was created using DarkBASIC Professional (Houlton 2003). He stated that *the prediction of the collision, and the selection of the route can however be combined into one function, since if a collision is detected, than that route cannot be chosen, and vice versa.* Firstly, a range for detection is needed, which will limit what area around the entity is being checked and should link directly to the visual senses normally present in humans. It can be found, from personal observation, that when people are walking in a crowded area individuals are more focused on what is happening directly ahead of them rather than on activity to either side. This is because the direction in which they are walking includes the locations where they will most likely be in a given time and they do not plan to navigate to the side. Other people to the side are only taken into account when they might influence the direction of walking.

Houlton (2003) reported that in order for the simulation to scan regions around a human model, it was necessary to scan the far regions, far out ahead, and sweep to a small angle to each side. If collisions were found in the scanned area, the next step would be to scan a little closer and wider

than previously. This is repeated until the safety bubble is reached, in which case, there would be no choice but to allow intrusion into this bubble. Figure 3.5 shows how this model was implemented.
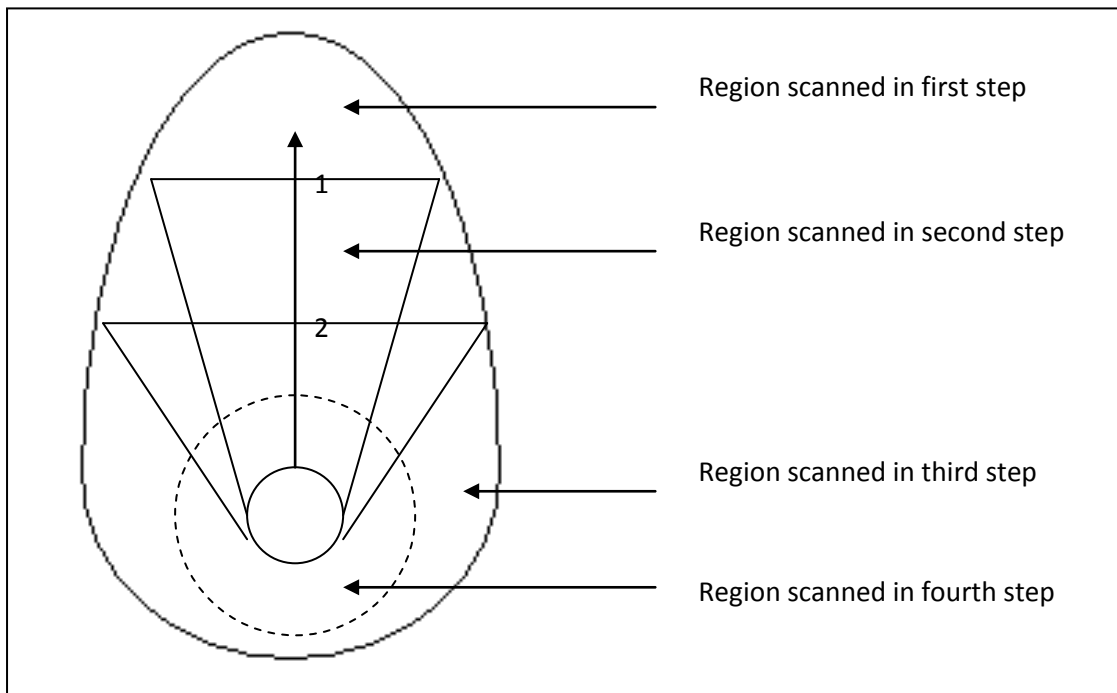
Figure 3.5   Region of Detection (Houlton 2003).

The method for using the collision detection available in the programming language was to place blocks in specific locations and change the size and rotation of this block, Figure 3.6 shows the scanning block in position.

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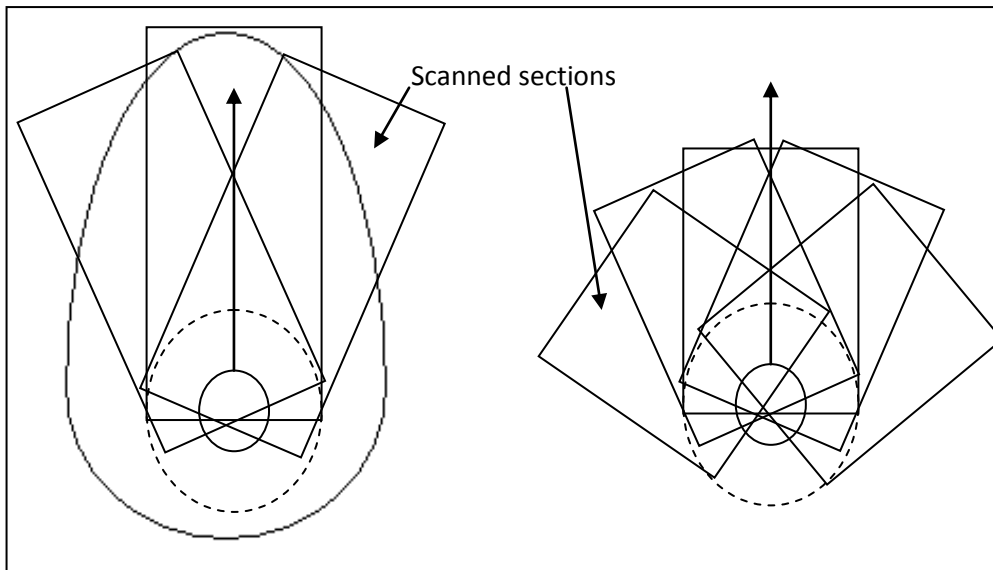
Figure 3.6   Scanning Block for Collision Detection of an Agent (Houlton 2003).

This simulation study works simply by predicting the location of all other entities, scanning the zones, placing the entities back in their original position before the scan, and then setting the entity the new angle to turn. Shown in Figure 3.7 is a screen shot of the work done by Houlton (2003) illustrating how human models are represented as white squares on a terrain (brick-laid floor) reacting to whatever conditions are imposed on them by the programmer.

With the simulation carried out in DarkBASIC Professional, Houlton (2003) has produced a substantial human behaviour simulator. He categorically divides his simulation work into several parts such as:

- Identification of the simulation package;

- Creation of the virtual world;

- Simulation of the human models and;

- Testing of the model and verification with the real world situation.
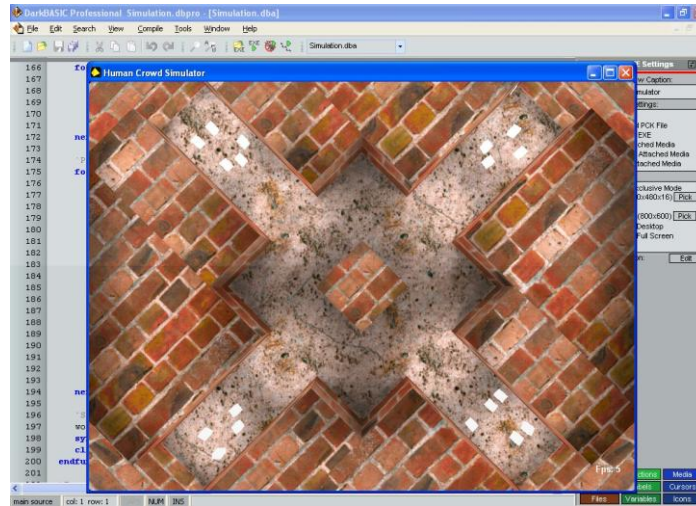
Figure 3.7   A Screen Shot of a Simulated Human Behaviour Modelling by Houlton (2003).

The simulator is used in such a way that the program first loads up and a splash screen is presented, displaying the control keys which are usable during the program running cycle. This is shown in Figure 3.8. These keys are the cursor keys, which rotate the camera on the x and y plane, shift and control will move the camera backwards and forwards. These movement controls give the ability to move to any position within the world, and point the camera at any desired target allowing for completely free viewing.
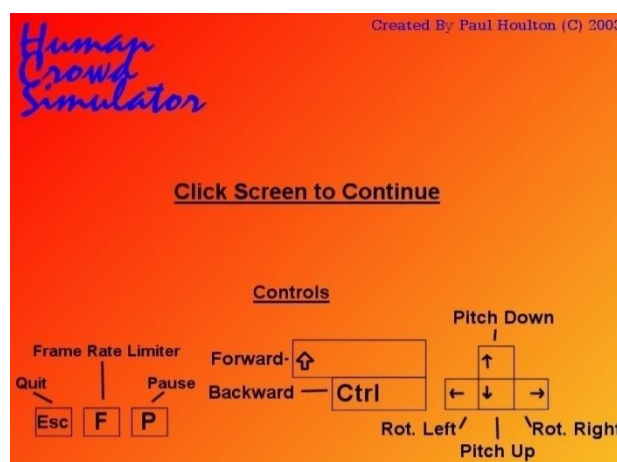
Figure 3.8   A Screen Shot of Human Crowd Simulator by Houlton (2003).

3.4 Samples of Human Model Behaviour

In the following sections, various algorithms that have been used in studying human walking behaviour are discussed.

3.4.1 Walking Model

For the purpose of a simple simulation model, the first feature will demonstrate a model of a walking pattern of a human character or entity in a pre-selected environment. How will an agent be shown to walk (traverse) in a manner similar to a real-life human being? Imagine that the targeted environment is a rectangular-shaped area as in Figure 3.9. The agent has the objective of moving from Point A to Point B. Let Point A be a corner in the bottom left hand side. He will then move diagonally across the area to Point B in the top right hand corner. Walking speed will also be an issue to resolve using DarkBASIC Professional.
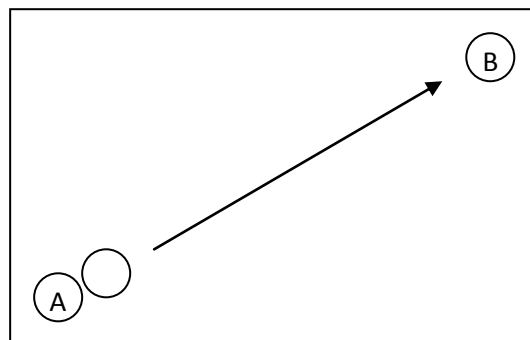
Figure 3.9   An Entity Walking Diagonally Across a Room.

3.4.2   Walking a Flight of Staircase Model

Most simulations of walking are limited to two dimensions in the sense that all movement takes place across a two-dimensional plane or floor. However, there is clearly an interest in modelling how people use stairways to move between different floor levels. This has not been attempted in this work but algorithms exist that rely on knowledge of the number of steps on the staircase, the height of each step and the time delay on each step. Different conditions are used to describe movement up and down the stairs.

3.4.3   Collision Detection Model

In the first example of collision detection two entities (X and Y, Figure 3.10) will be in the same area but their starting points are in different corners of the area (from Point A and 2A towards Point B and 2B). They will be moving diagonally towards the corners in opposite directions. What happens here is that when they are about to collide, one entity will stop. Then the other entity will be able to move first followed by the other entity after the former has passed. Here, the programming is done in such a way that it can detect any possible collision about to happen.
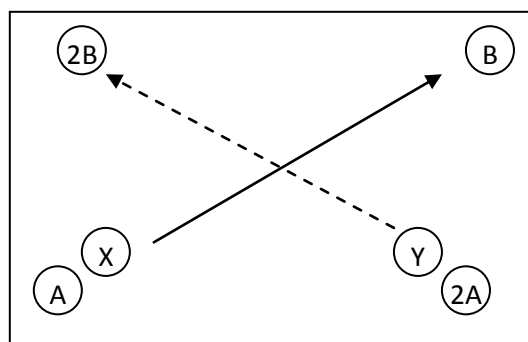
Figure 3.10   Two Entities on a Collision Course in a Room.

In DarkBASIC Professional, the syntax for collision detection is:

Command Syntax: Return Integer = OBJECT COLLISION(ObjectA Number, ObjectB Number)

The above command is used so that two objects should never be able to exist in the same location at the same time. This can be used by the simulation by moving the object forward so as to check if it will collide with any other objects. If collision would occur the object is moved back to its original position so as to process further calculations. If there is no collision the object remains in the new position.

In order to carry out collision detection, a method devised by Houlton (2003) is adapted. Houlton (2003) stated that the best method was to position a block in front of the entity and check for any collisions. If any were found, then it was known that a step forward would result in a collision. Before doing that, the definition of collision is having two cuboids close to each other. If a 'collision' is detected the program registers a value of *1* and a *0* for a non-collision as shown in Figure 3.11.

No collision, return value = 0   Collision, return value = 1
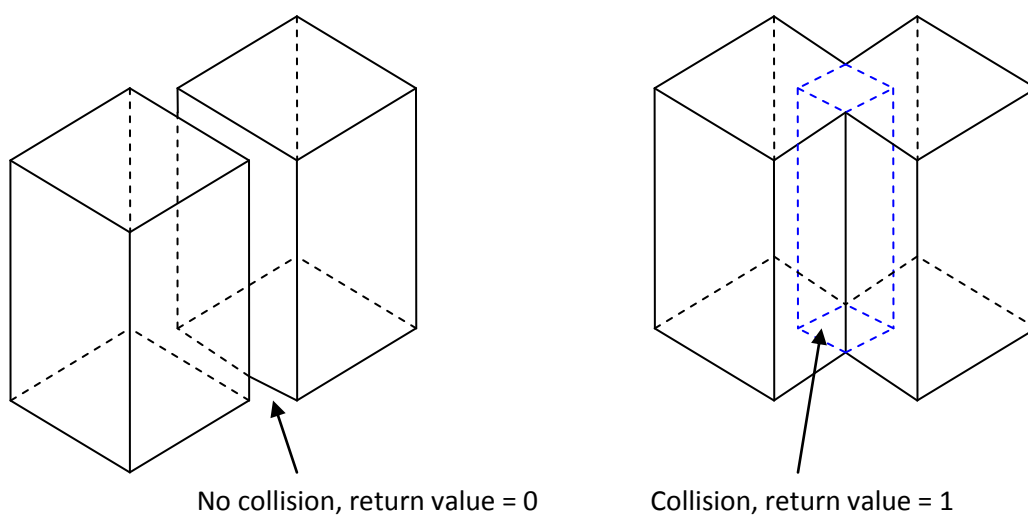
Figure 3.11   Collision Detection (Houlton 2003).

If no collision were detected, then it would be clear to walk forward. When a collision was detected, the detection block would rotate around the entity and check the next position. This would be repeated on both sides, slowly rotating further outwards, until an available location was found. Figure 3.12 shows the basis for this function. After a few trials, it became apparent that this could still be developed for future research work (Houlton 2003). In reality, the human will anticipate objects approaching from a distance, and those directly in front are taken into account first. The distance checked will usually be in the tens of meters or more, though usually only the path being planned is checked, people to the sides of this path are not taken into consideration.
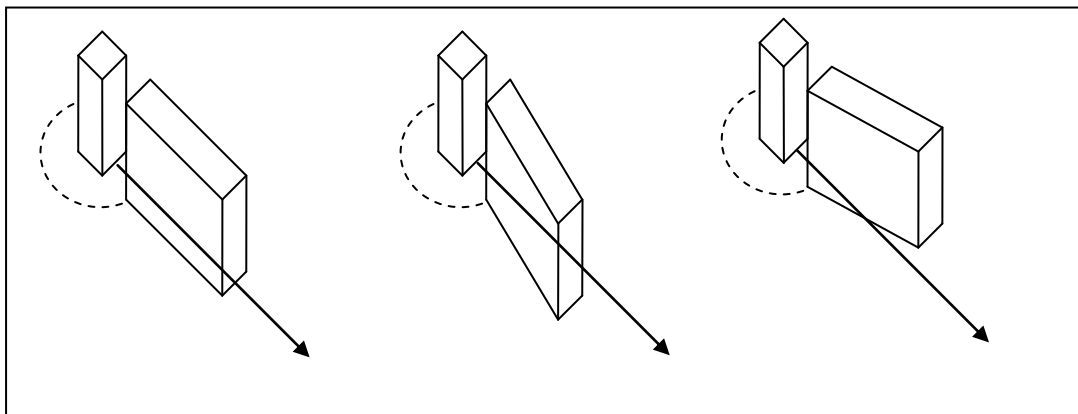
Figure 3.12   Collision Detection Functionality (Houlton 2003).

Below is a second example of a collision detection using coordinates:

1. Start with two objects, Object A and Object B as shown in Figure 3.13.

A   **B**

Figure 3.13   Object A and Object B.

2. The upper left corner of these objects are at some coordinates, which shall be called (AX1,AY1) and (BX1,BY1).

3. The bottom right corners of these objects are at other coordinates, which shall be called (AX2,AY2) and (BX2,BY2).

4. There is only one case where a collision might occur, and that is when the two blocks (AX1,AY1) - (AX2,AY2) and (BX1,BY1) - (BX2,BY2) overlap.

5. But there are many conditions where a collision is NOT possible. One example is since AX1<AX2 is true for all cases(same for AY1<AY2, BX1<BX2, and BY1<BY2), then the following conditions can be rejected:

    -   BY2<AY1;

    -   AY2<BY1;

    -   BX2<AX1 and;

    -   AX2<BX1.

    If any of the above relations are TRUE, then no collision can have occurred. If all of the above relations are FALSE, then a collision MIGHT have occurred.

6. Taking this algorithm further, we will try to see how much the objects overlap. The overlapping area will be placed in CX1, CY1-CX2, CY2. Then satisfy the following conditions:

    -   If AX1<BX1 then CX1=BX1 and CX2=AX2, otherwise, CX1=AX1 and CX2=BX2;

    -   If AY1<BY1 then CY1=BY1 and CY2=AY2, otherwise, CY1=AY1 and CY2=BY2.

The model is shown in Figure 3.14.
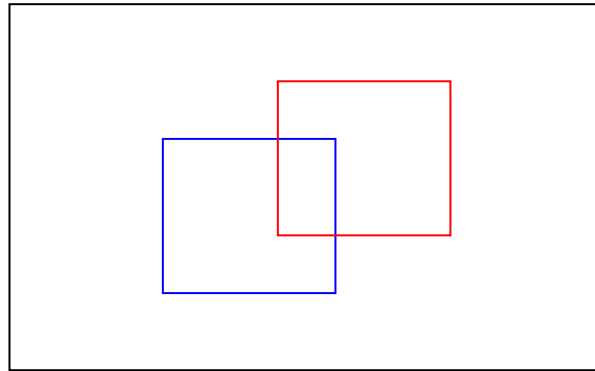
Figure 3.14   A Simple Rectangular Representation in A Collision Condition.

3.4.4   Model of Pedestrians in a Crowd Flow

An ideal situation for a collision detection model to work is that the human model can detect instantly any obstruction along its traversing path. At any one time, a human model will be always be on the lookout for any obstruction in front of him, and if present will stop to think of the next course of action. The decision might be to sway to the left or right, leap above the obstruction (for small, short obstruction) or duck low to avoid any obstruction placed above ground level as with a low-level ceiling in a cellar or attic. One example of the scenario (Ashida et al. 2001) is shown in Figure 3.15 together with the algorithm:

1. A person plans a path to his destination and walks along the path.

2. If there are obstacles in the walking space, he assigns scalar values to evaluate them by using their positions and velocities.

3. A person assigns an obstacle, which has the highest evaluation, a rectangular area as used by Houlton (2003) in Figure 3.12, to realize whether it disturbs his movements or not. The rectangular area (avoidance area) is characterised by a circle with a radius of *r* and a relative velocity vector between it and him.

4. If a person is within the avoidance area given to an obstacle, he changes the present path by using a fixed algorithm to avoid it.

5. If a person is within a circle with a radius of r, he stops movement.

6. If the following condition is satisfied when a person, who walks ahead of him, and he walks to the same direction, he intends to track a person.

7. The velocity of movement and human density around a person are in inverse proportion (Okazaki 1979).
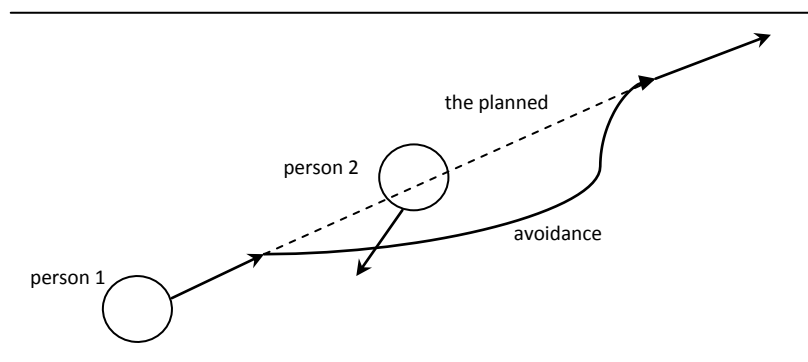
Figure 3.15　　**Modelling of a Walking Behaviour (Ashida et al. 2001).**

3.4.5 Other Various Walking Models

Other walking models that need to be considered for modelling (for example in a pedestrian mall) are:

(i) A person stops abruptly and makes a U-turn while walking and proceeds in the opposite direction from the original path.

(ii) A group of people meet in the middle of a walkway and start a conversation with other pedestrians behind their backs and this leads to a general halt in the flow of traffic.

(iii) A person walks on the right side of a walkway and sees something interesting on the left side. He then crosses over the walkway and stops at this point of interest. He will then proceed on the current path, back to his former path; either makes a U-turn or just stops.

(iv) An elderly or disabled person is travelling on the walkway. Other persons will either try to give way or for example offer to assist him getting into a shop. This situation also applies to the assistance given to a pregnant woman with a child walking together with her.

(v) A person walks and tries to find a place to sit and rest. He will stop at a seat in the walkway and then gets up after having enough rest.

(vi) A person wants some information regarding a shop and asks anyone along the walkway. Another person explains and will either point to the shop or brings him along to the intended shop. If the first person he met does not have the required information, he will proceed to the next person and stops doing this action until he finds the correct information.

(vii) A panic situation occurs like a fire breakout and everybody will run for his or her life to the next available exit. Individual behaviours will be shown here for different individuals likely to be found in a pedestrian mall.

3.5 The Use of Artificial Intelligence in DarkBASIC Professional

The phrase Artificial Intelligence has been used to describe computer actions that are similar to human intelligence. Artificial intelligence is however limited in terms of computing resources needed to compute extremely complex situations. Programmers, especially those in the gaming world, are able to come up with numerous high end games software that make use of complex graphics and sound effects. This is possible with the help of the latest technology in graphics cards and faster processing power of the latest machines. Since the start of the research the creators of DarkBASIC

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Professional have introduced a new add-on named Dark AI which is claimed to be a powerful tool in controlling the movement of entities in terms of path finding, avoidance, and adding intelligent behaviour to the game software that make the opponents and friends (allies) smarter. By using Dark AI, the work of programmers has become easier than with DarkBASIC Professional alone. Dark AI uses the flexible waypoints-based path finding system where real time calculations of a set of waypoints are carried out around all obstacles that are added to the Artificial Intelligence system.

The entities then use the A* algorithm to calculate the path between their current position and destination. The end result is that the entities always use the shortest path to travel and this is similar to human beings' walking behaviour whereby they are continuously trying to find the shortest route possible between any two points. The A* algorithm is a computer program that is known as a graph/tree algorithm. It uses a path finding mechanism based on a given initial node to a given goal (destination) node. It will always apply a heuristic estimate, $h(x,)$ by ranking each node x by an estimate of the best route that goes through that node.

3.6   Features of DarkBASIC Professional Used in Human Behaviour Modelling

Some of the features of DarkBASIC professional are particularly suited to the simulation of specific human behaviours especially path finding, collision avoidance, team control and entity commands that are found in the enhancement pack of Dark AI. These features are discussed in the following sub-sections.

3.6.1   Role of Path Finding in DarkBASIC Professional

Path finding is one of the most popular options used in computer programming to move from point A to point B. DarkBASIC Professional makes use of artificial intelligence found in an enhancement pack called Dark AI. The capability of Dark AI makes it easier to find a path around an obstacle like a wall, dynamic objects or doorways. The advancement in computing peripherals and processing power of the latest models has made it possible to meet the demands of the gaming players for greater intelligence in their own gaming consoles such as those found in real-time strategy (RTS) games like *Star Wars: Empire At War* released in 2006 and *Company of Heroes* also released in 2006. The other interesting genre is the enhancement of gaming opponents as in first person shooter (FPS) such as in Doom 3 released in 2004 and Halo 3 that was released in 2007.

The use of path finding in both genres has created a platform to introduce a more powerful use of artificial intelligence by using it to model human walking behaviour. This is important as a human being acts with his instincts in finding the best path to travel from one point to another. In Dark AI, a flexible waypoint-based path finding system is used that depends on several calculations in setting up a set of waypoints around any obstacles added to the AI system. The entities are then designed to use the A* algorithm in order to calculate their current positions and destinations. This is seen as the entities always use the shortest path possible between any two points at all times. The incorporation of Dark AI in DarkBASIC Professional makes it easier to produce a tool that can simulate human walking behaviour with regards to the needs of the elderly and disabled in a public space like a transportation hub.

3.6.2 Collision Avoidance and Team Control Features for DarkBASIC Professional in Human Behaviour Modelling

Apart from having the path finding feature for modelling purposes, the collision avoidance feature must be the other feature that plays an important role in manoeuvring the entities around the simulation. By using the AI Set Entity Avoid Distance command, the software is able to decide what is the best distance for an entity to attack its enemy if the latter drops within range of attack. If the target or enemy becomes closer than this distance, by either one of them moving, the former will move away from the enemy to a point at least the distance from the target in a strafing backwards action. Noticeably, the entities will automatically detect and avoid other entities that are in the way. Using an external collision system will notify the AI system that an entity has collided with something so as to force it to avoid non-AI, non-static objects.

The most important feature of Dark AI is in the aspect of team control among the entities involved. Team control in Dark AI is termed as its ability to differentiate between an enemy, an ally and lastly, a neutral entity. To locate an enemy, the system has to recognise an enemy beforehand. This is done by introducing the command line AI Add Enemy. The system adds an entity to the enemy team (working against the player) using a specific ID for the particular entity. The next command is AI Add Friendly where the same process occurs but this time an entity is included in the friendly team (allied with player) using another specific ID for the friendly team. The third command involves the neutral team which uses the command line AI Add Neutral. The entities in this team are those that are not involved in the line of fire.

3.6.3 Importance of the Entity Command Feature in Dark AI

There are various commands that constitute the Dark AI enhancement pack. They can be divided into two main areas of functionality or controllability which are entity control and secondly, world or environment control. These control functions are used as a platform to control any basic movements of entities in the specified simulation window. The categories are as follows:

a) Entity Control

This is the part in Dark AI which creates and controls the activity and movement of any entity in the simulation window. The entity control encompasses the following:

1) **AI Entity Add Target** – this command will add an entity to another entity's target list. This virtual list of entities is kept in a temporary list for future recognition. Once a specific target has been out of scope for quite some time, it is removed from the target list. The list is updated regularly once any entity reappears.

2) **AI Entity Random Move** – in this command, the entity moves by choosing a random direction from 0 - 360 degrees. The movement distance is between the MIN Distance and MAX distance. In the direction is blocked by an obstacle, movement is made as far as the obstacle and then the entity stops.

3) **AI Avoid Mode** – the avoidance modes of entities can be divided into four different modes. The modes are No Avoidance, Delayed Update, Real-time and Smoothed. In the first mode (mode 3), no avoiding action occurs and the entities are free to hit each other. In the second mode (mode 2), the collision avoidance action is delayed and the entities are well informed of the presence of other entities in the vicinity. Meanwhile, with the third mode (mode 1),

the entities avoid each other and the simulation is updated at each cycle (i.e. in 'real time').

The fourth and last mode (mode 0), is similar to the real time mode but the update only

occurs after 20 movements so that rapid changes in movement are avoided.

b) World or Environment Control

The inclusion of the Dark AI enhancement pack introduces the capability of DarkBASIC Professional

to control the world or simulation environment being tested. There are various commands that

make up the source codes of DarkBASIC Professional but the two important commands are as

follows:

1) **AI Entity Assign Zone** – this command assigns a designated zone to an entity that will provide an

   area of complete visibility for the entity to act upon. The entity receives a full controlling view of

   the zone that it is assigned to be in at any particular time. If there were an opposing entity in this

   control zone, it would be added to a virtual target list belonging to the friendly team and acted

   upon. The introduction of zones is helpful in enhancing the view range of an entity assigned to

   that zone. If the entity's view range is set to zero, it can still see enemies moving around it even

   though the view is blocked by obstacles. For research purposes, the whole simulation area is

   considered as a single zone. This factor is vital due to the fact that if ever the entity was to leave

   that zone, it will lose all of its capabilities to view the whole area. That is why a controlled zoning

   system plays a major role in determining the viewing success rate of the main entity.

2) **AI Entity Defend Area** – this is another command that is capable of enabling an entity into

   defensive mode which is an attempt to keep it within the specified simulation window whilst still

attacking enemies that come within its view range. This behaviour is similar to avoiding any collision with other entities in a specified space. In this case, the entity is allowed to perform normal evasive modes such as strafing like a soldier in attack mode. Being an automatic command mode, if the entity is about to stray away from the specified space, it is pushed back into the space immediately without any prompting from the system. This action is important so that it is easier to control the view in the simulation window so that it sticks to one spot only.

3.7   Human Behaviours in Simulation Study

The introduction of human behaviours is a vital component in determining the success of this simulation study. The study of the various behaviours of human beings has been a very difficult task as the list is endless. The suitable behaviours are categorised according to their level or repeated use by humans. The support of a particular type of human behaviour directly depends on the situation in which an entity is located.

The normal walking behaviours include:

- Walking from one activity location to another either intentionally or not.

- Avoidance mechanism in a crowded situation.

- Tailgating action.

- Walking with other entities such as in a pair or group.

But this is deemed to be a selection of normal human walking behaviours. Further research has shown that the involvement of personal spaces for humans plays a very important role in

determining the ability of a simulation program to mimic human movements. This is further discussed in the subsequent chapters especially, Chapters 6 and 7.

3.7.1 Early Work on Human Walking Behaviours Related to Research Work

This section provides an early list of possible behaviours that are related to the research work but they are not going to be used in the research work. The reason is that more generic terms for behaviours are introduced in the subsequent chapters which allow a simplification of the design of the software tool.

The walking behaviours are divided into distinctive categories that are closely related to behaviour of human entities in a public space. The primary category is known as *Physically-related Behaviours* and the secondary category is termed as the *Psychological-Effect Behaviours*. The former is termed in such a way that it involves human behaviours that are directly in contact physically with other entities in a public space.

These behaviours are consciously driven when the entities are in contact with others in their vicinity. The *Psychological-Effect Behaviours* are the secondary effects or consequent behaviours that happen when entities react instantaneously in a public place or space. Those categories are present at all times even without the entities noticing them. The behaviours are shown in Table 3.1.

List of Behaviours	
Physically-related	Psychological-effect
Adaptation	Angry
Altruism	Anxiety
Avoidance	Attention (Interest)
Defensive	Confidence
Escape	Confused (Distraught)
Exhausted	Excited
Ignore	Fear
Imitative	Frustration
Lost	Happy
Rejection	Threat
Resistance	Panic
Reflex	Sad

Table 3.1   List of Behaviours Related to Human Walking Behaviours.

These sets of behaviours will be later re-categorised into a different set of conditions based on where the entities are placed in the simulator especially during the peak and off-peak hours of the day. Therefore, the research will not get to see the behaviours being used in the real simulation. The research work will introduce a new list of human interaction walking behaviours to support this

research work such as Purposeful Movement (PM), Transition between Activity Location (TAL), Aimless Activity (AA), Interrupted Purposeful Transition (IPT) and Prompt Through Transition (PTT).

3.8   Summary

In this chapter, the various software available in the market has been discussed. DarkBASIC Professional was chosen as it is easier to understand for anyone who has no prior experience in game programming. Game programming remains the least known software that is used to realise human behaviour in simulation form. The availability of human interaction walking behaviours stated in this chapter will be used as a platform to carry out the simulation study in the later chapters. The next chapter introduces the observational studies of human walking behaviour using video technology and the results determined the next course action for the research work.

Chapter 4   Human Behaviour Observational Studies

4.0   Chapter Overview

This chapter describes the use of video technology to record, analyse and collect essential data to be interpreted and used as a tool to learn more about human walking behaviour in public spaces. The different characteristics of those involved in the survey are also discussed.

4.1   Introduction

Originally, the intention was to study public places such as market places, train stations, bus stations and shopping complexes, using Loughborough and Nottingham as examples of a small town and a large city respectively. However these intentions were limited to Loughborough shopping complexes due to security reasons that are susceptible to the current situations that needed to be taken into account. There was also no permission given to use existing security tapes in the shopping complexes due to the nature of privacy, ethical and security issues. Additionally, the use of the video camera at a higher level above the walkways was also not granted as it was felt that this could pose uneasiness among the users and security issues. The two chosen locations were The Rushes Shopping Centre and Carillon Court Shopping Centre. The former is an example of an open-spaced pedestrian mall where minimal roof cover is available and the shoppers use a very wide walkway of about 30 metres. The latter on the other hand is a closed-area shopping centre with a walkway that is 5 metres wide.

The idea of recording shoppers on video acts as an important tool to capture a general feeling of what transpires in the local shopping complex in Loughborough town centre, but the main objective of the video capture is to study the behaviours of different types of shoppers that use the shopping complexes.

4.2   Overview of Video Recording Session

Two observation sessions were conducted for each of the chosen places. These were weekday and weekend video shoots on Wednesdays and Saturdays in late 2005. Each of the sessions were then equally divided into three smaller hourly sessions to cover early mornings, lunch hours and late afternoons. The reason for doing this was to have a substantial spread of different conditions that can be used as a platform to show how individuals react in the different time frames. The time frame is detailed in Table 4.1

| Time (Hrs) | Carillon Court | | The Rushes | |
	Weekday	Weekend	Weekday	Weekend
0900 – 10.00	31/10/2005	5/11/2005	3/11/2005	12/11/2005
12.30 – 13.30	31/10/2005	5/11/2005	3/11/2005	12/11/2005
16.00 – 17.00	31/10/2005	5/11/2005	3/11/2005	12/11/2005

Table 4.1   Video Survey Schedule.

4.3 Observational Survey Scope

In this behavioural survey, the main factors considered included types of day (weekdays and weekends), characteristics of shoppers such as gender, age, physical ability and their purpose at the shopping centre. Other characteristics of shoppers that were observed included speed of walking, either walking alone or in groups of two or more persons, collision avoidance, passing through the place, window shopping and going to a specific point (e.g., into a shop) either predetermined or snap decision. Note that the area of observation does not cover the whole area of the shopping centre. The area of observation for Carillon Court Shopping Centre is a rectangular area of 5 metres by 10 metres and for The Rushes Shopping Centre the area is 10 by 30 metres. No contact was made with any of the subjects and all decisions as to characteristics and actions of the subjects were made by subsequent observation of the video recordings.

4.3.1 Characteristics of Subjects

An overall objective of the work was to consider a diverse variety of people, and age and capability have been used as major indicators in this survey. The male and female age groups identified were as follows:

(a)   Elderly people of 55 years old and above;

(b)   Disabled elderly people of 55 years old and above;

(c)   Able-bodied adults of between 18 and 54 years old;

(d)   Disabled adults of between 18 and 54 years old;

(e)   Able-bodied adolescents between 12 and 17 years old;

(f)   Disabled adolescents between 12 and 17;

(g)   Able-bodied children between 4 and 11 years old;

(h)   Disabled children between 4 and 11 years old ;

(i)   Toddlers below 3 years old.

A snapshot from the video taken in Carillon Court Shopping Centre is shown as Figure 4.1.

Figure 4.1   Elderly male and female walking together being avoided by a female pedestrian

pushing a child stroller at Carillon Court.

4.3.2   Definitions of Subjects

Elderly is defined as any subject that is 55 years old and above (Statt 1981). As for the term disabled,

it is defined as *when a person's physical or mental condition keeps them from being able to function*

in an expected manner. Disability may result from illness, injury, or wounds (Youthink! 2010).

However, in this research, disability is limited to wheelchair and mobility scooter users only in order

to ease simulation work and because of the difficulties of identifying other disabilities from the video recordings. Able-bodied adults are defined as those who have attained maturity or legal age of 18 years old and are eligible to vote in elections (Farlex 2010). Meanwhile, a disabled adult is someone who has attained maturity or legal age of 18 years old and has the features previously defined as a disability.

The World Health Organisation (WHO, 2010) defines human beings with physical disabilities *as those individuals having certain abnormalities from a normal human being that are related to disfigurement in terms of the human anatomy.* This factor causes their movement to be limited and slower than able-bodied human beings. According to WHO, the list of disabilities is very long including for example diseases such as cerebral palsy and upper limb disorder that might have been caused by accidents. For some disabled people life revolves around their impairments that negatively affect their quality of life (Figure 4.2., Newman, 2008). The scientific definition of the disabled can be further extended to the *macro* aspect of the anatomy of human beings where medical practitioners focus on the disease or *abnormality* and parts of the body affected by it. At the *micro* aspect, research scientists view disability at a more minute level by looking into the different processes that create the abnormality and how to ease the problem faced by the sufferer.

In another definition contained in the Declaration on the Rights of Disabled Persons by WHO, a disabled person is defined as *any person unable to ensure by himself or herself, wholly or partly, the necessities of a normal individual and/or social life, as a result of a deficiency, either congenital or not, in his or her physical or mental capabilities*.

Figure 4.2　　　　**A Disabled Person On A Powered Wheelchair (Newman, 2008)**

Able-bodied adolescents are defined as being 12 to 17 years old (Farlex 2010) and are also known as teenagers. A disabled adolescent is an adolescent whose physical or mental condition keeps them from being able to function in an expected manner (as in a disabled adult). An able-bodied child is a person who has not reached puberty (usually at the age of 12 years old) and a disabled child is a person who has not reached puberty and whose physical or mental condition keeps them from being able to function in an expected manner. A toddler is defined as a person who toddles (learning to walk and talk) usually up to the age of 3 years old. The last category that forms an independent part of this research and simulation work is the baby category. A baby is defined as a person in the age range from birth to becoming a toddler. They are not included in this study as they either travel in a push chair or are carried by their parents or carers and so are not independent entities.

4.4 Results of Observational Survey

From very extensive data analysis, the results of the survey are given in this section. The video footage captured was analysed according to the subjects' actions in the featured shopping complexes. The total number of subjects observed was 17,062 persons. The majority were able-bodied adults (63%) followed by the adolescents (18%), the elderly (8%), then children (5%), toddlers (3%), babies (2%) and the disabled (1%).

4.4.1 Speed of Walking

The first observational feature of the subjects is based on the speed of walking. The walking speeds involved were classified into:

(a) Average Comfortable Walking Speed (A) – $4.5 \leq A \leq 5.6$ kmh

The average walking speed of a human being in comfortable and ideal conditions is 5 kilometres per hour (kmh) (Lakes 2006). However, the range of speed for comfortable walking is between 4.5 and 5.6 kmh when walking alone without obstruction or distraction on a straight and level walking pathway.

(b) Slow Walking Speed (S) – $S < 4.5$ kmh

This represents a speed of less than 4.5 kmh (Lakes 2006) which is the comfortable walking speed of a normal adult human as explained in Section (a). Slow walking speeds might be used

when slowing down or for example may be enforced by physical conditions such as an elderly person walking with a cane.

(c) Fast Walking Speed (F) – $5.6 < F \leq 7.20$ kmh

A fast walking speed is considered to be between 5.6 and 7.20 kmh (Elert 2010). This can be found in a person who is jogging slowly or accelerating from an average walking speed to a new faster speed. An example of such speed is when someone needs to catch up with someone walking in front of them or merely just to overtake from a tailgating state. Another example would be walking at a trot. This is especially visible when there are obstructions slowing down the fast pace.

(d) Extra Fast Walking Speed (XF) – $7.20 < XF < 14.67$ kmh

This faster walking speed of up to 14.67 kmh is a representative of someone doing a fast jog or running which is defined as *moving swiftly on foot so that both feet leave the ground during each stride* (Farlex 2010). This is rarely found in an enclosed shopping mall, but can be found when people are in a hurry and resort to running to achieve the goal in the fastest time possible. This 'walking' speed is important when someone needs to move away urgently from any trouble or distress situations such as a fire breakout. Anything above the extra fast speed of 14.67 kmh is considered as running.

4.4.2 Categories of Subjects According To Their Intention States

There are basically five categories for discussion as follows:

(a) Passing Through Subjects

For this type of subject, he or she is just using the walkway of the shopping mall to move from one point to another (see Figure 4.3). They will not stop at any point in the complex. Their walking speeds are usually in the range of average to fast. In doing so, they do not stop for a quick look at the stores around the shopping complex. Passing through subjects will be walking through as fast as they can without being worried what is happening in front of them as long as they can get their right of way. In terms of age, this category covers the widest range from the elderly to toddlers as these are the most common types of subject.

Figure 4.3 Passing through Pedestrians at Carillon Court.

(b)   **Window Shopping Subjects**

The term window shopper is synonymous with someone who goes from store to store in search of merchandise or bargains (Farlex 2010). The definition shows that window shoppers will always walk slowly in front of the stores with their attention focussed on the merchandise in the showcases. Their action can be termed as intermittently stopping in front of stores and travelling from store to store. The window shopper can be seen walking alone or within a group of family or friends. Therefore, their speed of walking is in the range of slow to average.

They would not step up their pace as this defeats their purpose of doing window shopping. It was observed that a majority of the window shoppers are female shoppers. Men seldom involved themselves in window shopping, but instead, they are more interested in buying selected predetermined products (straight-to-the-point concept). An example of window shopping is shown in Figure 4.4.

Figure 4.4 Clockwise sequential shot from top left showing a couple window shopping.

Another feature of a window shopper is the impulsive buyer (a buyer making unplanned or otherwise spontaneous purchases). They are often tempted to purchase anything of interest without preplanning. An example in Figure 4.5 shows a couple attracted to a salesperson at a temporary side stall.

Figure 4.5   A Couple Stopping (Window Shopping) at an RAC™ Stall.

(c)   Going To Store Subject

This type of shopper is the most predictable of all the subjects observed. Their modus operandi is simply to appear from nowhere, walk along the walkway at average to fast speed and head straight towards the intended store to purchase the desired merchandise. They will then leave after the purchase has been made, or otherwise will look for other known stores for similar merchandise (Figure 4.6). This will decrease the time spent searching for the particular product and then they will have more spare time for other activities in the vicinity. The range of walking speed will be from average to fast as no window shopping is needed. As for the range of subjects, it covers all types of subjects with the majority being adult men and women, children with parents and a few of the elderly.

Figure 4.6   Clockwise Sequential Shot from Top Left Showing a Grandmother and Granddaughter Going to a Store.

(d) Store-To-Store Subject

This type of subject is seen to be crossing the walkway in the shopping complex from a store to another store (Figure 4.7). Usually their walking speed ranges from average to fast as they need to avoid any walkers along the walkway. Their objective of doing this is merely to buy specific merchandise that they have predetermined. If they fail to find the intended merchandise, then they will look for the next thing on their list. Anything not found at that moment can either be searched for somewhere else or a return can be made to the same store sometime in the near future to check availability.

Usually the types of subjects involved are the normal adults, adolescents and children plus toddlers with their parents. A very low count of elderly were found to be doing this as they appear to be more interested in doing shopping and less in window shopping. They maybe have to do this in order to conserve energy, lessen the probability of colliding with other subjects (frail factor) or for their own security. The longer they stay out, the more vulnerable they are to danger. Sometimes people tend to walk faster than normal as they cannot wait to see what is on offer in the next store.

Figure 4.7 Sequential Photos Showing Woman Going from Store to Store (left to right, from top to bottom).

(e) U-turn Subject

We are used to doing a u-turn in a car or in decision-making but it is seldom used as a term for human walking behaviour. A U-turn is defined as a turn, as by a vehicle, completely reversing the direction of travel (Farlex 2010).

This type of subject is not commonly found but it can happen to anyone once in a while. The reasons for doing this are as follows:

i. Remembers some unfinished matters in a place that he or she had been into initially;

ii. Had to go back to the place that had been missed initially;

iii. Had been to the wrong place and makes a u-turn to go to the correct destination.

iv. Undecided where to go during walking especially in window shopping and needs some u-turn manoeuvre to get to the intended destination.

Although the number of subjects doing the u-turn is very small it remains as a sight that certainly can be significant when an emergency situation demands quick evasive actions or a quick turnaround. An example in Figure 4.8 shows an adult male in a red jacket who turns around in the opposite direction to a store after disposing off rubbish at a litter bin across the walkway of Carillon Court Shopping Centre.

Figure 4.8   **An Adult Male in a Red Jacket Doing a U-turn into a Store Across Walkway of**

Carillon Court Shopping Centre.

4.4.3   Categories of Subjects According To Their Walking Speed

In this section, the types of subjects according to their walking speed are as follows:

(a)   Slow (S) Walking Speed

The subjects are:

   i.   The elderly walking with or without a walking aid;

   ii.   The elderly who tend to use the sides of walkways in order to avoid those walking faster in

       the main crowd flow;

iii. Disabled persons either elderly, adult or adolescent with or without walking aid;

iv. Children and walking toddlers;

v. Those tailgating a person who is a slow, average or fast walking person;

vi. Someone slows down when window shopping at a store in a repeated move-stop-move pattern;

vii. Those caught up when a crowd gets bigger which results in the walking speed getting slower to avoid collision with the slower person in front. This will always happen when crowd density increases;

viii. Someone walking slowly while (for example) talking on the mobile phone and paying less attention to his surroundings.

An example of slow moving subjects is shown in Figure 4.9.

Figure 4.9   Example of Slow Moving Subjects.

(b) Average (A) Walking Speed

The subjects are:

i. Those walking alone and going straight to a shop, window shopping or passing through;

ii. Those overtaking a slow person either in a low density crowd or otherwise;

iii. Those walking in a group in a leisurely pattern. Here, we would notice that the members in the group will always try to compensate each other's walking speed in order to catch up with one another.

See Figure 4.10 for those walking at an average speed.

Figure 4.10   Example of Average Moving Subjects.

(c)   Fast (F) Walking Speed

The subjects are:

i. Those finding the urge to hurry up matters that they are doing but not amounting to running;

ii. Those catching up with a faster person in a walking group they belong to or just any person in front;

iii. The disabled or elderly on a mobility scooter (not including those riding bicycles).

An example in Figure 4.11 of an elderly person on a mobility scooter moving fast on a walkway.

Figure 4.11   Example of a Fast Mover on a Mobility Scooter.

(d)   Extra Fast (XF) Walking Speed

The subjects are:

   i. Those who want to move faster in a crowded environment which is almost up to the same speed as running;

   ii. Those walking on an inclined walkway at an increased or decreased gradient will have to move extra fast if they wanted to overtake someone who has been walking fast.

   iii. Someone who is pushing a heavily laden trolley on an inclined walkway as above where he has to walk faster in order to compensate for the heavier load.

An example can be seen in Figure 4.12.

Figure 4.12   A Boy (Black Jacket) Running Slowly as an Example of Extra Fast Mover.

4.5   Analysis of Video Observations

In Loughborough town centre, the main activities are usually found in the farmer's weekend market. Most of the visitors arrive in bus loads in order to buy their weekly vegetable supply. A mixture of all age groups can be found here with a majority of able-bodied adults present. The presence of toddlers and children is low due to the crowded nature of the market. The Loughborough shopping mall pedestrian walkway is chosen for a better data collection as it is less crowded and easy to observe.

The results of the analysis of the captured videos involving shoppers in Carillon Court Shopping Centre are shown in Tables 4.2, 4.3 and 4.4. Table 4.2 shows the numbers of the different types of subjects on a weekday in Carillon Court at the three different times of day. The categories of entities involved are always kept the same in order to maintain a constant representation of entities in the simulation work of the later chapters. The analysis used a stop frame method where the video is sampled every 5 seconds.

Site:	Carillon Court (CC) (Weekday)		
Total Number Observed	3949		
	Tape 1	Tape 2	Tape 3
Numbers Observed	898	1653	1398
Types of Subjects:			
1 Passing Through (PT)	691	1298	919
2 Window Shopping (WS)	105	236	313
3 Going To Store (GS)	75	97	127
4 Store-To-Store (SS)	10	11	24
5 U-turn (UT)	14	4	4
6 U-turn & Window Shopping	3	7	11

Table 4.2   Numbers of Subjects for a Weekday at Carillon Court Shopping Centre.

4.5.1   Tape 1 (Carillon Court, Weekday)

Tape 1 was filmed in the morning slot of 9.00 am until 10.00 am. This was done to investigate the

flow of shoppers in the set time frame. It was observed that it covers a wide spectrum of subjects

consisting of the elderly, adults, children and toddlers. There were no adolescents noticed in this tape as this is a weekday and the school term was ongoing. The total numbers observed were 898 persons. The bulk of the subjects were passing through shoppers amounting to 691 persons and accounting for 76.95% of the total number. This may be due to them going to work and just passing through to go to other destinations in Loughborough town centre.

As for the window shoppers, they were made up of 105 persons (11.69% of the total number). The next largest group or subjects were going straight into the store and were made up of 75 persons (8.35% of the total). Those going from store to store are a mere 1.11% (10 persons) whilst those performing the u-turn were 1.56% of the total (14 persons). Meanwhile, those doing the u-turn plus window shopping were only 0.33% (3 persons), and hence were a rarity. A snapshot of the video is shown as Figure 4.13.

Figure 4.13   A Sparsely Distributed Crowd in Early Morning at Carillon Court Shopping Centre.

4.5.2 Tape 2 (Carillon Court, Weekday)

This is the second scene to be taped that runs from 12.30 pm until 1.30 pm (Figure 4.14). At this time, the crowd density has doubled from that of the morning session. The total number recorded is 1,653 persons with the bulk being made up of the passing through shoppers which covers all the subjects in question except for the adolescents as this is a school day. But an increase in the number of shoppers passing through (1,298 persons at 78.52%) and window shopping (236 persons at 14.28%) in comparison with the early morning was observed.

Apparently, the number of GS's and SS's has dropped to 5.87% (97 persons) and 0.67% (11 persons) respectively. Those doing the u-turn have also dropped to 0.24% at only 4 persons but the number of those doing the u-turn plus window shopping has risen slightly from the previous number to 0.33% (7 persons). This is in tandem with the rise in the number of total subjects observed.

Figure 4.14   Slightly Bigger Crowd at a Weekday Lunch Hour in Carillon Court Shopping Centre.

4.5.3   Tape 3 (Carillon Court, Weekday)

For this final tape (4.00 pm until 5.00 pm) as shown in Figure 4.15, the total number has dropped slightly to 1398 persons. The presence of adolescents is visible as with the other categories of subjects. Those passing through have dropped slightly to 65.74% (919 persons) and to compensate for this, the number of window shoppers has risen to 22.39% (313 persons). The same pattern is observed for those going into the store doing some shopping, that is, at 9.08% (127 persons). This may be because those on their way home from work or shopping have found some spare time to do some more window shopping or are looking for something to buy before going home.

Those who needed to buy more merchandise by travelling from one store to another have increased up to 0.29% (24 persons) compared to midday. An increase in those doing the u-turn plus window shopping of 0.79% (11 persons) is due to the increase in late shoppers at this hour. The number of those doing the u-turn remains the same at 4 persons (0.29% relative).

Figure 4.15   Low Density Crowd During Late Weekday Afternoon at Carillon Court.

4.5.4   Tape 1 (Carillon Court, Weekend)

In this tape, the time frame was from 9.00 am until 10.00 am (see Figure 4.16). The total number of subjects involved at the weekend is 8,192 persons which covers all walks of life from the old to the young. For Tape 1, the total numbers are 3,785 persons. An overwhelming majority of the subjects are the passing through subjects at 88.11% (3,335 persons). This may be mainly because the subjects are merely enjoying the weekend and going to the Saturday market located at the town's square at the entrance of Carillon Court. The subjects involved in window shopping are only 3.09% which is 117 persons, while the number of those doing serious shopping is higher at 8.24% (312 persons). Perhaps, the weekend is the only time for people, especially parents, to bring their children and little ones for a family outing and shopping.

It was obvious that those going from store to store are merely 0.18% which is only 7 persons perhaps due to avoiding the packed complex walkway. Those doing the u-turn are higher at 0.34% (13 persons) which would be expected as the crowd gets bigger. Since the numbers of window shoppers dwindle, the knock-on effect to those doing u-turn plus window shopping is profoundly down to 0.03% (1 person only). See Table 4.3 for the observational data on subjects during the weekend video shoot at Carillon Court.

Figure 4.16   **Free Flowing Subjects at Early Weekend Morning in Carillon Court Shopping Centre.**

Site:	Carillon Court (CC) (Weekend)	
Total Number Observed	8,192	
	Tape 1	Tape 2 & 3
Numbers Observed	3,785	4,407
Types of Subjects:		
1 Passing Through (PT)	3,335	4,067
2 Window Shopping (WS)	117	90
3 Going To Store (GS)	312	226
4 Store-To-Store (SS)	7	5
5 U-turn (UT)	13	18
6 U-turn & Window Shopping	1	1

Table 4.3   Numbers of Subjects for a Weekend at Carillon Court Shopping Centre.

4.5.5   Tape 2 and 3 (Carillon Court, Weekend)

This combination of tapes from 12.30 pm until 1.30 pm (Figure 4.17) and 4.00 pm until 5.00 pm (Figure 4.18) shows there is an increase in the number of passing through subjects at 92.29% (4,067 persons). The observations for Tape 2 and Tape 3 were combined as there was little activity in the

late afternoon session. In a similar way to the morning session, the subjects included all the age groups. The large number of subjects shows that at the weekend the maximum number of subjects is found during the lunch hour onwards until late afternoon. The number of those doing window shopping, going to store and going store to store have decreased to 2.04% (90 persons), 5.13% (226 persons) and 0.11% (5 persons) respectively.

The observed pattern is that a higher crowd density poses some difficulty for people wishing to stop in front of a store for window shopping. This is due to the fact that higher traffic volume makes it difficult for window shopping as somebody might collide with the window shoppers. Subsequently, there is an increase in those doing the u-turn as the number of subjects increases at the weekend. This contributed significantly to the chaotic nature of a large crowd resulting in some people possibly finding it hard to reach the intended point in the shopping complex.

Figure 4.17   A Very Crowded Carillon Court Shopping Centre at a Weekend in Midday.

Figure 4.18   Number of Subjects Went Down at Late Weekend Afternoon in Carillon Court

Shopping Centre.

As a summary (Table 4.4), the subjects going into Carillon Court can be seen to be mainly passing through, followed by those doing some window shopping. Third on the list are those going straight into the store, followed by those going from store to store. A small number of subjects are doing u-turns and a very low percentage performs u-turns plus window shopping. A pattern emerges that the subjects are more interested in passing through a shopping complex on a weekend. This may be because they are leisurely enjoying the weekend and also using the walkway to go to the weekend market located in front of the other entrance of the shopping complex. The remainder of the subjects go to shop or already have shopped at some part of the centre not covered by the video.

	Percentage Recorded						
	Carillon Court, CC (Weekday)			CC (Weekend)		Average	Average
	Tape 1	Tape 2	Tape 3	Tape 1	Tape 2 & 3	Weekday	Weekend
Passing Through (PT)	76.95%	78.52%	65.74%	88.11%	92.29%	73.74%	90.20%
Window Shopping (WS)	11.69%	14.28%	22.39%	3.09%	2.04%	16.12%	2.57%
Going To Store (GS)	8.35%	5.87%	9.08%	8.24%	5.13%	7.77%	6.69%
Store-To-Store (SS)	1.11%	0.67%	1.72%	0.18%	0.11%	1.17%	0.15%
U-turn (UT)	1.56%	0.24%	0.29%	0.34%	0.41%	0.7%	0.38%
U-turn & Window Shopping	0.33%	0.42%	0.79%	0.03%	0.02%	0.51%	0.02%

Table 4.4   **Percentage of Subjects at Carillon Court Shopping Centre for Both the Weekday**

and Weekend.

4.5.6 Tape 1, 2 and 3 (The Rushes Shopping Centre, Weekday)

The result of the analysis on the captured videos involving shoppers at The Rushes Shopping Centre is shown Table 4.5. This shopping centre is a good example of an open-space shopping centre with minimal roof cover for shelter. The walkway is about 30 metres in width wall-to-wall. The time frames taken for the video shoot are the same as those for Carillon Court Shopping Centre. The type of subjects is diverse except that adolescents are only present in the late afternoon session.

	Site	The Rushes (TR), (Weekday)
	Total Number Observed	1,170
		Tape 1, 2 & 3
	Numbers Observed	1,170
	Types of Subjects:	
1	Passing Through (PT)	985
2	Window Shopping (WS)	10
3	Going To Store (GS)	136
4	Store-To-Store (SS)	22
5	U-turn (UT)	17
6	U-turn & Window Shopping	0

Table 4.5   Numbers of Subjects for a Weekday at The Rushes Shopping Centre.

From the observations, it is noted that the number of subjects involved is 1,170 persons. The passing through subjects are 84.19% (985 persons) of the total number recorded. Surprisingly, the number of window shoppers is very low at 0.85% (10 persons) as the subjects are more interested in shopping as observed in this section of the complex. The number of those going into the stores (the total number of stores along this section is six units) is 11.62% (136 persons). This may be because the bigger stores are located on the other side of the shopping complex where the management prohibits the use of video cameras for security, copyright and privacy reasons. One distinguishable feature of this shopping complex is the lack of window showcases where the merchandise is displayed in-store due to the huge size of the stores.

For those going from store to store, the number is relatively higher than those found at Carillon Court (1.88% or 22 persons) where the subjects have predetermined where they are going before setting out for their shopping journey. This may be because it is a high street shopping complex where the stores offer more choices under one roof such as TK Maxx®, Virgin Megastores®, Marks & Spencer®, LA Fitness®, Cargo Shop® and JJB Sports®. Shopping is more specialized and there is no need for subjects to look elsewhere. This shopping complex can be defined as a mini retail park where the brand owners open up retail stores to sell their merchandise directly to customers without going through normal retailers. The shops may also be described as department stores which literally means a retail establishment which specializes in selling a wide range of products without a single predominant merchandise line.

Department stores usually sell products including apparel, furniture, appliances, and additionally, selected other lines of products such as paint, hardware, toiletries, cosmetics, photographic equipment, jewellery, toys and sporting goods (Farlex 2010) as seen Figure 4.19.

Figure 4.19   Weekday Crowd at The Rushes Shopping Centre.

Meanwhile, it is found that the subjects are spoilt for choice and this may have made them undecided where to go first or just being impulsive buyers has created a high number of those in the u-turn category at 1.45% (17 persons). Although the total number of subjects (doing u-turns) is low, it is indicative that the effects of surroundings can play a role in the mood of shopping among the subjects. On the other hand, the number of those doing a u-turn together with window shopping is nil. This is may be for the same reasons that there was a relatively low count of window shoppers and u-turn subjects.

4.5.7   Tape 1 (The Rushes Shopping Centre, Weekend)

The results of the observation for the weekend shot at The Rushes Shopping Centre are shown in Table 4.6. The total number of those recorded for the weekend was 4,541 persons. The time frame was the same for the one taken in Carillon Court Shopping Centre. The total number of subjects for Tape 1 in the morning video shoot was 2,138 persons which covered all walks of life. Results for the weekend are characterized by the overwhelmingly large number of subjects passing through the complex at 98.74% (2,111 persons). This is due to those walking in groups going to the large stores

and those leisurely enjoying the weekend with friends and families. The number of those doing window shopping is relatively low at 0.14% (3 persons) possibly because they were more interested in going to other bigger stores with better offers not shown in the recording. See Figure 4.20 for an example taken from the video.

Site:	The Rushes (TR), (Weekend)	
Total Number Observed	4,541	
	Tape 1	Tape 2 & 3
Numbers Observed	2,138	2,403
Types of Subjects:		
1 Passing Through (PT)	2,111	2,399
2 Window Shopping (WS)	3	0
3 Going To Store (GS)	23	0
4 Store-To-Store (SS)	0	0
5 U-turn (UT)	1	4
6 U-turn & Window Shopping	0	0

Table 4.6   Numbers of Subjects for a Weekend at The Rushes Shopping Centre.

Figure 4.20   Weekend Midday Crowd at The Rushes Shopping Centre.

Meanwhile, those going from store to store are nil as it is difficult to walk across without colliding with the large numbers of people passing through. It can be said that most subjects pre-planned their journey so as to avoid all the difficulties. This will be especially true for the elderly and those walking with children. This is also the reason why the number of subjects doing the u-turn is only 0.05% (1 person) and none were to be found doing the u-turn plus window shopping activity.

4.5.8   Tape 2 & 3 (The Rushes Shopping Centre, Weekend)

The total number of subjects recorded for this session was 2,403 persons. There is a diverse range of shoppers with normal adults, adolescents and children making the bulk of it. Compared to the results in the morning session, the number of those passing through is greater at 99.83% (2,399 persons). Due to the fact that a majority of the subjects are moving in groups of two or more, there is a tendency for the walking pattern of others (apart from groups) to be affected as they frequently have to avoid and manoeuvre around groups. In that case, many were seen to force their way through the large crowd. Some were even seen to be making u-turns to avoid the crowd (0.17% at 4

persons only) but strangely enough, there were no occurrences of any subjects doing window shopping, going to store and those going from store to store.

The video observation in The Rushes Shopping Centre can be summarised (Table 4.7) as with a different pattern of subjects observed for the weekday and weekend. For the weekday, there is trend that the subjects are made up mainly of a mixture of office workers and shopping mothers in the afternoon. That is why we get the lower turnout for those passing through compared to those on the weekend.

As for the other categories, the percentage is lower due to the higher crowd density which restricts movement and causes them to minimise window shopping (to avoid collision), going straight to store, going from store to store and u-turns. One example can be seen in Figure 4.21 for a late afternoon scene.

	Percentage Recorded			
	The Rushes, TR (Weekday)	TR (Weekend)		Average Weekend
	Tape 1, 2 &3	Tape 1	Tape 2 & 3	
Passing Through (PT)	84.19%	98.74%	99.83%	99.29%
Window Shopping (WS)	0.85%	0.14%	0%	0.07%
Going To Store (GS)	11.62%	1.08%	0%	0.54%
Store-To-Store (SS)	1.88%	0%	0%	0%
U-turn (UT)	1.45%	0.05%	0.17%	0.11%
U-turn & Window Shopping	0%	0%	0%	0%

Table 4.7   Recorded Percentages of Subjects at The Rushes Shopping Centre.

Figure 4.21   Sparse Crowds at Late Afternoon in The Rushes Shopping Centre.

4.6 Movement Pattern Characteristics

There are various movement patterns observed in the video that are appropriate for observation purposes in the research work:

a. An example is a straight-line movement between two points. This can be from one point of interest to another (an example is from a shop to another) or passing through a place (walking through a pedestrian mall). This also includes from one point of interest to an unplanned point, and between two unplanned points.

b. Moving in an unplanned pattern where the destination could be anywhere on the grid which represents window shopping or looking for a particular product but not finding the exact location. For the bus station model (introduced later), this could be a passenger who is searching for the correct platform to board a bus or a passenger who has just got off the bus is searching for the exit door out of the bus station. Another example is an entity or more roaming about in public space where a meandering pattern among the crowd of shoppers was observed.

c. In both models, there are two main types of entities which represent those who are either familiar or unfamiliar with the place.

4.7 Percentage of Age Groups at Particular Times

The percentages of entities present at a particular time are as follows:

a. The main age group in terms of numbers present during the simulation are those that involve the able-bodied adults (75% of the total number of entities) during all hours with the bulk being present during the morning and evening rush hours and during lunch time.

b. The toddlers (5% of the total number of entities) presence is normally observed during off-peak hours with their parents especially for the weekend shopping spree.

c. Normally, during rush hours, a small number of the elderly (10%) and the disabled (5%) are present due possibly because they are avoiding large crowds at other times for their own health and safety. The bigger the crowd, the bigger the risk posed to them in negotiating around the crowd. Being injured is always the first thing that comes into their mind during these busy hours, which could be tormenting for them to move around the large group of people.

d. Unpredictable entities such as the security patrol, cleaner on the job, people running through the place or space, and the deliveryman pushing a trolley of packages actually account for only 1% of the total crowd at any one time.

4.8   Summary

The achievements and conclusions arising from the observational studies are:

1. The video recordings are an excellent tool for analysing the various behaviours of human subjects in public spaces like shopping centres.

2. The data taken from the various video recording sessions allows the identification of the most important categories of human subjects in terms of age, ability and mobility.

3. New understanding of the walking behaviours exhibited by the subjects has been generated.

There are however limitations to this approach:

1. Not all subjects moving along the routes in the shopping centres can be captured on video as their mobility is very robust in nature when a very crowded scene is concerned. This is where the stop frame method was used as a tool to analyse the video tapes in an interval of 5 seconds each.

2. The time frame for the video recordings is limited to only a few hours related to peak and off-peak hours and not a whole day. This is because the longer the hours are, the more difficult it is to analyse the very large number of subjects. 17,062 individuals have been analysed in the current study and this analysis took approximately three months.

The data in the video will be used as platform to formulate the next step in the research which is the simulation of the entities based on the data. The simulation work will cover a certain area of a shopping centre with stores, entities and obstructions. This also includes suitable walking behaviours of the entities.

The results of the video recordings and video observations show that human subjects can be divided according to their age but not particularly according to their gender. This is because observation of the videos shows that males and females have the same walking behaviours. That is why no gender research was conducted. For the u-turn window shoppers, their presence is nil and there is a possibility to combine them with the u-turners but this is not done as there are still u-turn window shoppers in other video observation tapes except for those who are on Tape 1 covering The Rushes Shopping Centre on weekend. The category for u-turn window shoppers is still needed in order to show that these shoppers do play a significant role in influencing the flow of other entities in the vicinity and hence, influence the crowd flow.

The role of babies is not included in the observations although their presence is significant on the weekend. This is because they are either being carried by their parents or are in a pram and hence have no bearing on the overall results.

The video observation work plays a vital role in determining what are the various characters that are usually found in a typical scenario involving human entities in a public place. The emphasis for the next stages of the work is on how the various entities can be simulated in a simple program that will show their interaction behaviours and especially the walking behaviour for the elderly and disabled.

Chapter 5   The Human Walking Behaviour Mechanism

5.0   Chapter Overview

In this chapter, the human walking behaviour mechanism will be discussed based on the video observations of the previous chapter. The most important feature that needs attention in this chapter is how human beings react towards each other when they are in crowded public places such as shopping malls and public transport facilities such as bus stations, train stations and underground stations.

5.1   Introduction

First of all, there is a need to explore the basics of the human walking behaviour mechanism itself. The mechanism of considerable importance is the avoidance mechanism which plays an important role in determining that entities in simulations as well as in real life situations do not collide with one another whilst moving from one point of interest to another.

5.2   Avoidance Mechanism

The author has observed that entities all behave similarly avoiding an obstacle in front of them. The obstacle can be in the form of either a static or dynamic obstruction. An example of a static obstacle is a row of shopping kiosks situated in the middle of a walkway in a shopping complex. People have

to avoid it as it poses an obstruction in their walking path. Meanwhile, an example involving a dynamic obstacle is when someone is tailgating a slow walker whom he needs to overtake. The slow walker is termed as the *dynamic obstacle*.

The avoidance mechanism of the entities is as follows:

- (a) *Traverse* (Slow Walk, Average Walk, Fast Walk, Extra Fast, Run);

- (b) *Look* (for any obstruction ahead);

- (c) *Think* (decide either to move ahead on original path, make a u-turn, stop a while, make a complete stop or turn to the left or right);

- (d) *Action* (movement executed after decision is made).

5.2.1   Discussion on Traverse

Traverse is defined as *to travel or pass across, over, or through a space or dimension* (Farlex 2010). In this instance, the entity will be moving along their intended path at a stipulated speed of either slow, average, fast, extra fast or run. An entity can be seen walking naturally and with ease when the walkway is empty. If we look at the top view orientation of the walkway, the subject will be seen travelling in five different patterns (Figure 5.1) that are:

(a)   The North-South orientation (N-S), where the subject is seen moving to and fro along the path;

(b)   The East-West orientation (E-W), where the subject is seen moving across the path;

(c)   The Diagonal orientation (DIA), where the subject moves in a diagonal fashion across the path;

(d)   The meandering orientation of walking which is unpredictable with aimless movement without

a fixed direction. This behaviour is usually found in crowded situations and is used in avoiding

others or when overtaking slow walkers in front. An example is a person walking fast across the

walkway to a store in order to avoid someone walking in a North-South direction;

(e)   The U-turn (UT) orientation, where someone completely reverses their direction of travel.

(a)   (b)   (c)   (d)   (e)
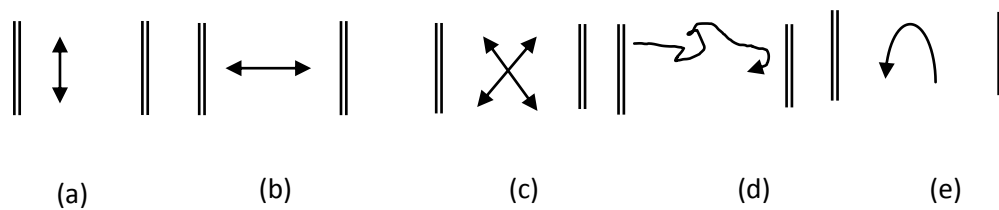
Figure 5.1   **(a) North-South Orientation, (b) East-West Orientation, (c) Diagonal, Orientation,**

(d) Meandering (e) U-Turn Orientation.

The "traverse" mechanism is mainly associated with the movement across a particular space in any

direction from one point of interest to another point in the same plane (the horizontal plane parallel

to the ground). In the industrial working environment, the traversing action is considered to be the

movement of a worker across the shop floor from one machine cell towards another in a straight

forward direction or in a meandering motion so as to avoid any obstacles that are present in the

path of movement for the particular worker.

This concept varies considerably from the work of Sharma (2000) who concentrated on the use of

multi-agent systems to classify the movement of entities in terms of their flexibility and general

applicability. His terminology involving flexibility only encompassed the movement of a crowd in a

public space; a community where everyone has a tendency to move in unconstrained ways without

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having to consider the needs of other individuals. The emphasis of this research is different from Sharma's as individuals might be constrained by their physical characteristics (examples are the elderly and disabled individuals).

5.2.2 Discussion on Look

'Look' has associations with the Stop-Look-Go rule when crossing a street junction, where the situation precedes decision-making. Look can be defined as *to employ one's sight, especially in a given direction or on a given object* (Farlex 2010). In this case, the entities would always seek to see what lies in front of them along their intended pathway. There would always be two situations that the entities are looking for. One would be an obstacle or on the other hand, an area free of any obstruction. This means to say that entities are always on the alert for any changes upfront. This is important in determining the next course of action; be it avoiding an obstacle or just moving ahead with ease.

The mechanism that involves "look" is associated with the characteristics of an entity that needs to have a clear angle of vision that enhances the ability to judge a situation where the space might be crowded or empty of people and where there may be other external obstructions. This can be further discussed in terms of the elderly and disabled where the former in particular may have a vision problem caused by glaucoma or myopia. These diseases have a continuous effect on the ability of the sufferer to have a good look or judge a particular situation it is in.

The work of Benyon et al. (1993) commented on the use of adaptive systems in the interaction of humans and computers in a workplace. Their work basically supported the idea of adaptive software written to meet the demands of users to mimic everyone in the simulated space with human-computer interaction as their main interest. It is seen that they were not actually concentrating on the individual walking characteristics of each entity. The existence of an adaptive system in their work has not really addressed the characteristics of each entity.

The addition of the "look" characteristic into a simulated space will definitely reduce the need for every individual to be adaptive towards any change in the situation even though adaptivity plays an important role in the movements of the entities. The inclusion of 'look' places a new dimension in terms of adaptive control for crowd movement but with the addition of control for each entity with different characteristics like the elderly, the disabled, adult, teenager, children and toddler.

5.2.3   Discussion on Think

This is the next important aspect of the avoidance mechanism. In this case, 'think' can be defined as *to exercise the power of reason, as by conceiving ideas, drawing inferences, and using judgment* (Farlex 2010). After the entity has carried out the 'look' step, the next foreseeable thing to do must be to think on the next course of action. This is done in a split second as timing is crucial in determining the best way to move in the next few seconds. This is fairly important when encountering an obstruction upfront especially if there is a greater density of crowd lying ahead. When an emergency situation like a fire breakout occurs, this aspect plays an important role in determining the best, quickest course of action that might be life saving to an entity. A favourable split second decision might mean life or death to someone.

The ability of the entity to decide what is the best available option in its walking path is the main criteria in determining its next course of action. This is where 'think' comes in. This mechanism needs to be alert at all times for a better judgement of the scene it is experiencing. The entity behaves in a way such that it is looking for the next available opportunity to move in the easiest manner with minimal obstruction. Related works on this subject are by Gleicher (1997) and Zhongxiang et al. (2001). Their research involved the use of constraint modelling. Gleicher incorporated space-time constraints which actively used the movement in a certain space with respect to time where this is used as a timeline in calculating the exact position of travel and its direction. This strategy used space constraints in time to calculate the entity's behaviour in a simulated space.

Zhongxiang et al. (2001) used space-time constraints to control and edit the movement behaviours of entities and even to the extent of retargeting the type and direction of motion of each entity. This research work formed the basis for the current research where the constraints for personal space can be used to represent the walking mechanism for each entity.

5.2.4   Discussion on Action

Here, action is defined as the process or manner of acting or functioning (Merriam-Webster 2010). This is the final stage in the avoidance mechanism where the entity would change pace and direction as the next course of action. The action is the result of a decision made from the previous three avoidance mechanism steps. An entity will slow down if there is an obstruction in front, and then will try to avoid the situation either by going around the obstruction or just force a way through. This can be seen when a single person tries to manoeuvre around a set of entities walking together or

wriggles (to move or proceed with a twisting or turning motion) his way through them. This is a very basic observation where human beings will always try to find the shortest and quickest way around any situation whether it is a dangerous one or not.

As a summary, the combination of the above four factors plays a vital role in determining the best possible way to guide an entity in a situation which permits or prohibits movement of any kind. The situation could be either a simple walk or the extreme situation of avoiding dangerous and emergency situations such as panicking in fire breakout.

The last mechanism that is included in the avoidance movement is "action". The word action literally means the end result of the three previous mechanisms. This is important in determining the best possible action to be taken by the entity in its journey from one point of interest to another. The works of Ashida et al. (2001) have initialised the use of human behaviours in terms of subconscious actions to react as human beings in a simulated situation. The addition of subconscious actions has led to the addition an extra step going towards a goal. This concept is very different from the current research where the concept of human personal space is the main agent in determining the walking behaviour of human entities in crowded spaces.

5.3   Observation of Avoidance Distance (AD)

As with the normal walking behaviour of human beings, this research work attempts to show how human beings manoeuvre themselves in a public space. From the video observation work, human beings, whether they realise it or not, have a special mechanism in determining the best course of

action when encountering an obstacle in front of them. The obstacle is defined as an object that stands in the way and must be removed or surmounted or circumvented (Word Web Online Dictionary, 2010). Human instinct tells someone of his current position or whereabouts and what should be the next course of action in avoiding an obstacle. This ability is known as determining the Avoidance Distance (AD) when encountering an obstacle.

Avoidance Distance is defined as *the total distance required in making a small adjustment to the walking direction of an entity (avoidance mechanism) either to the left or right upon noticing an obstacle ahead of it which is either a static or a dynamic obstacle*. From the video observation, the avoidance distance is affected by two Crowd Factors (CF) which are Crowd Size and Speed of Walking.

5.3.1   Discussion on Crowd Size (CS)

Crowd Size is defined *as a cumulative size of a group labelled as a collection consisting of a number of humans who share certain aspects, interact with one another, accept rights and obligations as members of the group and share a common identity* (Farlex 2010). Using this definition, society can also appear as a large group. From observing the videos, it has been noticed that in a less crowded place (for example early morning at 9.00 am or late afternoon at 4.30 pm and after), the entities travel at an average comfortable walking speed, and 90% of the entities observed a potential obstacle at a distance of 10 metres and take a split second decision to react (Figure 5.2). This is where personal space plays an important role in deciding the best possible solution for collision avoidance due to the fact that humans are more conscious of their personal space when they are at ease.

For a very crowded place, personal space is considered as irrelevant due to the fact that the entities tend to disregard it and this means the more dominant ones have an upper hand in terms of the right of way. This can also mean that the able-bodied entities give way to the disabled and elderly without any concerns for the personal space.
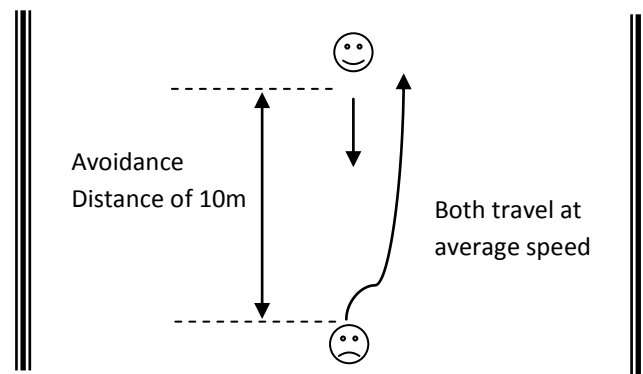
Figure 5.2   Representation of Avoidance Distance.
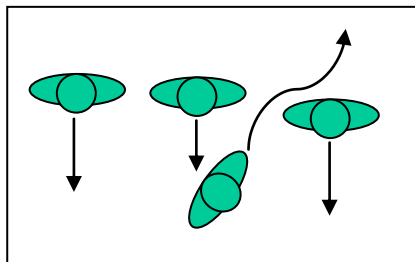
Figure 5.3   Sideways Walking Pattern in a Crowded Space (Personal Space Is Irrelevant).

A typical avoidance scene can be viewed from the snapshot in Figure 5.4 at the Carillon Court Shopping Centre.

Figure 5.4   Avoidance Behaviour in a Crowded Space With Small Avoidance Distance.

5.3.2   Discussion on Speed of Walking

It was observed that 80% of the entities walking at a fast pace (F) had an avoidance distance on average of 5 metres which is about half of those walking at a leisurely pace. Those walking at a very fast pace (XF) will have their avoidance distance lessened to an extent until it is less than one metre (and sometimes can be defined to be zero AD). That is why sometimes it can be seen that those who are walking fast are actually exposing themselves to collision with other entities (greater momentum needs more distance and time to stop).

A comparison in real life is that avoidance distance is similar to the safe driving distance in between cars travelling in a single file (also known as the *two second rule*). The higher the speed, the greater is the force needed for a safe braking distance. Failure to adhere to the rule may result in an accident. A summary can be made that the two above factors are important considerations in determining the avoidance criteria of humans in public places.

5.4 Discussion on General Avoidance Ability Percentage (GAAP) Count

In this section, the probability of an entity's ability to avoid an obstacle is investigated. This probability is called the General Avoidance Ability Percentage, or GAAP count. The numbers shown in Table 5.1 depict the probabilities that entities will avoid obstacles along their walking path. It does not show the non-avoidance percentage as non-avoidance is represented as the total percentage (100%) minus the GAAP.

In any case, these figures were interpreted from the video observations and may be considered as the real values and not theoretical. They are subject to the current conditions of the observation as the place may be crowded or otherwise. Let the first observation on an elderly male be an example. The GAAP is 70% which means that generally, there is a 70% probability that an elderly male will be able to overtake an obstruction that lies in front of him. In that case, there is also a 30% probability that the entity will not be overtaken or avoided. This is due to the factors discussed earlier on, which are crowd size and speed of walking.

	Entity Markers	General Avoidance Ability Percentage (GAAP)
Elderly	A	70%
Disabled	B	65%
Adult	C	90%
Teenager	D	92%
Children	E	40%
Toddler	F	5%

Table 5.1   Summary of General Avoidance Ability Percentage (GAAP) Based on Video

Observation Exercise.

From the same table, the disabled elderly have a General Avoidance Ability Percentage (GAAP) of

5%. This is due to their mobility difficulty (*ability to manoeuvre with respect to physical ability* where

a disabled person has higher mobility difficulty) in getting around as they have to rely on others or

mobility aids. They have to be given some allowance in moving around in the shopping complex as

they are prone to collide with other more mobile human entities. An exception has been made in

the sometimes aggressive nature in which mobility scooters are driven by the elderly and disabled

resulting in excessive speeds of more than 4 km/h. As for the adults, they have a high GAAP of 90%.

A good percentage shows that their easy movement is due to a low mobility difficulty. As for the

disabled, their GAAP is about 5% less than that for the elderly as they are able to move more easily

compared to the elderly even though with walking aids. We must take into account that the disabled can be less frail than the elderly as they are possibly younger.

As for the teenagers, their General Avoidance Ability Percentage (GAAP) is the highest due to their age factor and very low mobility difficulty. An example can be school children walking in a group and engrossed in their conversation and forcing other subjects to stop in front of them and let them past. As for the children, their GAAP is rated at 40% as they still need guidance from their elders and friends on where to go although they have a low mobility difficulty. As for toddlers, their GAAP is the lowest as they are too immature to walk alone and are unpredictable in their movement. Guidance from their parents is always necessary. It is noted that General Avoidance Ability Percentage (GAAP) for the disabled adolescent and disabled child is not available due to non-existence in the videos. If any were to be found, they would be reclassified under disabled adult as they are assumed to be using the same mode of transportation like a wheelchair or any other mobility aid.

5.5   Overtaking Probability in a Simulated Environment

The probability of an entity overtaking another entity by turning either to their left or right is observed to depend on the following factors:

- Crowd situation;

- Personal space;

- Walking speed;

- Interpretation of opposing subjects and;

- The subject's location.

There are four situations that need to be considered in the overtaking probability:

(a)   Forced-through situation;

(b)   Avoiding oncoming entity or group;

(c)   Tailgating entity or group and;

(d)   Avoiding static entity or object.

5.5.1   Discussion on Forced-Through Situation

Based on the above factors, the situation can be shown where there is a high density of people or a crowd and where the number of entities is shown to be at a maximum with respect to the floor size. In terms of personal space, a large crowd means a high density of entities which means that the personal space of entities is minimised to the point where it is basically redundant for simulation purposes. The entities will be closely located to each other where they can be seen brushing each others' shoulders when the situation gets too crowded. When this occurs, the walking speed is gradually decreased in order to compensate for the high density crowd. If the situation improves with less crowding, the walking speed is gradually increased and manoeuvrability becomes easier than previously found in a crowded situation.

In terms of interpreting the opposing entities, an entity will normally look for the easiest point where the slowest entity can be easily overtaken. So, for example, an adult will decide to overtake

either a slow child or a slow moving elderly person in front. The subject's location such as being trapped in a crowded situation is the final deciding factor in determining what to do if he tries to get out of the situation. Finally, when this situation occurs with the correct factors in place, the entity will be engaged in a *Forced-Through Situation* mode where it will force itself through a large pack of people in a fast and careful manner by wriggling or wading through the latter even if it has to collide with them slightly or rub shoulders as long as the objective of getting through the situation is achieved. After successfully executing the Forced-Through manoeuvre, the subject will return to the original walking mode, original pace and perception of the surroundings. This situation was shown previously in Figure 5.3.

5.5.2   Discussion on Avoiding Oncoming Subject or Group

As with the Forced-Through Situation, the avoidance of oncoming people will also be based on the crowd situation. It is noticed that in a crowded situation, the entity will assess what lies ahead well before it gets to the space where the crowding is occurring. With the Avoidance Distance mode in place, the entity is able to assess the distance it should take in order to tackle the situation. The rule of thumb is that when the crowd size is large, the avoidance distance is raised to an extent that the entity will try avoid the oncoming people at a distance of more than 10 metres before the reaching the crowded spot. If the situation crowd size is small, the avoidance distance of the entity will be reduced to as little as about 2 metres.

It should be recognised that the entity will accept a smaller personal space in order to compensate for the upcoming crowd situation. In examples of very crowded situations based on the video observation and personal accounts, it is noticed that most entities will ignore their personal space

just to get through the sticky situation. It should be understood that if every entity were to exercise their personal space strictly in accordance with those stated by Forsyth (2006), there would be instances where the entities would avoid each other with a very large radius as compared to the real situation where the personal spaces of entities decrease with an increase in the crowd density. In the simulation sense this will create a chaotic scene where all entities try to squeeze into the space provided.

From observation, generalised collision avoidance can be pictorially represented as a sliding motion across a walkway as shown in Figure 5.5. In the example, an entity walking on the right hand side of the walkway has a 70% probability of swerving to the right well ahead of the oncoming group of entities. For the remaining 30%, it is probable that the entity will make a move to the left to avoid them. The shortest and fastest available option is depicted as 100% either side. This also depends on the walking speed of the subject as it was observed that there is a 100% probability for the faster person to overtake a slower person (elderly and disabled). This is where the use of personal space is irrelevant in nature. The average comfortable walking speed for humans is 5.0 km/h (Lakes 2006) and the fastest walking speed is 7.19km/h (Elert 2010).
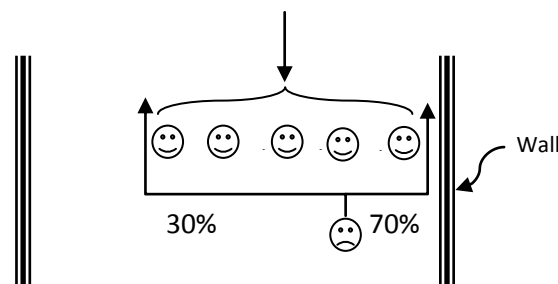
Figure 5.5   Generalised Collision Avoidance Route For an Entity Walking on The Right Hand Side of Walkway.

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5.6   Summary

In this chapter, the various human characteristics found in a public place, including walking behaviours have been described. The inclusion of all the data and facts will assist the research in determining the relevant characteristics that are suitable for the simulation. However, not all subjects can be simulated as they sometimes fall into the same category such as the u-turn and the u-turn plus window shopping, which will actually make the real-time observation more complicated. More complications will raise the difficulty in determining the correct amount of data needed for the research.

The amount of data must be realistic enough to accommodate the time spent in collecting and analysing the data which later needs to be transferred numerically (percentage) and simulated. The number of subjects in this study which exceeds seventeen thousand persons is a suitable number to consider. Anything more than twenty thousand will increase the error and hence affect the eventual result. That is why in the initial stage, the number of days of recording was trimmed down to three hour sessions for both shopping complexes on a weekday and a weekend.

The data obtained from this chapter will have an important bearing on the success of the research. Without them, the reference point is difficult to obtain due to the lack of research being done on the spatial behaviours of shoppers especially in shopping complexes. The two places were chosen initially for the research because a smaller crowd is easier to observe rather than a large crowd in an open spaced market which will defeat the purpose of simulating human behaviours at an early research stage. The author is hopeful that this initial research will invoke more future research on

complex behaviours. As for the types of entities chosen, their variety which covers all walks of life will add to better understanding of how various human being react in different conditions.

It is interesting to know how the elderly and disabled react in public places especially shopping complexes. It is hoped that this research will help in finding the best solution that will benefit them in terms of how human react in the final design of public places. This is a good platform for other facilities such public transport stations and workplace environment that are suitable for the elderly and disabled as in a sustainable urban.

Chapter 6   Software Design and Modelling

6.0   Chapter Overview

This chapter will cover the use of DarkBASIC Professional as the tool for the simulation aspects of the research work. The simulation work is carried out to demonstrate that a simple program is able to simulate certain human walking behaviours in public places. The program acts as a platform to show how human beings as entities work in an artificial environment. The environment or world is modelled from the previously recorded videos of the interactions of human beings in a crowded walkway of a shopping mall in Loughborough's town centre.

6.1   Software Design Methodology

6.1.1   Design of Model

The design of the software is based on the human walking behaviours taken from the video observation sessions in Loughborough's town centre. The behaviours are spatial in nature, which means that they are based on the personal space of each entity involved. The personal space of each entity is based on four different types of spatial personal space; namely, intimate, personal, social and public distances. In this research work, the space of concern is the personal space of entities in public spaces such as shopping malls, public transport system stations such as train stations, bus stations, underground tube stations and airports.

The design of the model involves the implementation of a particular level of complexity, simulation levels and spatial behaviours for every entity.

a. **Level of Complexity –** in this feature of the simulation model, the number of entities interacting at any particular time plays an important role in determining how close the result of the simulation is compared to the real time scene. Initially, the number of entities is restricted to only one in order to show a simple, single entity at work. The number of entities increases in order to match real situations. The allowable number of entities is restricted to 100 at any one time in order to ensure a viable simulation. This has similarities with the real world situation which would be difficult to observe due to the large number of entities.

During the simulation phase, the number of entities is similar to the real life situation found in the video observation footage. The simulation task is able to cover two extreme cases, which are a very lightly spaced scenario and at the other end of the scale, a heavily crowded space (an example can be a bottleneck case). The simulation is also able to carry out tests on an average intensity space situation, which means a crowd of between 30 and 60 entities. Anything below 30 entities is considered as a sparsely populated space and more than 60 entities is known as a highly dense scene. In order to cover the two main focus groups, the activities of the elderly and disabled are examined and incorporated into the case study.

b. **Simulation Levels –** the initial simulation consists of a single entity moving freely in an open space. Then, a gradual increase of entities is shown by having two different entities moving around in a simulation space and being on a collision path with each other. The next stage has two entities moving together side by side. This is then increased in complexity by introducing another couple to the simulation window (moving freely as the former couple) and at any point in time being on a collision course with the former. The behaviours of each entity are examined

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to determine whether or not they follow traits recognisable in real people. The emphasis is on focussing on the spontaneous walking behaviour of the elderly and disabled.

Increasing the simulation complexity level again, two different entities are introduced, each one in a different age group. An example could be an elderly man walking with his son side-by-side. These entities travel together in the same plane and direction. The introduction of another pair of entities travelling in the former's space but in the opposite direction is the next level of complexity in the simulation work. This is where the observation work of avoidance activities in between the entities involved is carried out. The simulation complexity level increases in terms of paths taken by the entities. Examples of the paths are from left to right and vice versa, north-south orientation, diagonally across a space and in a random manner (meandering).

6.1.2 Design of Entities

The design of the entities for simulation uses the features in DarkBASIC Professional source codes classified as an object in the software. The codes representing the elderly entity are as follows.

```
rem disabled entity setup

make object cone nn,7

color object nn, RGB(0,255,0)

xrotate object nn,90

fix object pivot nn
```

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position object nn,-200,2.5,5

AI Make Path Between Points nn,1000, 0,-1000,0

AI Add Enemy nn, 1

AI Set Entity Speed nn, entities(n).speed

The line of code *make object cone nn,7,* defines the shape of the entity as being conical. The term *nn* represents the entity number of the object which carries an integer value of 51 (nn = 51). As an example, the size of the object that represents an elderly person is 10 units as perceived by the software. Table 6.1 shows the summary of sizes and colour guides for entities in the simulation process.

Entity Type	Relative Size Guide	Colour Guide
Elderly	27	Yellow
Disabled	30	Black
Adult	25	Turquoise
Teenager	20	Orange
Children	17	Pink

Table 6.1   Summary of the Size and Colour Guide for Entities in the Simulation.

For the third line, the codes *color object nn, RGB(0,255,0)* relates to the colour of the intended object and in this case, the colour is green. It is represented by the colour codes RGB(0,255,0).

The next line in the source code, *xrotate object nn,90*, states that the object *nn* rotates along its x-axis. This will show a conical-shaped object rotating with its apex as the direction of movement. The object number uses an integer value whereas the rotation angle uses a real number.
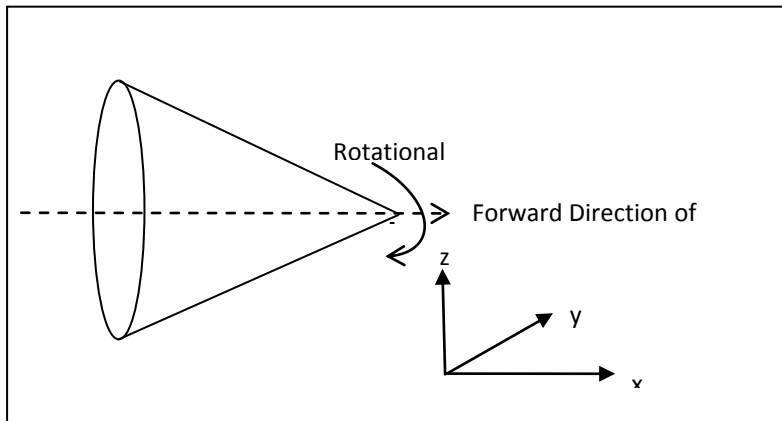
Figure 6.1   **Direction of Movement for a Conical Entity Based On The X-Z Plane (Original**

Design).

The command *fix object pivot nn* fixes the current angles of the specified 3D object as the new absolute rotation of the model as shown in Figure 6.1. It is often required to load, rotate and fix models to face a particular direction before using them. For the position of the entity in the simulation window, the command *position object nn,-200,2.5,5* is used. The values of -200, 2.5, and 5 represent the world position of the entity in the X, Y and Z-axes. In DarkBASIC Professional, the axes X and Z make up the main plane. This command will place the specified entity in 3D space. In order to see the 3D entity, the *camera* (user viewing window) must be pointing in the right direction and the camera and 3D entity are within 5000 units of each other. The object number and 3D coordinates are specified as an integer and real numbers respectively.

At this stage, a command *AI Make Path Between Points nn,1000,0,-1000,0* is used to create a path between the two specified points and this takes into account all obstacles in its way. The numbers 1000, 0,-1000 and 0 represent the initial and final x and z-ordinates respectively. If the initial and end points lie within obstacles an attempt will be made to find the closest point that is not within an obstacle. If this fails, or there is no clear path between the points, then a path is created with no points.

The command *AI Add Enemy nn,1* adds an entity to the enemy team (turning against the player or user) using the entity number that was specified earlier. This should be a non-zero positive integer, and not already assigned to any other entity. In this command, the entity involved is *nn* and the object involved is Object 1. The next command is *AI Set Entity Speed nn,entities(n).speed* where the speed of the entity *nn* is controlled by the speed array written as entities(n).speed. The variable *n* represents the number of loops that the simulation has to go through in order to achieve the intended results.

Together, this set of commands will be the deciding factor in determining which entity is displayed on the simulation screen. Therefore, the simulator can show clearly how an elderly or disabled person reacts towards the particular situation it is currently in at any time. This process repeats itself for the other entities by simply entering the different entity numbers. The viewer will be able to see the difference in the reaction of those entities towards each other during peak and off-peak times. The definition of peak time is the busiest time during the morning and evening rush hours including lunchtime and all other time are considered off-peak hours.

6.2   Specifications of the Movement Objectives of Entities

The specifications of the main movement objectives of the entities based on the video observation are as follows.

a. **Purposeful Movement** – this represents the movement of entities from one activity location to another activity location with prior knowledge of the next route, and absolute knowledge of what lies ahead at the final destination. An example would be an entity passing through an open space or a walkway without moving towards other entities around it. This entity will move straight towards its destination.

b. **Transition Between Activity Location -** this is the most common objective for the entities where they could be seen moving from one activity location to another location at all times, pausing for a breather and continuing to proceed to the next phase. An example would be an entity in a shopping mall doing window-shopping from one store to another (*walk-pause-walk motion*). The pausing period ranges from 5 seconds to 30 seconds maximum depending on the entity's interests. A 5 seconds time frame represents less interested focus on a product and, meanwhile, the 30 seconds time frame, shows that entities are interested in a particular object in the showcase which would bring benefit to them if purchased.

c. **Aimless Activity –** this third objective shows how an entity moves to and fro in the open space without specific aims and keeps on doing the same things endlessly. An example would be an entity that has just forgotten an initial plan. At this point, the entity will move aimlessly towards another activity location and the direction of motion could be in a straight line and could then, take a u-turn without any sense of purpose for the next activity.

d. **Interrupted Purposeful Transition** – the fourth objective is shown as travelling from one activity location to another activity location in an open space but it is interrupted by frequent pausing activity. An example could be the meeting of another entity for a chat or a cleaner picking up rubbish from the floor.

e. **Prompt Through Transition** – the fifth objective is when an entity moves along a space very promptly without having any need to pause or stop. An example would be someone just passing through in a space or a deliveryman going through a walkway aiming to reach a destination somewhere else.

6.3   Specifications of Simulation Software

In this section, the specifications of the software are given to show how it works on every level of simulation according to the requirements of the research work. The first specifications relate to the characteristics of the various types of entity.

6.3.1   Specifications of Entity

a. **Entity A** – This age group covers those who are 65 years old and above (also known as Old Age Pensioner, OAP) and includes both male and female entities. The reason for combining the genders is that the video observation exercise at the shopping mall walkway has shown that men and women actually use the same walking behaviour. This is particularly evident when an

elderly couple presumably a husband and wife team actually have similar behaviour as they have

the same intention and destination to reach. An example is shown in Figure 6.2.

Figure 6.2   Entity A as in Elderly Couple Walking Together in Loughborough's Shopping Mall

Walkway.

b.   **Entity B** – The second entity would be those that fall into the category of disabled persons. The

definition of a *disabled person* is *someone who is incapacitated by birth, illness or injury and*

they are of any age group (Word Web Thesaurus, 2010). Examples of disabled persons are

those permanently on manual wheel chairs, electric wheel chairs, using mobility scooters, using

crutches, unable to travel unaided, visually impaired, mentally retarded, developmental delay in

terms of psychomotor control, hearing impaired and other disabilities that impair movement

and communication. For this research, only those who are on wheelchairs and crutches will be

analysed, as it is difficult to monitor the simple walking behaviours of the others and none were

to be found in the observational videos.

Figure 6.3   Entity B as in a Disabled Person on a Wheelchair in Loughborough's Shopping Mall

Walkway.

An example of such an entity is in Figure 6.3 where a disabled person on a wheelchair is window-shopping.

c. **Entity C** – This category includes normal adults of between 18 and 65 years old. They formed the backbone of the simulation, as they are the majority of all the age groups present. Their role is minimally shown but will complement the movement of the main entities (Entity A and B). The numbers of Entity C made up the bulk of entities simulated as the number of elderly and disabled are small. This is where the spatial walking behaviour of the elderly and disabled are easily analysed and hence, obtaining the correct data for simulation and discussion of the results.

Figure 6.4   **Entity C as in Normal Adult in Loughborough's Shopping Mall Walkway.**

The introduction of Entity C acts a benchmark for the other entities in determining the success of showing the spatial walking behaviour of human beings especially for the elderly and disabled.

d. **Entity D** – This set of entities represents the age group for teenagers from 12 years to below 18 years old. They typically move around in an orderly manner when moving in pairs or in a group. Their movement pattern depends on their requirements at any particular time such as when there is a crowded situation, the entities will try to break away from their group when confronted by an obstacle or crowd and then regroup or rejoin to continue their journey. From the video observation, this is the main noticeable pattern possessed by this particular entity. Seldom have they been noticed to travel alone especially during the weekend when most of them are free from schoolwork. Figure 6.5 is an excerpt from the video observational session.

Figure 6.5   **Entity D as in Four Female Teenagers Moving in a Group Among Other Entities in Loughborough's Shopping Mall Walkway.**

e. **Entity E** – This entity represents the age group of between 7 and 12 years old known as *children*. They are mostly travelling within their family group during outings especially on the weekends. From the video observation, their movement pattern is rather unpredictable as they are an active age group where curiosity plays a part. Being curious makes them wander around looking for new things to look at. Notice that they are sometimes very mobile or may just stay put at a point of interest. At this age they are forming their own field of interest on a particular subject or thing. They tend to need the help of grown-ups to guide them while taking a walk on the streets (See Figure 6.6).

Figure 6.6   Entity E as Children in Loughborough's Shopping Mall Walkway.

f.   Entity F – this entity represents the age group of below 7 seven years old. They are very unpredictable in their walking pattern. That is why we can see that toddlers walk in wobbly manner. The entity walks with the aid of parents. However, most of the time, they can be seen travelling in pushchairs and that is why this entity is the least common. An example of Entity F is in Figure 6.7. The inclusion of children in the research shows the difference in specific movement of adults, elderly and disabled compared to the unpredictable movements of children. For simulation purposes this category of entity is not involved in the simulator as toddlers are always on the move with their parents or guardians near the shopping mall. Their walking characteristics are purely following the latter most of the time. Therefore, the final five categories of entities are the elderly, disabled, adults, teenagers and children.

Figure 6.7   Entity F as Toddler in Loughborough's Shopping Mall Walkway.

All of the entities have no reference to gender as male and female entities seem to show the same behavioural walking patterns. The number of entities involved in the simulation varies with the place and time selected.

6.3.2   Specifications of Research Locations

The specifications of the shopping mall for the purpose of simulation are stated below

a.   Shopping Mall Model

The general specifications for this model are:

i.   This is the only place of observation in the main case study due to unavailability of other locations such as tube stations, bus stations and airports due to current security concerns as explained earlier on in the thesis.

ii. The main feature of a shopping mall is that people (entities) move in different directions and manners. The number of people walking will be determined by the time of the day. The most

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number of entities will be present during rush hours in the morning and evening and during lunchtime from 12 noon until 1.30pm.

iii. Those walking will always take the shortest route from the starting point to the destination point.

iv. The main walking route will be in the middle of the walkway and as the crowd gets larger slower entities will use the sides to move in order not to be on collision course with others either from the rear or head on.

v. For the two-dimensional simulation window, small blocks of red will represent stalls, the shops by yellow blocks, flowerpots by green sun-like objects and staircases as blue. The entities are spherical in shape with a built-in direction finder for better movement control in a controlled simulated space. The emphasis of the simulation is on the forward movement mode especially for the elderly and disabled.

vi. As for the entities in the simulation, they will travel either individually or as groups of two or more and some will join either an individual or a group to form a larger group or simply part ways accordingly.

vii. The groups can be either in the same age group or otherwise.

viii. The entities are carrying shopping bags, walking with pushchairs, having a conversation with another entity, looking for a particular place and window-shopping.

ix. Other considerations are the presence of other entities such as the security patrol, cleaners on the job, people running through the place and delivery men all of which can disrupt the movement flow of entities.
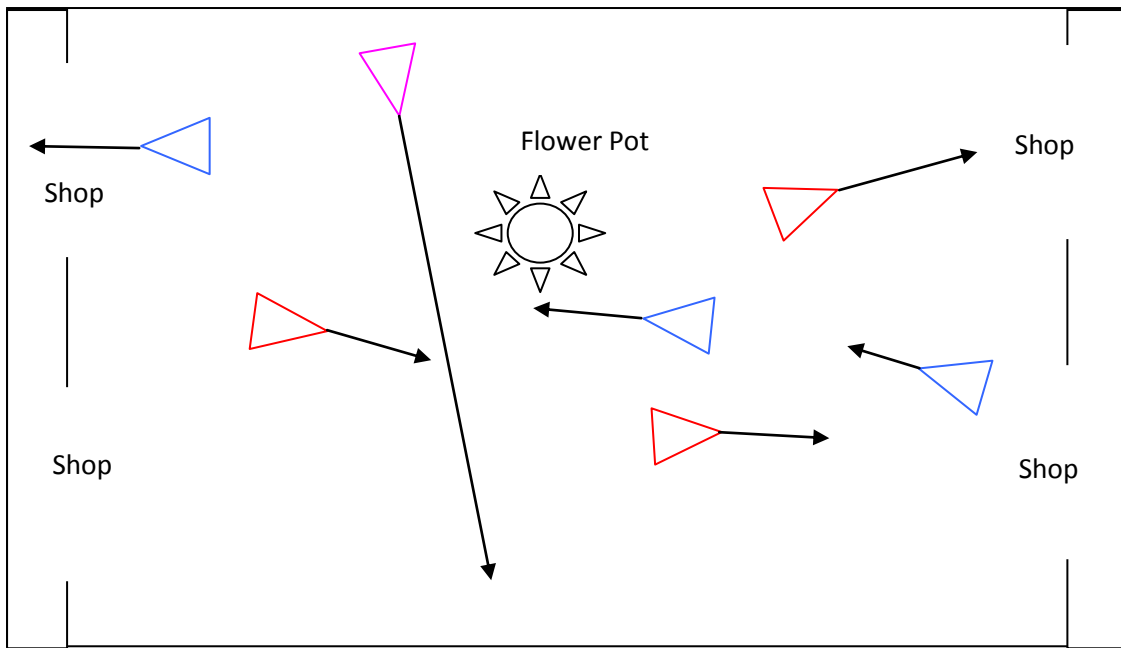
Figure 6.8   Example of A Shopping Mall Model.

b. Bus Station Model

The bus station model (see Chapter 7) has the following general specifications:

i.   The bus station is another good example where individual entities interact with each other in a different manner as compared with the shopping mall model. Although they look similar in walking pattern the goals for entities determine the nature of the output and outcome of the simulation.

ii. The main activity of the place is the boarding and disembarking to and from buses and the bus platform. The entities will either appear from an entrance to wait for buses in the boarding room or appear to be queuing up to board a bus.

iii. Another activity will be the meet and greet scene or the sending off scene. One common feature of a bus station is the queuing activity at a ticket or information office, entities queuing up in front of the travel information point, buying food and drinks at a food kiosk.

iv. The presence of many seats for waiting passengers is the main feature of a bus station. Entities move back and forth from the seats (starting point) to the bus platform door (destination point) and vice versa.

v. The schedule of buses actually dictates the number of individuals present in the bus station at any particular time. The peak times are the morning and evening rush hours and during lunchtime.

vi. The parameters for sampling purposes vary with the type of venue. An example is that the percentage of those carrying luggage bags on public transport is more than that found in a shopping mall. There could be more people travelling in groups at a bus station compared to the crowd in mall. An assumption made is that the number of commuters (entities) in any model is equal. This is to show the effects when the same number of entities react but in a different scenario.

vii. The concentration of the entities in a bus station is always higher than the one found in a shopping mall especially during peak hours. This is the main thing that the research aims to investigate how the entities in different conditions react with each other for different age group.
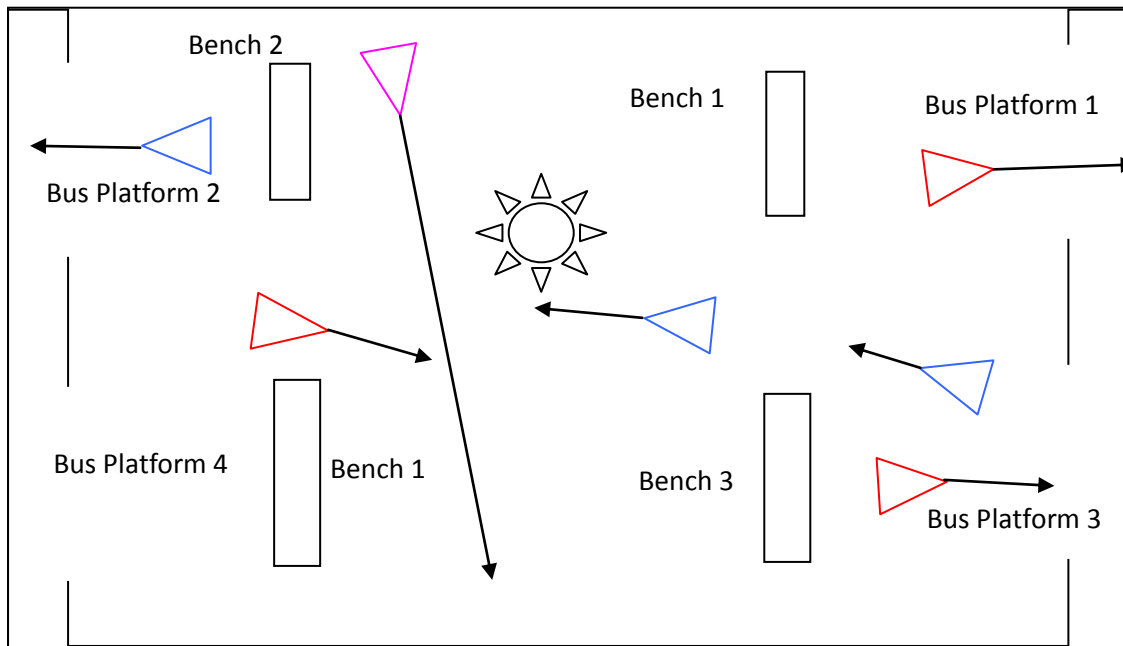
Figure 6.9   Example of Bus Station Model's Departure Bay.

6.6   Summary

Artificial intelligence features of the software are used in determining the type of entity that one encounters during the simulation run. These are part of the simulator's expansion pack known as DarkAI pack which is an important tool that has greatly reduced the need to write very lengthy source codes that represent collision avoidance and entity recognition features of human behaviour simulation schemes. It is hoped that the simulation work will lead to a new understanding of human walking behaviours especially for those who are disabled and elderly. Their presence is a benchmark in determining for the future the best possible solution for the design of a public space.

Chapter 7   Case Study and Evaluation

7.0   Chapter Overview and Introduction

The previous chapter showed how human walking behaviours observed at a shopping mall have been used to establish the basis for a simulation. The next step is to consider a mock up of a place of interest as a case study.

The case study was chosen so that the situation involved all the entities described in the previous chapter. The area of interest for the case study is public transport, but due to security reasons concerning public transport, it was not possible to obtain permission for video observation. Therefore, validation work is limited to showing the feasibility of the program in typical public transport situations. Consequently the two main case studies are the simulation of the shopping mall and a bus station departure hall.

7.1   Simulation Results and Discussions on Simple Movement

The results of the simulation exercise in terms of time taken to travel from one activity location to another are described below. The simulation is based on the observation videos from an earlier chapter. The simulation may be from one store to another or from one point of interest to another within the same simulation window.

a. Entity Traversing in An Open Space

This is the case where an entity moves in an open space between specified start and end points. The entity moves according to the current surroundings in the simulated scene. Other entities and obstacles might be present and the obstacles might be either static or dynamic. The presence of other entities shows the interactive capability of an entity towards others. For this initial simulation work the entities chosen were the elderly and disabled and the two entities moved from one end of the floor to the other. The time taken to travel in between the points depended on the distance travelled, speed of traversing and types of entity. The entities tried to move in a straight line from the start point to the endpoint but the presence of other entities and obstacles hampered this straightforward movement. This is where the AI engine of the software assisted in trying to find the nearest waypoints that guided the entities around the obstacles.

The entities travelled a distance of 20 metres to get from one end of the space to another at a speed suitable for each entity. The disabled had an average speed of 2.1 km/h and the elderly had the slower speed of 1.8 km/h. The difference in speed meant that the disabled person was possibly travelling on a mobility scooter and the elderly person was using a set of crutches or a mobility aid. This showed that the latter needed more time to travel along any route. Typically the time taken to travel for the disabled and the elderly were 11.6 and 19 seconds respectively. The presence of personal spaces for each of the entities clearly showed that the elderly and disabled had larger spaces compared to all other entities, as they needed more time to think about their surroundings. Without such large spaces, they would be very exposed and vulnerable towards any untoward incidents. The availability of such spaces greatly expanded their capability in making decisions before proceeding towards the next point of interest.

The disabled and elderly had an Avoidance Distance (AD) of approximately 5 metres and 5.5 metres respectively from the opposing entity which was travelling in either the same or opposite direction. The AD of an entity had an important role to play for the vulnerable (elderly and disabled) such as in determining the next course of action when encountering any obstruction (static or dynamic). Here, it is noticed that the long avoidance distance meant that there was a pattern, which was present in all entities during the simulation runs. The findings of the Avoidance Distance for the entities are shown in Table 7.1. The work of Hall (1966) showed that the personal space of entities in a public area covered the range of 3.6 to 7.5 metres but this was not the case in a real time situation. The reduction of the personal space of each entity occurred as soon as the crowd size swelled during the peak hours.

Entities started to follow the avoidance distance as a mechanism of avoiding collision as soon as the density of the crowd increased within a particular space of interest, for example the walkway in front of a store. At high crowd densities personal space is not observed by the entities because the need to manoeuvre in a very crowded space results in physical contact if any progress is to be made.

	Avoidance Distance (AD) in metres	Personal Space in metres
Elderly	5.5	3.63
Disabled	5	3.63
Adult	3	3.63
Teenager	3	3.8
Children	1.5	3.0
Toddler	0.5	1.0

Table 7.1   Summary of Observed Avoidance Distance and Personal Space.

For the elderly, the time taken to overtake an entity in front is based on the current speed of that entity. The entity in front determined the speed of walking of any entity that followed it. A faster entity in front influenced the speed of walking for any entity following behind. A faster speed made the route travelled by other entities easier.

b.   Entity Traversing in A Counter Flow in an Open Space Model

In this case, all the entities are involved in the counter flow action. This is where the entities travel in opposing directions in order to reach their respective destinations or point of interest. In this travel pattern the use of avoidance distance and GAPP play an important role in determining the best choice of routes taken without colliding with the opposing entities.

The result of the counter flow action was that the larger the personal space is, the higher the ability of an entity to avoid collision. An example in Figure 7.1 shows entities of different types moving in opposite directions.
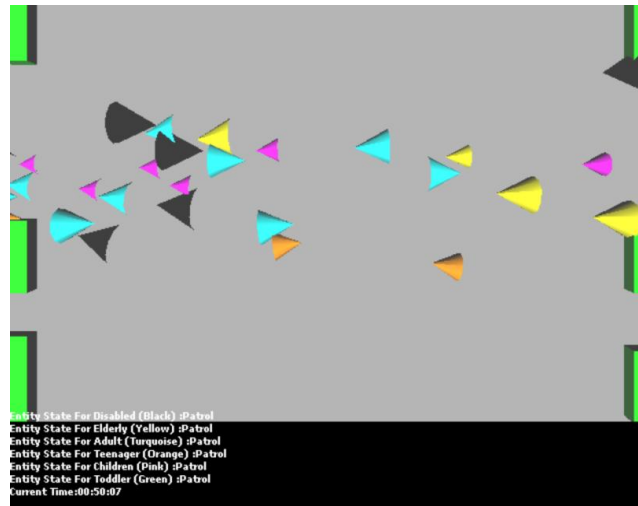
Figure 7.1 **Snapshot of A Counter Flow Crowd Action Simulation Window (Original Version).**

The result of this simulation exercise is in favour of those entities that have a greater avoidance distance and a larger personal space. Notice that the avoidance distance is less than the distance found in the single entity moving freely in a certain space. This example is a platform in determining the relationship between the avoidance distance and the size of a crowd. With this relationship, the needs of the elderly and disabled in meeting their requirements for example in building designs can be met.

In this section, the case study uses the Carillon Court Shopping Centre as a reference. The video recording is part of the total video observation exercise in Loughborough's town centre and the number of entities recorded in the session was 428 persons. The simulator is designed to work on a maximum number of 100 entities in order to keep the system running smoothly. The percentage of

users in the results below is based on the number of entities passing through the simulated area. Note that the total percentage of entities does not amount to 100% due to the repeating entities returning to the simulation window at a later time during the same simulation exercise.

The results of the simulation show that the majority of the users use the middle of the walkway to pass through the shopping centre. This involves two movement routes of south to north route and vice versa. The south to north route is used by 41.12% of the entities and the north to south route accounts for 31.31%. The remaining entities shown in the simulation exercise could be using other routes to reach their final destination. The other routes noted in the simulation are the diagonally across routes (6.54%), and those going from left to right (7.84%) and vice versa (7.01%). On the other hand, for the entities using the same route but in the opposite direction register a percentage of 8.41%. This shows that most of the shoppers in the shopping mall use the middle walkway travelling in the north-south direction. They are using this pattern to move from one point of interest to another which is located outside the simulated space.

From the video observation results, the majority of the entities make use of the middle way to move freely in either the peak or off-peak times. The results show the number of entities choosing a variety of routes during their presence in the video shoot. That is why the percentage of entities is not consistent with respect to the total number of entities involved in the simulation. This mixture shows that the unpredictability of the route taken by an entity determines the next expected course taken during the travelling period. It is noticed that the elderly and disabled follow a strict route whilst travelling on a walkway in a public space. Their choice of route is influenced by the size of the crowd such that as the crowd gets larger, the elderly and disabled steer themselves towards the left or right of the walkway. This is done in order to avoid the massive oncoming traffic which can make

them prone to accidents simply by colliding with other people. This is particularly important as the elderly and the disabled can be slow to react in any situation, and they need extra space and time to think, react and recover to a better position.

The results or outputs from the simulation exercise carried out using DarkBASIC Professional are similar to the results from the video observation exercise. However, several results do differ from the real time outputs and this is typical where simulation is concerned. The results are as follows:

1. The numbers of those who use the south to north route are 70% of the total of 100 persons and the opposite orientation is used by 75% of the total. A mixture of the same repeating entities explains why the percentages do not add up to 100%. This also happens in 2 below. These percentages look similar because these routes are the most used of all the routes used in both the video and the simulation exercise. It can be deduced that the results showed that this is the factor that influences the size of the crowd at all times. The more entities using the walkway or space are the single contributing factor that most influences the success of the simulation tool.

2. Those walking on a diagonal course are part of the 67% of the total entities involved in crossing the walkway of the shopping mall as if it is square in shape. Travel is between the opposite corners of the 'square' or moving towards a point of interest at an angle from a base line. This is a classic case of entities using the route in a shopping mall where a point of interest is located at the far end of the walkway. The entities use the route as a means of moving between two positions of interest.

3. The next category includes those who are moving from a store to another across the walkway of the shopping mall. The percentage of those involved is 47% of the total 100 persons recorded in the video that are sampled in the simulation tool.

The addition of these entities in the simulation is the defining factor in determining whether the exercise is a success.

7.2   Simulation Description

Before users enter the simulation, they have to enter required information in the menu of the simulation. An overview of the simulation is shown in Figure 7.2. All of the Programming codes for this simulation are included in Appendix 3.

```
                          ┌─────────────────────────────┐
                          │          SIMULATOR          │
                          └─────────────────────────────┘
                                         │
                                         ▼
┌──────────────────────────────────────────────────────────────────┐
│           Decide worlds and the design to enter                    │
│           Decide whether to use default settings or not            │
│                                                                    │
│              Default                        Manual                 │
│        • Number of entities          • Time period (peak or        │
│        • Run time = 30 minutes          off-peak)                  │
│        • Number of entities for      • Simulation run time         │
│          different categories =      • Number of                   │
│          random                         entities(with rules)       │
│                                      • Number of entities for      │
│                                         different categories       │
└──────────────────────────────────────────────────────────────────┘
          │                    │                        │
          ▼                    ▼                        ▼
```

Empty Space Simulation	Shopping Mall Simulation	Bus Bay Simulation
• Plain Space • No extra Design • Cannot control camera	• Design 0 - No Extra Condition Design 1 - Souvenir Kiosk Sphere Shape • Design 2 - The 3 Intersects Block of Kiosk • Design 3 - The 'Curve Outward' Shape Location of Kiosk • Design 4 - The 'Curve Inward' Shape Location of Kiosk • Design 5 - Random Location of Kiosk	• Design 0 - No Extra Condition • Design 1 - Tree Design Barrier • Design 2 - Vertical Design Barrier • Design 3 - Smooth Flow Design Barrier • Design 4 - Round Design Barrier • Design 5 - Cone Design Barrier

Figure 7.2   Overview of Simulation

7.2.1   Simulation Menu

The simulation was developed with a choice of three different worlds and additionally, the shopping

mall and bus bay simulations each have six different designs. Before entering the worlds and the

design of the worlds, it is necessary to enter some specifications. Figure 7.3 displays the welcome screen of the simulation.
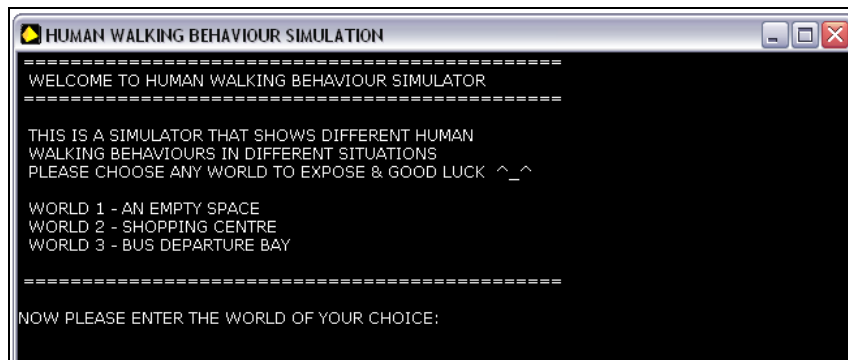
Figure 7.3 Welcome screen of the simulation

The menu of the simulation is programmed, so that it is only possible to enter certain values for the simulation. For example a maximum of 99 entities is enforced as it has been found that larger numbers slow the simulation down to such an extent that it becomes unworkable.

7.2.2   Empty Space Simulation

World-1 is referred to as an Empty Space Simulation (ESS). In this simulation, the entities only appear in two locations; Exit1 and Exit2. Figure 7.4 shows the empty space environment. The entities either start from Exit1 or Exit2, and go to Exit2 or Exit1 respectively. There are no other functions in the simulation and hence, this is the simplest simulation.
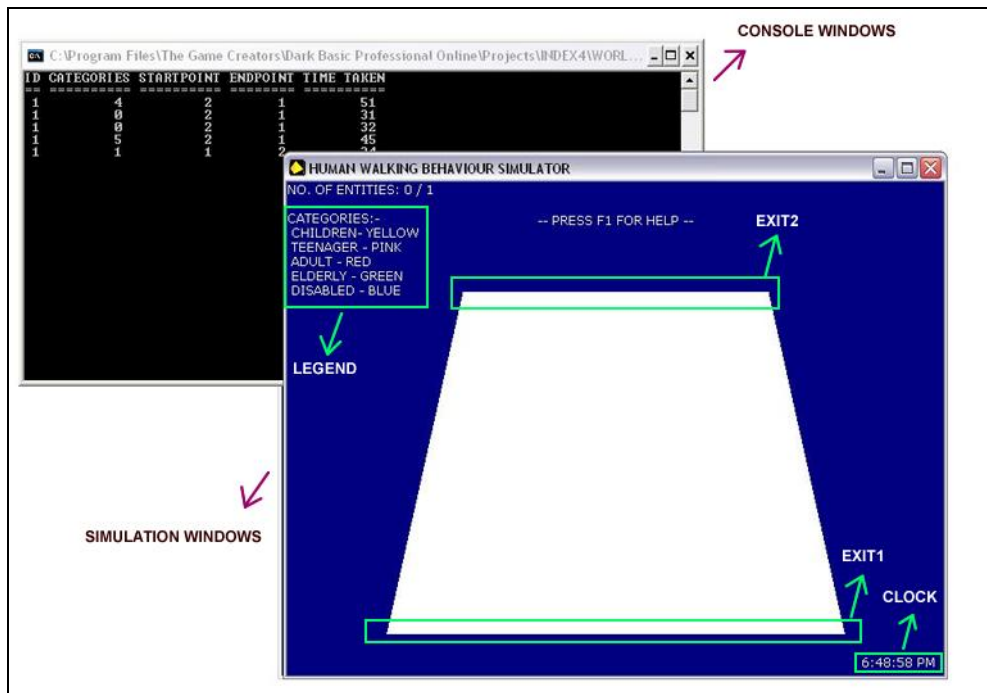
Figure 7.4   Empty Space Environment

Figure 7.5 shows the walking behaviour of the entities. During the simulation it is possible to debug the walking paths of the entities by pressing '1', debug the avoidance angles by pressing '2' and view arcs by pressing '3'. All of these are shown on Figure 7.5(b), (c) and (d) respectively. Meanwhile, Figure 7.5(a) shows the normal mode without any debugging. Displaying the paths of the entities allows the detection of the journey for each of the entities. Avoidance angles only appear if the entities are avoiding other entities and are shown in green. The normal human viewing angle is between 10° and 170° and by using view arcs, it is possible to observe the direction of the entities. For example in Figure 7.5(d) the entities are moving towards Exit2.
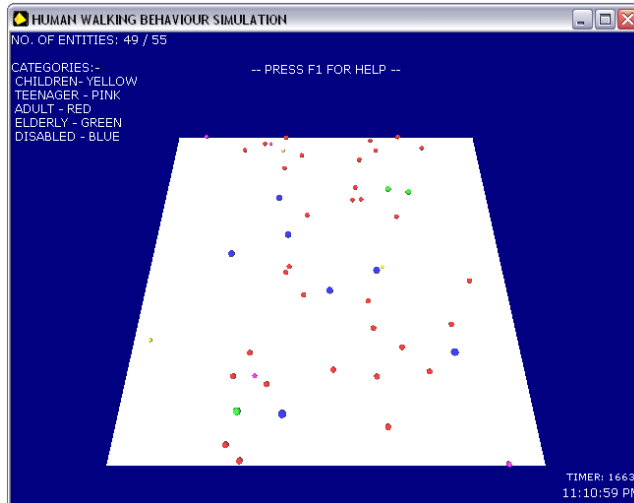
(a) Simulation in Normal Mode
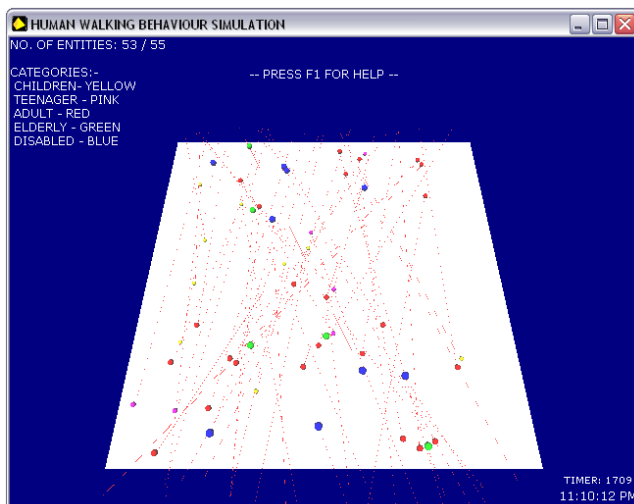
(b) Walking Paths of Entities
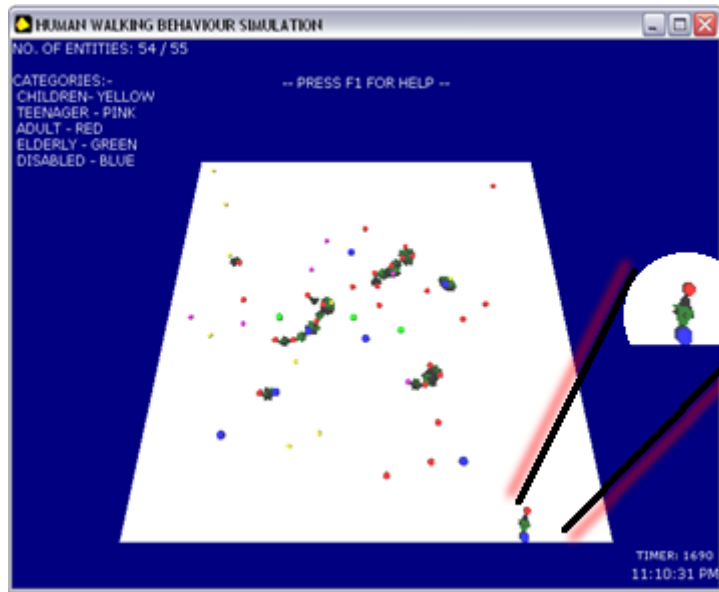
(c) Avoidance Angles of Entities
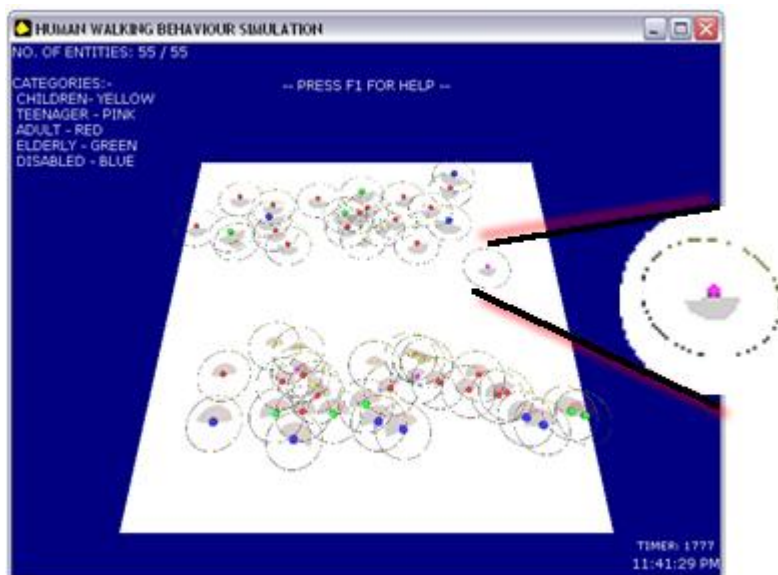
(d) View Arcs of Entities

Figure 7.5 **Simulations of Walking Behaviour with debugging**

7.3   Shopping Mall Simulation

World-2 is a Shopping Mall Simulation (SMS). The entrances for this simulation are the same as in the Empty Space Simulation. However, there are many different destinations for the entities. The main destinations are the shop entrances on the left and right sides of the mall. In this example (Figure 7.6) there are eight shops on the left and another eight on the right providing a wide choice of destination. After the entities have entered one of the shops, they would acquire a new destination within or outside the area of the simulation. As some of the entities leave the mall, new entities are created to enter the simulation window.
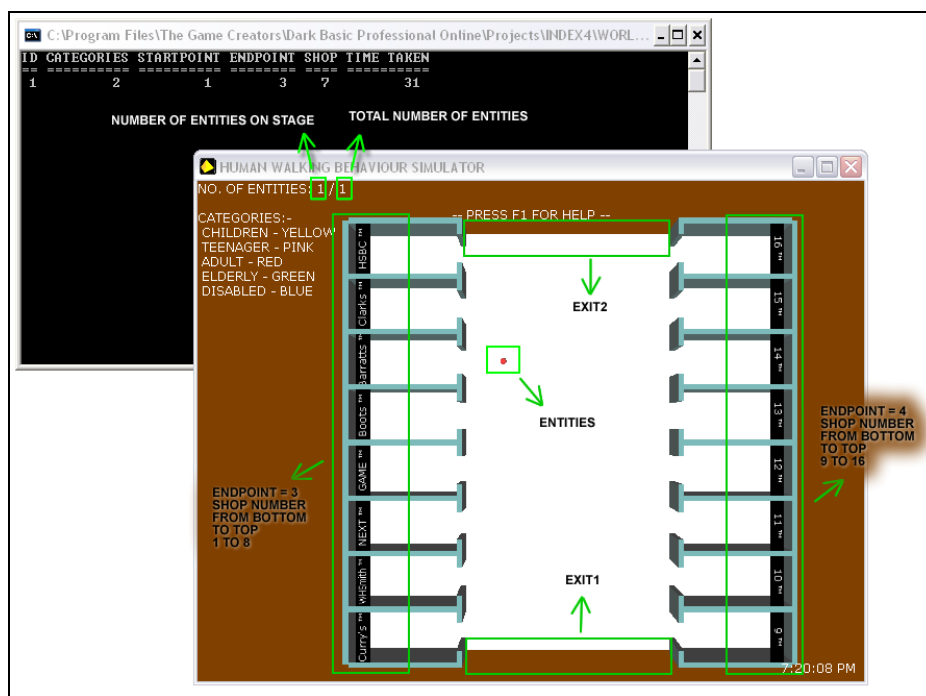
Figure 7.6   Environment in a Shopping Mall

There are six different designs in the SMS. Design-0 has already been described and is shown in Figure 7.6. In Design-1 there are three sphere-shaped obstacles in the middle of the shopping mall walkway. The main idea of this design has similarities with roundabouts in a road network. The moving entities are separated from each other based on their walking paths so that congestion or

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collisions do not happen. This design has failings because crowd situations (shown in Figure 7.7) are not properly addressed.
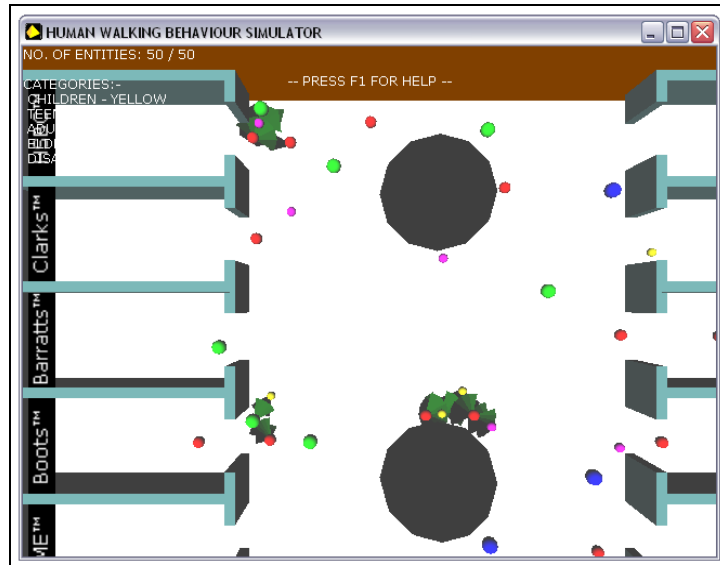
Figure 7.7   Scene in SMS Design-1

Three intersecting blocks are created in Design-2. This design allows the entities to move in separate routes and the crowd situation does not happen in the empty space and at the entrances of the shops. However, shopping malls seldom implement large obstacles in front of the shops to block the walking flow. In addition, this design does not meet the objective since there are some entities stuck inside the obstacle area as shown in Figure 7.8.

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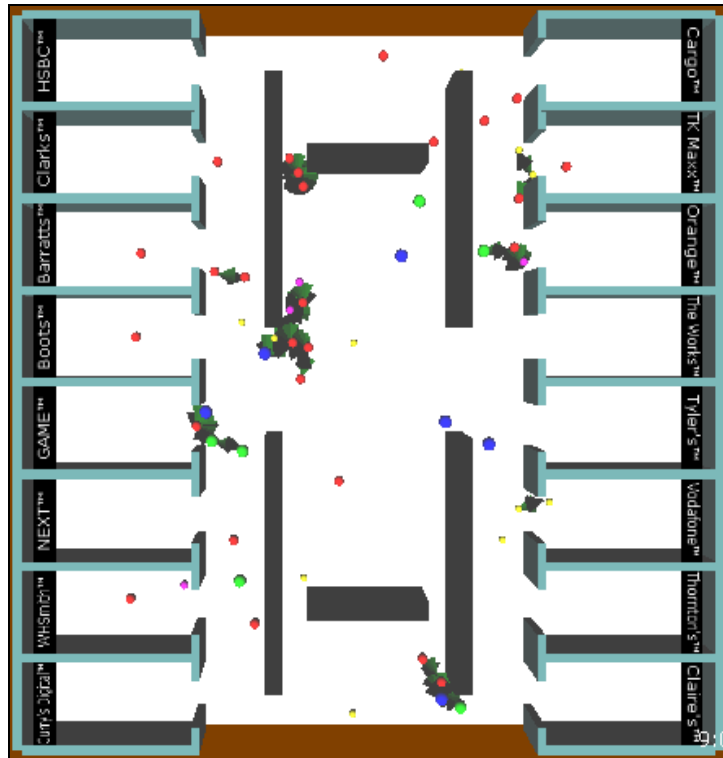
Figure 7.8   Scene in SMS Design-2

The design concept for Design-3 and Design-4 are very familiar. Obstacles are arranged in two columns and each of them is formed by several small rectangles. The difference between the two designs is the method of positioning those obstacles. Crowding will happen in the narrow spaces of both designs (Figure 7.9). However, both designs are able to divide the walking flow and ease crowding. Separating the walking flow would also create a friendly environment for the elderly and disabled people.

(a) Scene in SMS Design-3

(b) Scene in SMS Design-4
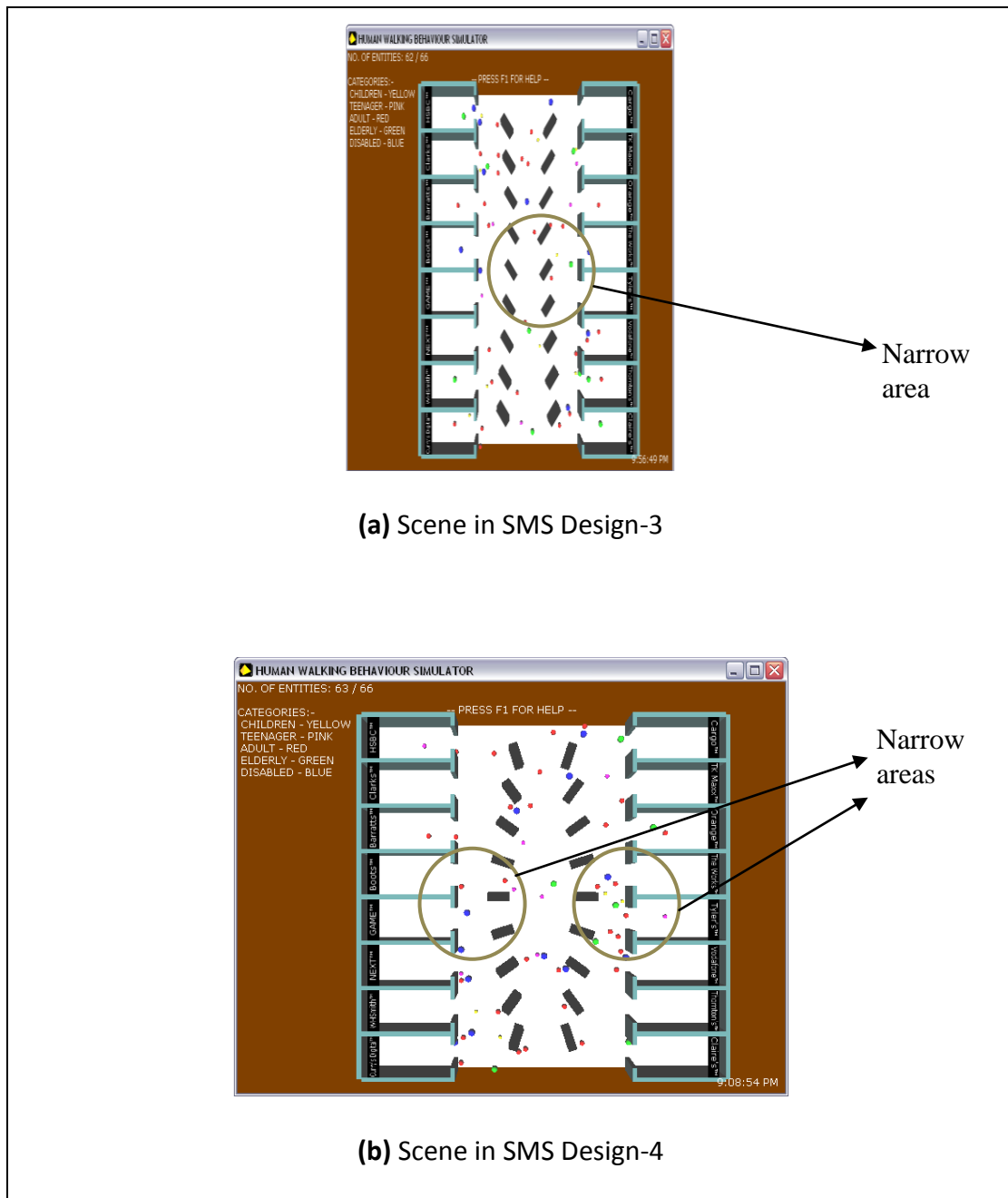
Figure 7.9   Comparisons of Design-3 and Design-4 in SMS

The last design, Design-5, uses a random method to arrange the obstacles but with some limitations. Obstacles are free to rotate at any angle and are positioned in the x-direction at any point within the limits of the area (Figure 7.10). The arrangement in the z-direction is in a fixed pattern, the obstacles are arranged from bottom to top of the stages. The purpose is to set the limitations to make sure

that the obstacles do not overlap and functions well. If large areas are required for certain activities then this design would be suitable. From the simulation, the user would be able to notice the crowd situation; the obstacles are arranged randomly which eases crowd control procedures when overcrowding occurs. This option is suitable for the elderly and disabled to move easily and avoid any accidents.
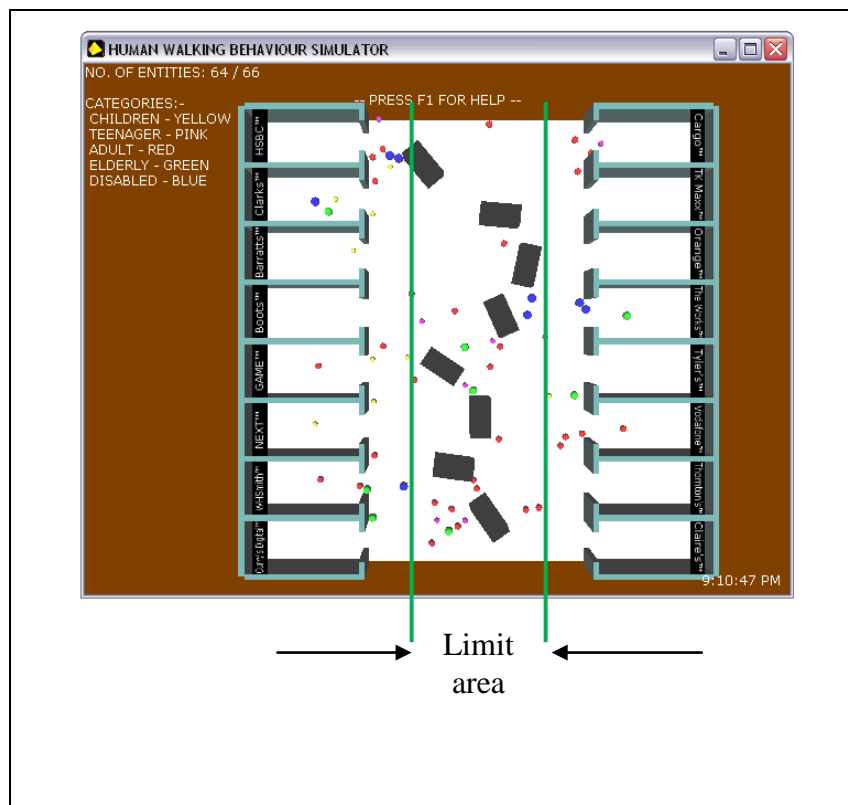
Figure 7.10   Scene in SMS Design-5

From Design-5, it can be seen that the elderly and disabled are able to move freely even though there are some narrow gaps due to the random manner the obstacles are arranged. The narrow spaces are usually used by the able bodied entities and on the other hand, the wider gaps are used by the elderly and disabled where they need a bigger space to think and move due to their larger personal space. in this way, this design is also able to control and divide the walking flow and hence has achieved the objective of controlling flow.

7.3.1   Evaluation of Loughborough's Shopping Centre Simulation Exercise

This simulation exercise was based on the work done using DarkBASIC Professional software for game scripting work. The Loughborough Shopping Centre is a typical public scene where people can be seen flocking to the area in order for their particular activities at many points of interest. The model is from one of the observation scenes in the Carillon Court Shopping Centre of Loughborough. The simplified floor plan of the space shown in Figure 7.11 depicts the floor size and other entities usually found in a shopping mall. The selected floor area is 5 metres by 20 metres. The main walking area is shown in white and the stores are shown in yellow. There are no specific dimensions for the stores as they are for representative purposes only as the research is more interested in walking behaviours of entities in the main walkway in the middle of the mall. Here, we will find entities moving in all directions either having a specific aim towards points of interest or not.
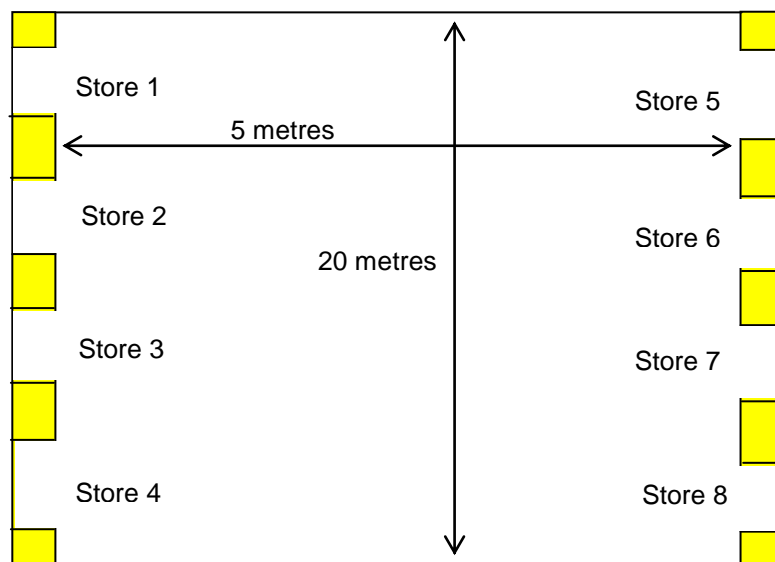
Figure 7.11   Floor Plan for Selected Area of Interest.

From the above floor plan, the idea is translated into the DarkBASIC Professional script, which resulted in the setup of the following snippet from the simulation window as in Figure 7.12 with the real scene is as shown in Figure 7.13.
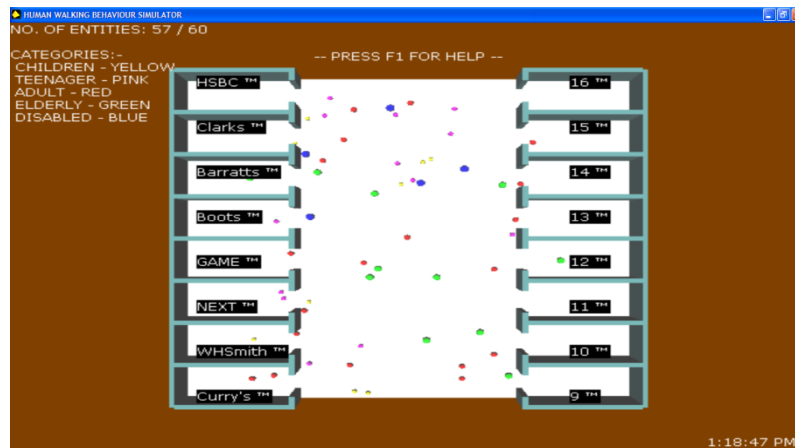
Figure 7.12   Screenshot of A Simulated Scene for Carillon Court Shopping Centre in Loughborough.

Figure 7.13   Snapshot of a Crowded Scene in Carillon Court Shopping Centre.

The model in DarkBASIC Professional is a direct translation of the floor model found in the video observation of the same venue. The representation of the entities is as follows:

a. A disabled person is represented by a black spherical entity with a relative size of 30 in DarkBASIC Professional units. It has a DarkBASIC Professional traversing speed of 30 units.

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b. An elderly person is represented by a yellow spherical entity with a size of 27 units and a traversing speed of 15 units.

c. An adult is represented by a turquoise spherical entity with a size of 25 units and a traversing speed of 30 units.

d. A teenager is represented by an orange spherical entity with a size of 20 units and a traversing speed of 55 units.

e. A child is represented by a pink spherical entity with a size of 17 units and a traversing speed of 20 units.

The different colours, sizes, and speeds show how the different entities react towards each other and how they fare with changes in the surroundings. In this simulation work, the entities are roaming in the specified space in any direction either across, diagonally or just passing through. The example in Figure 7.12 is translated from the scene in Figure 7.13, which shows a crowded walkway in a shopping centre.

7.4   The Bus Station – A Case Study

The bus station is one of the most crowded places in terms of our everyday experience. Being a transportation hub, most of its management is concentrated on security and crowd control factors. The bus station receives different types of commuters trying to pass through it. The early designs and planning may be focused on able-bodied human beings to the relative exclusion of the elderly and disabled. A general objective is to fulfil the concept of inclusive design for building projects of the future involving the elderly and disabled.

7.4.1 Introduction to the Case Study

The bus station is one of the main areas with a high concentration of commuters, and a simplified model for the floor plan will show how the simulation works in catering for the needs of commuters. In this case study a simplified representation of a bus station is used and it involves various categories of people including:

a. The Elderly (first main subject of study);

b. The Disabled (second main subject of study);

c. The Normal Adults;

d. Teenagers and;

e. Children.

The number of bus commuters varies during the various times of a day. They are at their maximum during peak hours such as in the morning and evening rush hours. The maximum capacity is easily reached during the weekend as well as there are many commuters thronging into a city centre doing their weekend shopping or when there is a carnival going on. The numbers will dwindle substantially at other times. The possible breakdown of commuters is as follows:

- During weekdays, the types of commuters will vary with the able adults as the main group that congregate in the bus station. The next largest group are the elderly who might be shopping in the market or searching for a place to visit such as a museum or other place of interest. An example of a bus station is shown in Figure 7.14 from a scene at Norwich Bus Station.

Figure 7.14   Scene from Norwich Bus Station (http://www.chetscorner.com/)

- As for the number of teenagers in a bus station, they are higher in the early morning or afternoon going to and from school during weekdays. Their numbers are very low during the lunch hour on weekdays and they are at their highest number during weekends when many teenagers loiter in town centres and their numbers see an increase as the bus is their most favoured transport mode.

- The number of children and toddlers is at its highest during the weekend when they board buses on pushchairs with their parents.

- Generally, those commonly found at bus stations are shoppers, workers, transiting travellers and finally, students of the local schools and universities. Others are workers in the station such as the station manager, cleaners, ticket inspectors, ticket officers, information counter officers, drivers, the maintenance team, owners of shops operating in the station and lastly, the occasional porters (found only in large stations).

7.4.2 Description of the Case Study

The bus station is used as the boarding (ingress) and disembarkation (egress) point for the public bus services and the bus commuters. It is the main focal point for the bus service providers to render their services to the public. People with all abilities use bus stations or wish to use them. Hence, it is important how to show the disabled and elderly commuters behave especially their walking behaviours.

7.4.3 Relevance of the Bus Station Case Study

The research involves the simulation of people of all abilities as entities in a program studying their walking behaviours with the disabled and elderly as the focus of study. To test the method produced and its worthiness, it is important to perform a case study that involves the various entities and a place of interest that are of special importance to the public. The functionality of the program developed is duly tested against a particular place of interest that involves a wide range of factors and individuals.

A bus station satisfies the following criteria:

- People of all ages and abilities are readily available for observation purposes, which makes it a good platform as a case study.
- Important physical features in a bus station such as the departure/arrival hall, ticket office and information kiosk, are cramped into an area of activity, giving it an ideal setting for testing the proposed methods of users interacting with each other, interaction with the various physical features of the bus station and the suitability of the design. A bus station will provide sufficient

complexity in its design with respect to the above-mentioned features where they are very important in determining the success of the research.

7.4.4 Movement Characteristics of Entities in a Bus Station

During the simulation study, there are different types of movement characteristics used by the entities. The five different categories of characteristics involved are as follows:

1. **Purposeful Movement** (**PM) –** this includes moving from one point to another knowing what is to be expected when reaching the destination (e.g. going towards a bus with the intention of boarding it.) Another example is searching for a ticket counter or a ticket vending machine with the hope of subsequently boarding a bus. One further example is moving from one platform to another in search of the next bus to board that is also known as in-transit from one point to another where the next destination is known to the entity. The entity knows exactly where and when to disembark when getting on the next bus to continue an outward journey.

2. **Transition between Activity Location (TAL) –** this characteristic is shown when the bus commuters stop in front of the bus terminal to find their way into it. This is when the *walk-pause-walk motion* comes into effect. They will repeat this activity until their intended destination is reached (perhaps a departure hall). They can also be seen going to the information counter looking for directions or schedules for their intended destination on that particular day or advanced departure dates. Then, they will proceed to the next activity location such as waiting for a bus or going to a ticket counter for their onwards travel ticket.

3. **Aimless Activity (AA)** – this can be seen when an entity just moves around in the bus station having no sense of purpose such as when browsing the facilities offered by that particular station. They will move in an erratic pattern simply to have a casual walk to look for anything interesting that will entice them to use the bus station as their local transport provider. Note that the bus commuters will move in a disorderly manner forward or turn around without any sense of purpose for the next activity.

4. **Interrupted Purposeful Transition (IPT)** – this can be seen when a bus commuter is travelling from one activity location to another activity location in an open space but it is interrupted by frequent pausing activity. One example could be when a commuter meets up with an old friend and stops for a chat about old times. They do this for quite a while (maybe, ten minutes) and move on towards another location such as a pub for a pint or two. Another example could be a cleaner who is doing his daily routine of picking up rubbish on the floor or doing some mopping or sweeping. A further example is when a crowded situation halts the transition of an entity from one activity location to another - intermittent interruption without any specific time span between each pausing activity. The time span is typically one to three seconds.

5. **Prompt Through Transition (PTT)** – the fifth characteristic is when an entity moves along a space promptly without having any need to pause or stop. An example would be someone just passing through a space or a person just passing through the bus station aiming to reach a destination somewhere else. The fourth characteristic affects this characteristic when the passing space is either crowded or empty.

At times, there are combinations of two or more characteristics present but it is not possible for all to happen simultaneously. These combinations lead to the use of crowd dynamics factors that will determine the success in the movement patterns or characteristics of entities in a public space.

7.4.5   Crowd Dynamics factor (CrowD) in walking

The emergence of two or more characteristics found in section 7.4.4 is unavoidable as the crowd factor is unpredictable due to the dynamic nature of the crowd system. The dynamic nature of a crowd is defined as *the tendency of a crowd to move towards any point of interest in a dynamic fashion*. This dynamic nature is a deciding factor in determining the outcome of the simulation. This leads to the introduction of a human walking behavioural factor called the Crowd Dynamics (CrowD) factor. CrowD is defined as *the predictability factor an entity possesses when travelling in a crowd with a scale of 1 to 5 where 1 means 100% movement predictability and 5 stands for 100% unpredictability*. The more crowded it is, the higher is the dynamic factor. A CrowD of one means that the speed and direction of an entity are 100% predictable with respect to crowd density. i.e. the crowd is so sparse that the presence of others is not affecting the behaviours described above. At a CrowD of five, the entity moves with very unpredictable speed (slow or fast) and direction (random) as the dense crowd is very significantly affecting the normal walking behaviours.

For a CrowD of three, the entities have both predictable and unpredictable speeds and directions of travel. An example of this situation is when someone is lost in a crowd of people. That entity might know where to go but is still unsure of the next route to take in order to reach the next point of interest. Now, the entity has a tendency of 50% in reaching the next point of interest. Another 50% is spent on trying to get more information regarding the directions for the intended point of interest.

For a scale of two, the entity has a tendency of 75% for predictable known speed and direction to the intended point of interest. The other 25% remains unpredictable for its next course of action.

A similar situation occurs for the scale of four but it reciprocates the predictability scale as in factor of two. Therefore, with the combination of CrowD and personal space, the predictability of an entity in a crowded situation is justified with respect to the situation it is encountering. The relations between both factors play a major role in defining the nature of the entities' walking behaviours in any situation.

7.4.6 Bus Bay Simulation

World-3 is referred to as the Bus Bay Simulation (BBS). The entrances of this simulation would be different compared with the previous worlds as there are four entrances in BBS. The additional two entrances are Bus Bay1 and Bus Bay2 respectively. There is a ticket counter in BBS. Figure 7.15 shows the Bus Bay environment.
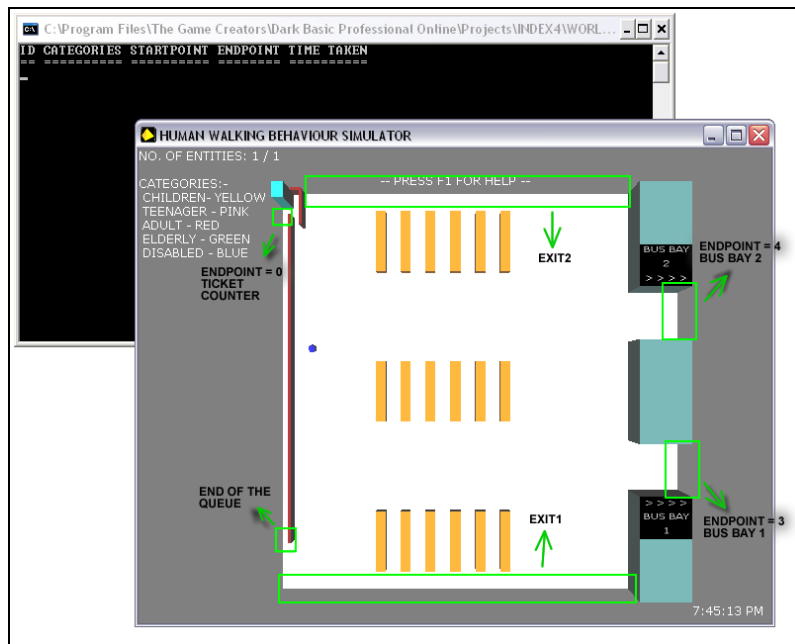
Figure 7.15   Simulated Bus Bay Environments

This enables a complex task situation where, if the destination of the entities was the ticket counter, they have to go to end of the queue barrier and queue for ticket purchasing. As they reach the ticket counter, they would stop (pausing in the simulation) there for five seconds for purchasing purposes. After that, entities decide on the next destination. They can choose any entrance to go out of the stage. The program codes for Bus Bay Simulation are shown in Appendix 3 (Refer to B–4: Bus Bay Simulation source code).

Design-0 is shown as Figure 7.15 and the concept is same as with the SMS. In order to control walking flow another five different designs have been developed.

The concept of Design-1 was based on a tree diagram as shown in Figure 7.16. The main idea is to separate the entities walking flow as the tree branches. Thus, the smooth walking flow can be developed and helps in reducing bottlenecks. However, bottlenecks still happened, mainly at the ticket counter entrance and at the bus bay entrances.
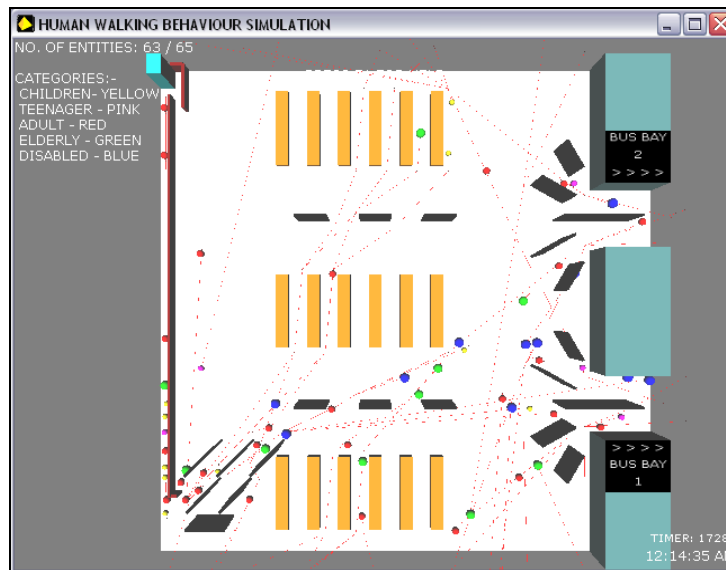
Figure 7.16   Scene of BBS Design-1

A vertical barrier is found in the Design-2 of BBS (Figure 7.17). The design is intended to control the moving flow of the entities so that they do not reach the destination simultaneously and cause a bottleneck. Thus, the brick concept has been developed. As the entities came out from bus bay entrances, they decide the direction for the next move through the narrow gap between the barriers and the flow separates as they face the barrier. The entities from Exit1 and Exit2 would walk through the gap smoothly. However, this did not function well as most of the entities from the bus bay entrances passed through the gap between the wall and the barrier and caused a bottleneck to happen there instead. Sometimes entities were in a locked position, blocked by others and unable to move forward.
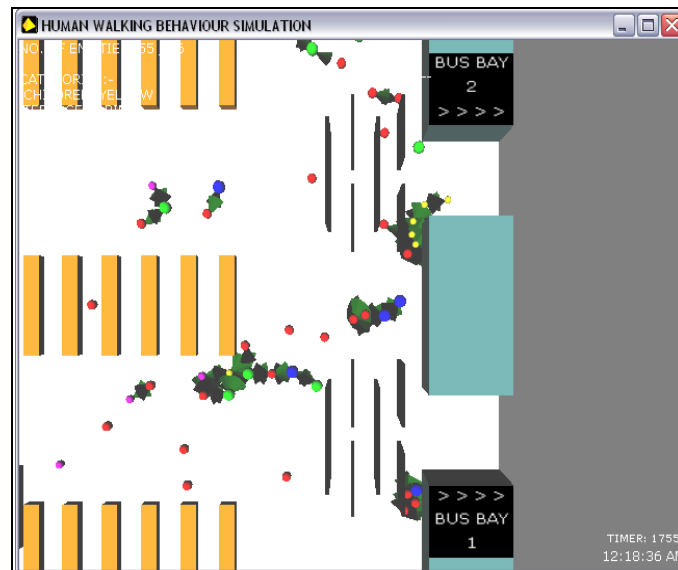
Figure 7.17   Scene of BBS Design-2

Design-3 is based on controlling the flow before the entities get to the empty space. Thus, they were separated by two barriers at each of the bus bay entrances. Entities would take the left route if they go to Exit2. If they were not turning straight away after passing the entrances, they would take the middle route. The same concept applied to the ticket counter area. The extra horizontal barrier allowed entities that went to the ticket counter to pass by or else they would take alternative routes. However, bottlenecks could happen because the flow is smooth allowing most of the entities to arrive at the destination at the same time. In Figure 7.18, entities are moving towards the ticket counter simultaneously and causing a bottleneck at the counter.
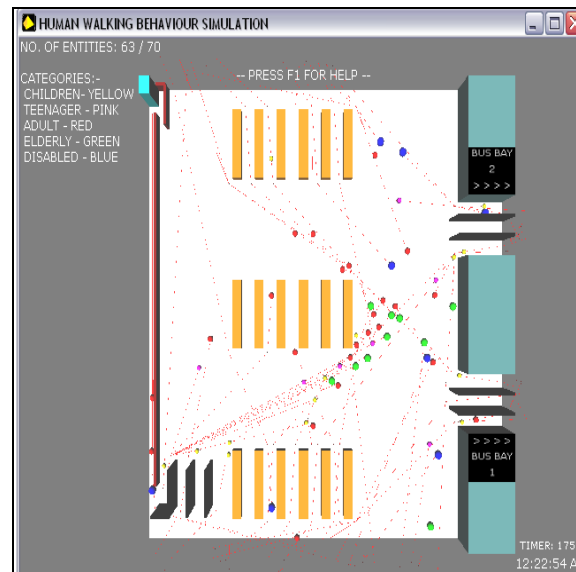
Figure 7.18   Scene of BBS Design-3

Round-shaped barriers were used in Design-4 (Figure 7.19). The concept of the design was the same as Design-1 in SMS. The positioning round-shaped barriers in between the seats purposely separated the flow of movement so that entities would not be able to reach the destination simultaneously. The round-shaped barriers near the ticket counter are bigger than the others. Thus, the coverage area would be bigger and flow could distribute evenly. However, bus bay entrances were crowded and caused the entity 'locking' condition again. Also, the round shaped barrier located near the ticket counter is unable to control the flow. Conflicts happened at the gap between the round shape and the queue barrier. Some entities moved upwards by passing through the gap and came into conflict with other entities at the ticket counter.
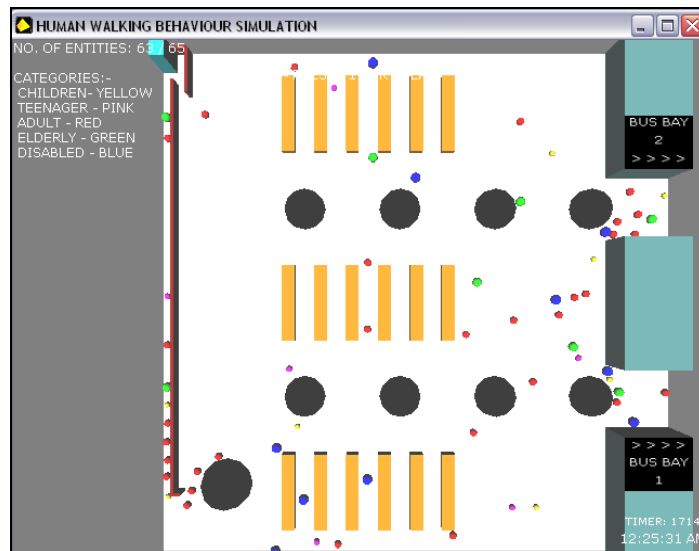
Figure 7.19   Scene of BBS Design-4

The last design, Design-5 (Figure 7.20) uses cone-shaped barriers. The cups of the cones functioned as flow separators for the crowd. The bases were used to separate the flow into large parts and normally crowding would not occur at these points. This concept is similar to the round-shaped barriers, but differs in shape. By having a cone shape, entities are evenly distributed. The cone-shaped barriers would block the flow towards ticket counter evenly. Some would take the longest distance; some would have to take the short one. Therefore, this design would be the best for bottleneck control. However, there are still many improvements that could be done on the design in order to perfectly control the moving flow.
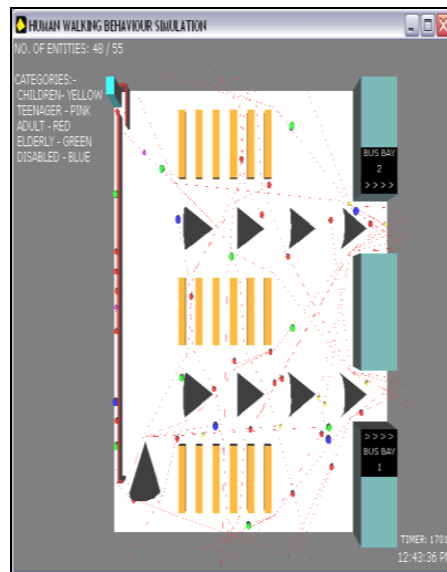
Figure 7.20   Scene of BBS Design-5

7.5   Evaluation of the Case Study

In the research, the two case studies generated results that are favourable for the design of public space in terms of transportation interchange hubs such as a bus station suitable for the elderly and disabled. The results in the following sections, illustrated in the accompanying graphs, show the relationships between the movement characteristics of entities and Crowd Dynamics factors (CrowD) that are used to determine the success of the simulation in human walking behaviours using the HIMs program.

This case study is based on the selected floor scene found in Figure 7.20 for the BBS Design-5 as it is found to be the most suitable of the all the designs featured in the research work. The findings of the case studies show how the movement characteristics of entities react to various predictability levels of entities available in certain conditions involved in the simulation program of HIMs. The

findings of the simulation runs will be used as a guide or reference on the ability of the program in showing the best movement behaviours in terms of movement characteristics and crowd dynamics movements.

7.5.1   Case Study for the Elderly

The first part of the case study covers the activity involving the elderly during the peak period of a virtual bus station scene. Each of the graphs in figures 7.21 to 7.30 show the percentage of elderly or disabled that are using a particular walking characteristic under the different crowd dynamic conditions. Figure 7.21 shows the results of simulation for the elderly in the bus station case study for Purposeful Movement (PM). It shows the relationship between the movement characteristics of the elderly and the numbers involved in the simulation. The total number is capped at 100 entities for this simulation work as explained earlier in the chapter. As can be seen from the Figure 7.21, 50% of the elderly adopt Purposeful Movement characteristics when the CrowD factor is 1. So, for example, there might only be 10 elderly people in the total population of 100 but 50% (5) will be using Purposeful Movement.

Based on the characteristics of the elderly entities, the author was able to see the similarities with the real time observation videos. The percentage obtained is purely based on stop-frame observation using the *pause* mode in the simulator program. The reason of having to show the case study is to explain how the movement characteristics are used as a tool to predict the movement of

entities in a public space that are suitable for a sustainable environment especially for the elderly and disabled.

The simulation (Figure 7.21) shows that the elderly are the next most vulnerable of the two in the group together with the disabled. The reason behind this is that they have the highest count of those in the Purposeful Movement mode. They account for 68% involved in the simulated scene when compared to the other groups comprising the disabled and others.
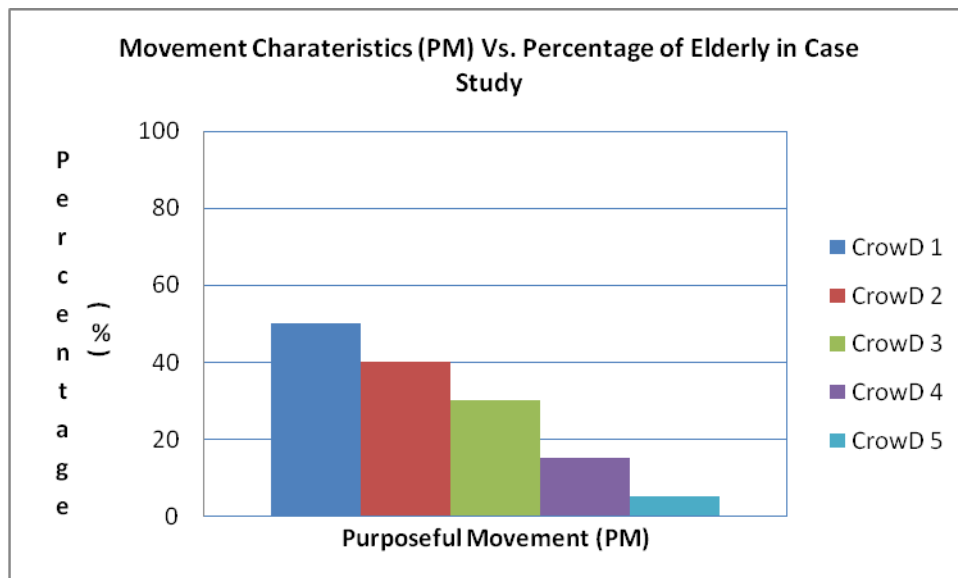
Figure 7.21   Graph of Purposeful Movement Versus CrowD Percentage of the Elderly in the Case Study.

(a) The graph in Figure 7.21 shows the elderly are involved mostly in the *Purposeful Movement* (PM) characteristic. The elderly account for 50% of those with CrowD 1 probability of movement in the PM movement characteristic category. The reason being was that they planned their destination well before going on their next journey.

(b) The next category is those involved in the *Transition between Activity Location* (TAL) movement pattern (Figure 7.22). For this walking characteristic, the percentage of the elderly involved is the highest with CrowD 2 with a percentage of 30% in which this set of entities are 50% predictable in their movement plan. In conclusion, a majority of the elderly carefully plan their walking route in order to reduce any unnecessary hindrance along the way towards their place of interest.
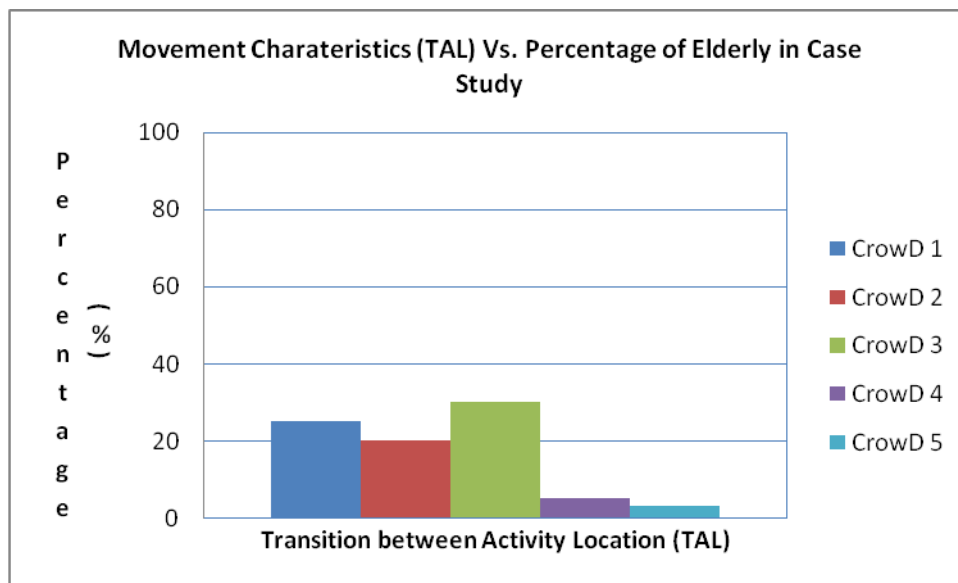
Figure 7.22   Graph of Transition between Activity Location Versus CrowD Percentage of the Elderly in the Case Study.

(c) The third movement characteristic, *Aimless Activity* (AA) is shown in Figure 7.23. From the graph, it seems that the elderly are seen wandering aimlessly in the bus station without any particular sense of direction in which it may be known or not what they will do next. It shows that they are at 40% on CrowD 4 and 5. It can be concluded that most elderly are somewhat unpredictable in their aimless activity movement pattern
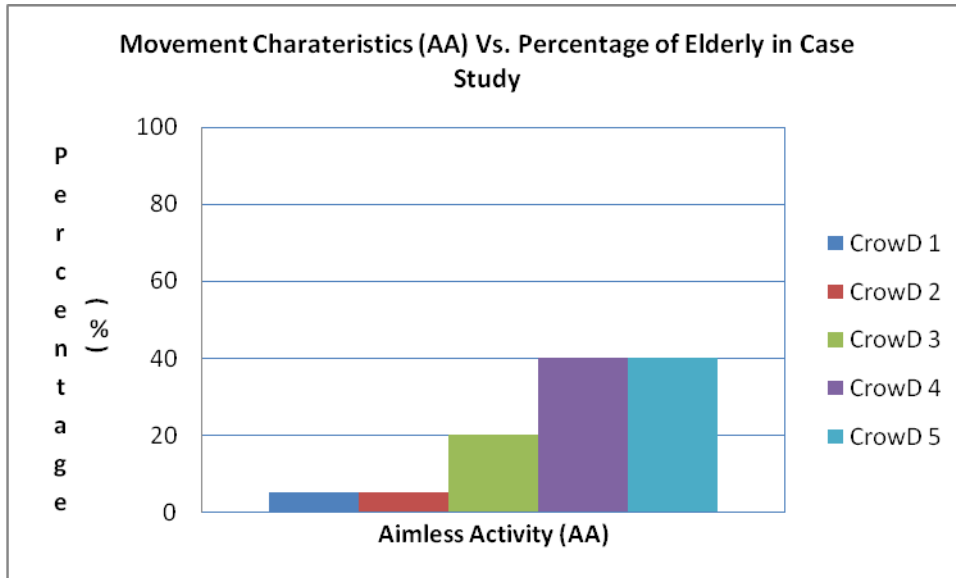
Figure 7.23   Graph of Aimless Activity Versus CrowD Percentage of the Elderly in the Case Study.

(d) Only 20% of the elderly are involved in *Interrupted Purposeful Transition* (IPT) for CrowD 2 (Figure 7.24). The reason is that they actually planned their route beforehand so as not to meet with any unpredicted collisions along the way where this action is 75% predictable.
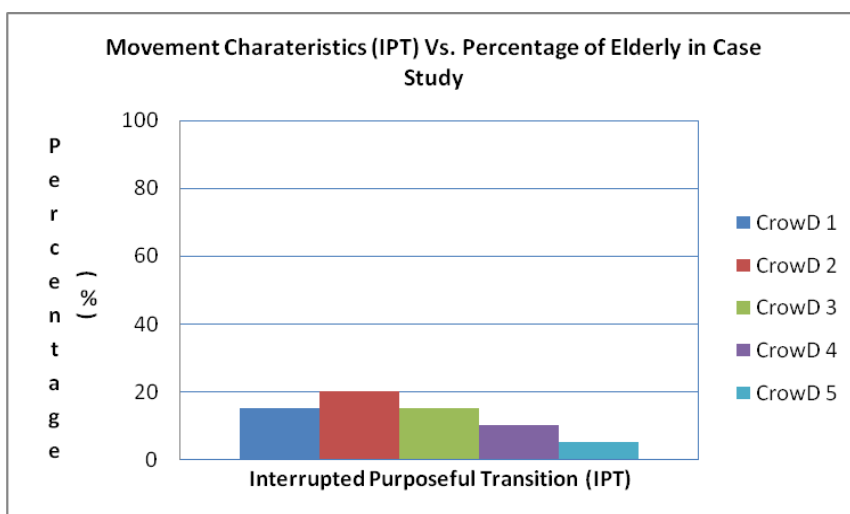
Figure 7.24   Graph of Interrupted Purposeful Transition Versus CrowD Percentage of the Elderly in the Case Study.

(e) The next feature is the *Prompt Through Transition* (PTT) characteristic for the elderly in the simulation (Figure 7.25). Under CrowD 4, the percentage of entities is at 30%. This is where the elderly try to avoid a large crowd while another 25% of the elderly are easily unpredictable even though they are involved in a large crowd. For this group, it has shown that those who need to move faster to a new destination can be seen to be very predictable in their movement through the crowd.
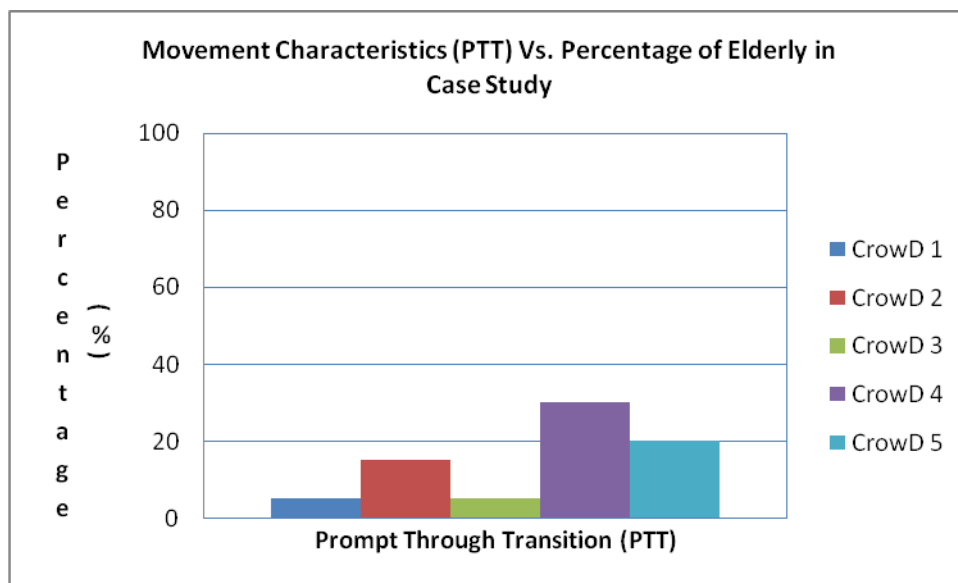
Figure 7.25   **Graph of *Prompt Through Transition* Versus CrowD Percentage of the Elderly in the Case Study.**

7.5.2   Case Study for the Disabled

The second set of graphs involves the movement characteristics versus the percentage of the disabled in the case study. The situation is similar to the elderly case study that focussed on the

movement characteristics of the elderly. The number of entities involved is also capped at 100 entities.

a) In the first graph (Figure 7.26), the occurrence of the PM scenario is analysed. This phenomenon occurs at the highest level in the activity of disabled entities in the CrowD 1 category of entities 70% of the total number. This high percentage accounts for a large number of entities moving in the PM mode having planned their movement early to avoid accidents. The rest of the CrowD factors reduce gradually towards a minimal 10% in CrowD 5.
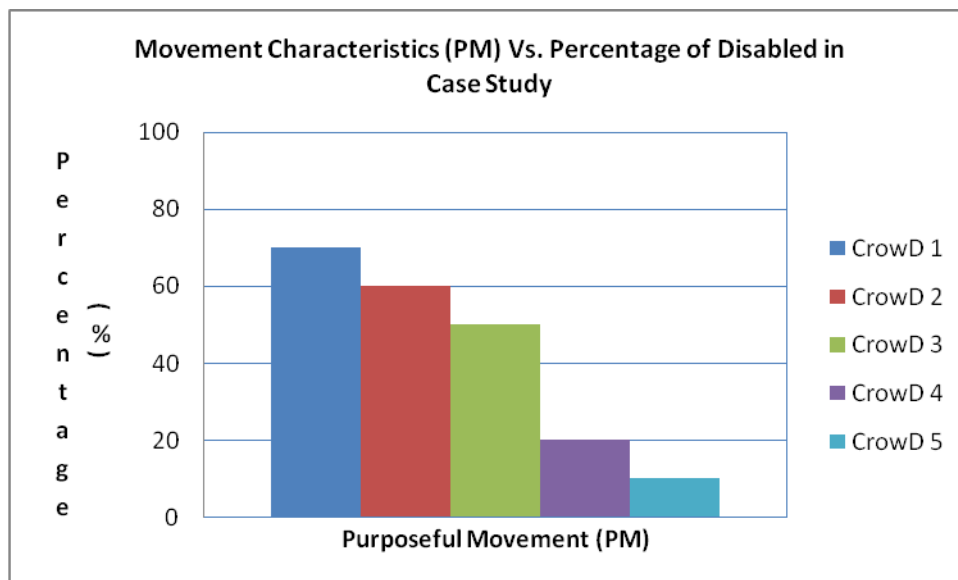
Figure 7.26   Graph of Purposeful Movement Versus CrowD Percentage of the Disabled in the

Case Study.

In order not to be involved in any untoward incidents, the disabled entities must plan their route and their movement to make them more predictable from one point of interest to another.

(b) The next category involves the *Transition between Activity Location* (TAL) activities. For this category (Figure 7.27), CrowD 1 and 5 are more attractive for the entities at 20% of the total

percentage. For this category, the entities are either predictable or otherwise in their crowd involvement. This phenomenon occurs due to the nature of entities that sometimes are predictable and other times unpredictable when moving from one point of interest to another that are not available in the simulation window. Any problems involving difficulty travelling in such enclosed spaces during peak hours or during any time apart from the former are determined using the simulation software (*Human Intelligent Movement software*, HIMs). The application of HIMs enables the user to forecast the best design for a particular building or public space.
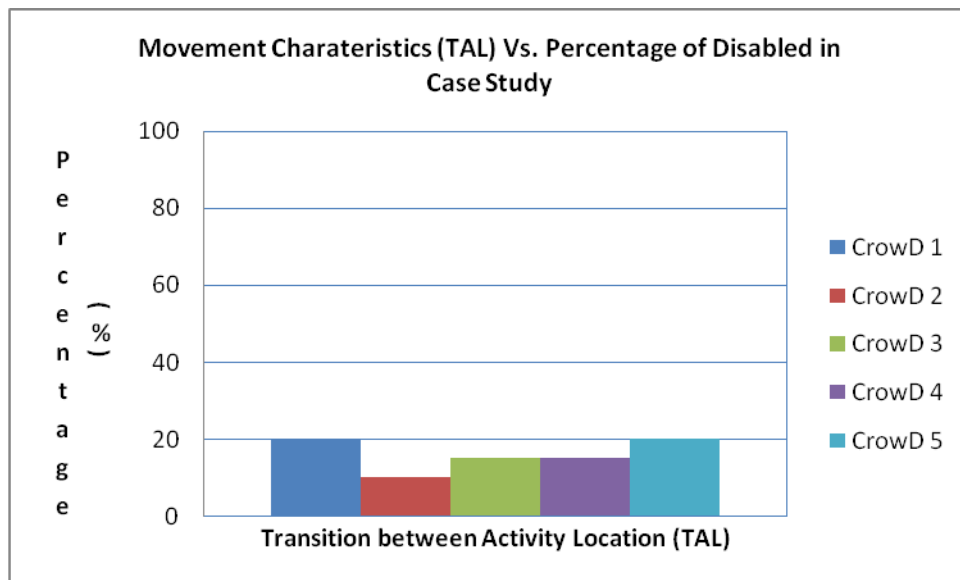
Figure 7.27   **Graph of Transit*ion between Activity Location Versus* CrowD Percentage of the Disabled in the Case Study.**

(c)   This section covers Aimless Activity (AA) that accounts for the entities that are free to move in the simulated space without having to think where their destinations are. Notice in Figure 7.28 that the percentage is very low for levels in the Crowd Dynamics factor because the disabled are those that plan their journey carefully. The graph shows an absence of the disabled

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pursuing aimless activities in a public space. All of the Crowd Dynamics factors show a very low percentage of involvement in the AA characteristics which means that the disabled stick to their walking plan of travelling on preselected routes and between points of interest in order to avoid accidents that may happen to them if no proper planning were in place.
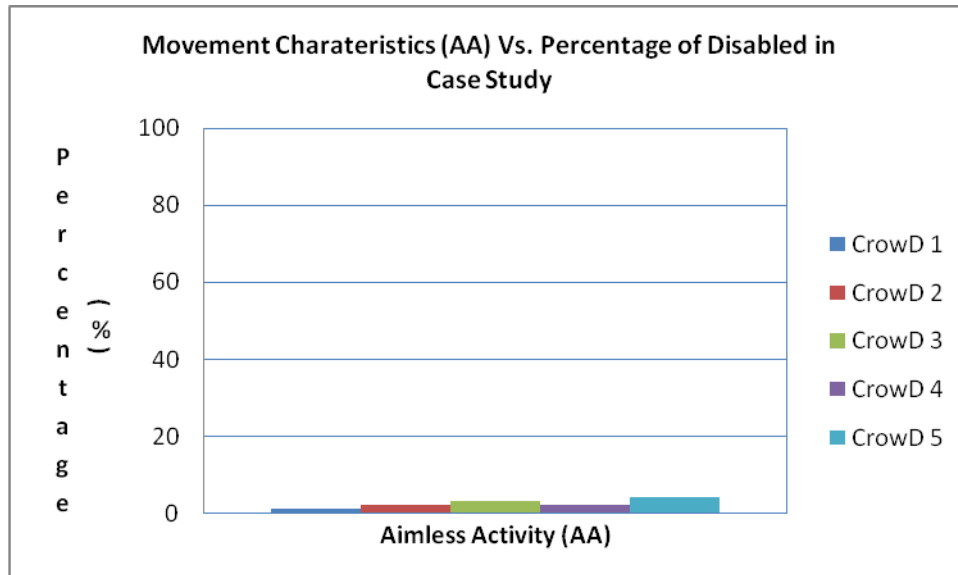
Figure 7.28 **Graph of Aimless Activity Versus CrowD Percentage of the Disabled in the Case Study.**

(d) This section covers the IPT section involving the disabled entities. In Figure 7.29, CrowD 2 and 4 shows a similar percentage of 20% which means that the elderly entities can sometimes be more predicable (75%) at most times or otherwise at 25% predictable. In CrowD 2, a percentage of 20% means that the disabled are predictable in determining their walking plan when they are interrupted momentarily during their walking activity. A high occurrence for CrowD 4 level means that there is a possibility that this particular scene happened at a busy time when the volume of the crowd is large and the personal space is not practised here.

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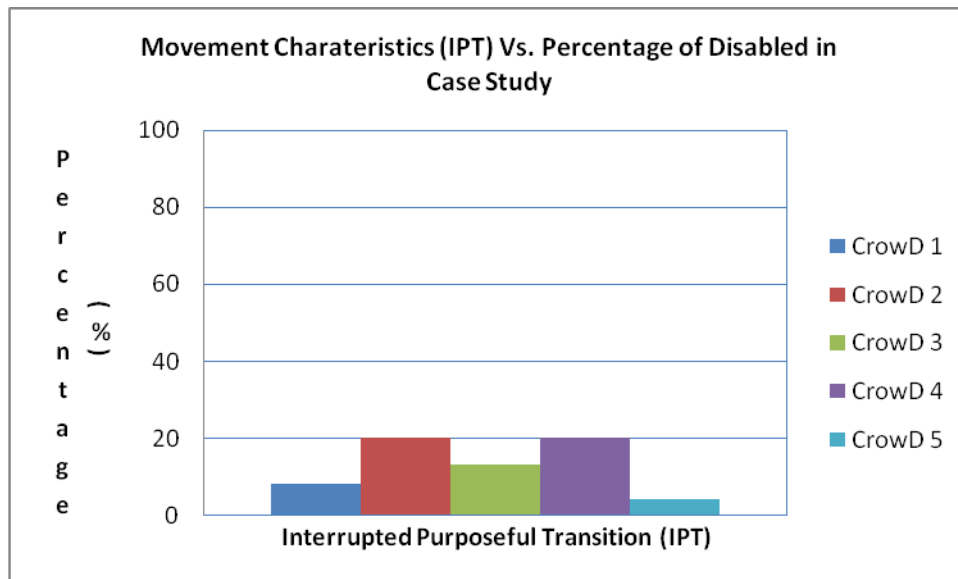
Figure 7.29 **Graph of Interrupted Purposeful Transition Versus CrowD Percentage of the**

Disabled in the Case Study.

(e) This is the last characteristic that involves the disabled in the simulation study, that is, the PTT characteristic. In Figure 7.30, looking at CrowD 1 level of the disabled in the PTT where the percentage is only 1%. This low count means that those disabled entities are actually passing through without any hassle where only a very small number is involved. A gradual increase until 65% at CrowD 5 shows that the disabled normally practised the walking characteristics of PTT that are more unpredictable in nature. This is where the entities are not following any walking pattern and their movement is purely based on the instinct to move.
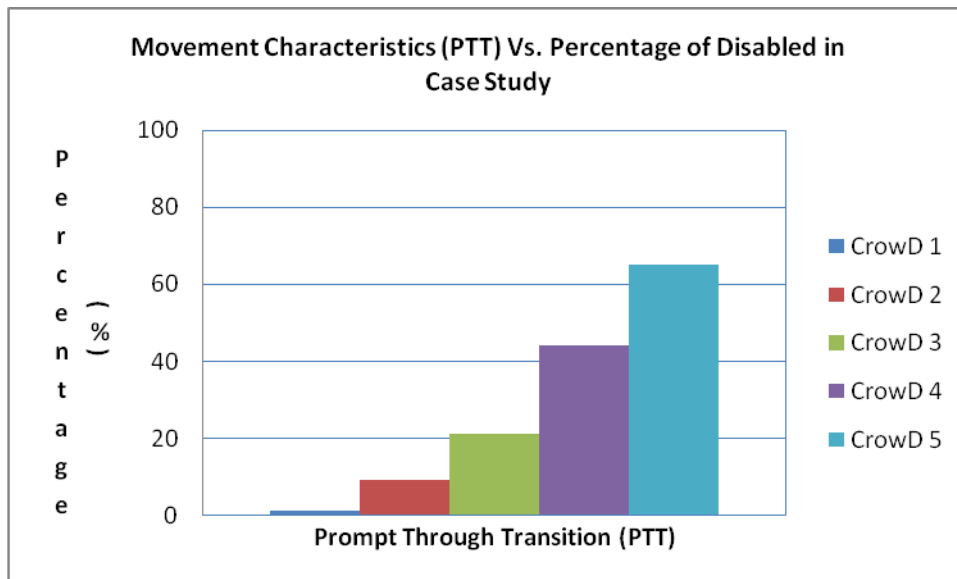
Figure 7.30   Graph of Prompt Through Transition Versus CrowD Percentage of the Disabled in the Case Study.

For both the elderly and disabled, it can be concluded that for the floor design based on BBS Design-5 has shown that their movement can be simulated in a public space especially in a transport interchange hub such as a bus station. The movement characteristics and predictability factor in CrowD enables the user to design the best floor layouts that are suitable in crowd control and user friendly towards the elderly and disabled.

7.6   Summary

This case study has successfully shown that the simulator is able to simulate the two main focus groups comprising the elderly and disabled adults. The design of a public space can be a vital point in determining whether the building or space follows the criteria that support a sustainable urban

environment. This is particularly useful when a public space is required that can accommodate the two groups in a user-friendly manner without having any prejudice towards them when the design aspect of the space is concerned.

Chapter 8   Discussion and Conclusion

8.1   Chapter Overview

A brief discussion of the research is presented in this chapter. The research is summarised and the new findings described. Conclusions are drawn confirming the contributions made to knowledge. Further research opportunities originating from this work are also suggested.

8.2   Discussion

Design for a Sustainable Urban Environment was the starting point for this research. This is interpreted as a 'Design for All' approach to the design of public spaces such that they are inclusive or suitable for a very wide range of potential users. The elderly and the disabled are the most likely to be excluded and so they form the focus for this work on the basis that successful design for the elderly and disabled is likely to also lead to good designs for the broader population and thus meet the objectives of Design for All. Indeed, the elderly and disabled can form a majority of those who are present at any time in a public place when the able-bodied adults, teenagers and children are at work, school or kindergarten and this was observed in the video footage of the walkways in Loughborough town centre.

A methodology based on the commercially available Dark Basic Professional gaming software development system was created based on the information derived from the video observation and initially tested to ensure that it produced simulations that were recognisably similar to situations observed in the shopping mall studies. A design case study based on the provision of barriers to assist passenger control and flow in a bus station was then conducted to show how the approach has value in assisting in producing design solutions.

8.3 Conclusion

The three objectives of the research were:

d) To study and identify various human behaviours relevant to the area of study. The area of study is focused on the walking characteristics of the elderly and disabled in crowded public spaces and is closely related to research into sustainable urban environments.

e) To develop a prototype simulation program for the modelling of human walking behaviours and characteristics of the elderly and disabled.

f) To verify and validate the effectiveness of the human behaviour models for the elderly and disabled through a relevant case study.

8.3.1 Objectives

From Chapter 1, the first objective was:

To study and identify various human behaviours relevant to the area of study. The area of study is focused on the walking characteristics of the elderly and disabled in crowded public spaces and is closely related to research into sustainable urban environments.

Understanding of aspects of human walking behaviour was gained by studying the appropriate literature, but very considerable effort was expended in acquiring detailed and practical information through a very extensive video observation of more than 17,000 subjects. The analysis of this data revealed that there were important differences in behaviour with regard to the elderly, the disabled, adults, teenagers, children and toddlers. No gender effect was recorded.

Preliminary analysis identified that these different types of subjects had different personal spaces and avoidance distances and that these could vary according to the crowd dynamics. Different characteristics or behaviours were observed in the shopping mall test area including Passing Through, Window Shopping, Going to Store, Store-to-Store, U-Turn and U-Turn and Window Shopping. It was possible to generalise these into a set of five characteristics or behaviours that were used in the case study. These five characteristics were:

1. Purposeful Movement (PM). This is a movement from one activity location to another with prior knowledge of the route and absolute knowledge of what lies ahead at the final destination. An example would be a movement from the entrance of a bus station to the ticket office.

2. Transition Between Activity Location (TAL). This is a *walk-pause-walk* motion which could for example be used when window shopping from store to store.

3. Aimless Activity (AA). This is movement without a specific aim or regular pattern in terms of speed or direction. An example could be a cleaner collecting litter in a bus station.

4. Interrupted Purposeful Transition (IPT). This is a Purposeful Movement that is interrupted for some reason such as meeting an old friend.

5. Prompt Through Transition (PTT). This is a Purposeful Movement but the purpose lies outside the area of interest. For example a shopping mall might be used simply as a thoroughfare.

It was further found that these behaviours were modified according to the crowd density or dynamics. For example at crowded times the elderly and disabled were very much more likely to adopt Purposeful Movement as a defensive action to minimise danger of collision. Conversely, the elderly and disabled showed little interest in Aimless Activity in crowded situations.

The second objective was *to develop a prototype simulation program for the modelling of human walking behaviours and characteristics of the elderly and disabled.*

The computer simulation program (Human Intelligent Movement system – HIMs) has been developed using the commercially available Dark Basic Professional gaming software development tool. The developed system is able to simulate the walking characteristics of the elderly and disabled. Their behaviour is controlled by the presence of the personal space, avoidance distance and walking behaviours in the form of Purposeful Movement characteristics (PM), Transition between Activity Location characteristics (TAL), Aimless Activity characteristics (AA), Interrupted Purposeful Transition characteristics (IPT) and Prompt Through Transition characteristics (PTT). The purpose of having these five characteristics is their use as an important tool to determine which movement pattern the elderly and disabled follow.

It can be concluded that the combination of personal space and walking behaviours together with crowd dynamics is the key to success in simulating the movement behaviours for the elderly and disabled.

The third objective was *to verify and validate the effectiveness of the human behaviour models for the elderly and disabled through a relevant case study.*

The case study involved a typical bus station used by the five different human entities (the elderly, disabled, normal adults, teenagers and children). In this case study, the introduction of five different walking characteristics of human entities is a vital addition to the earlier methods that relied simply on personal space. For the case study, there is an absence of observation work as it was not possible to take any videos in public transport stations due to security and privacy reasons. This did not hamper the research work as the author has made use of the simulator as a standalone research tool.

The case study explored a range of design scenarios where the introduction of simple barriers could be shown to influence the movement patterns of the passengers in movement for example from an entrance to a ticket office. Security issues prevented the practical evaluation of these designs as it was not possible to experiment with different barriers and video the resulting movement of passengers. However, some confidence can be placed in the simulation based on its reference back to the original shopping mall study.

It is believed that the case study gives some credibility to the idea of using this methodology to contribute to design for a sustainable urban environment by incorporating human behaviour in the

future designs of public spaces and buildings such as public transport hubs and shopping complexes. In particular, it is hoped that designers and architects will gain a better understanding of suitably designed buildings or structures that meet the needs of the elderly and disabled.

8.3.2 Contribution

The contributions made by this research can be summarised as:

1. An understanding that Personal Space alone as used by many researchers is not a good basis for simulation as it is not capable of generating the behaviours observed in the real world.

2. A recognition that all humans in a simulation are not going to behave in the same manner. In particular different behaviours can be observed for the elderly, the disabled, adults, teenagers, children and toddlers.

3. The very large observational study has resulted in the identification of a number of walking behaviours including Purposeful Movement, Transition between Activity Location, Aimless Activity, Interrupted Purposeful Transition and Prompt Through Transition.

4. Crowd Dynamics (density) has a profound influence on walking behaviour in that different types of subjects (elderly, disabled, etc) will change their walking behaviours (Purposeful Movement, etc) as crowd density changes. Personal Space and Avoidance Distance make a useful contribution in simulating sparsely occupied areas but become increasingly inappropriate as crowd density increases.

5. It has been shown that the elderly and disabled do behave differently from their able-bodied and young counterparts and need due consideration in the design of public spaces.

6. The use of gaming software for this kind of simulation has proved to be valuable. It is particularly appropriate where there are a large number of independent entities acting within the same space and influencing the behaviour of others.

7. The case studies have indicated where benefit might in the future be gained in using simulation as an aid to designing public spaces.

8. The overall contribution made by this research is the development of a methodology for incorporating the walking behaviour of human beings especially for the elderly and disabled. This has potentially increased the consideration of the two categories into designs of public spaces such as bus stations and shopping malls. This has provided a new perspective for buildings that can adapt and adopt sustainable urban environment (SUE) concepts.

8.4   Future Research

Human behaviour modelling is the modelling of certain human behaviours that can be used by any design regardless of the age and abilities of the human entities involved. The disabilities considered included people with limited strength and physical disability. Future research may include those with visual impairment and severe physical disability that limits their movements. Since this research focuses on those who have physical abilities/disabilities, new avenues accommodating a wider range of entities with other types of disabilities could be worth exploring and investigating in future research.

The design of public spaces that accommodate people with all types of abilities or disabilities needs a very high commitment and researchers, designers and architects should fully understand all types of disability and how the designs of public spaces can be developed to meet the needs of all users. Further extensive surveys on human behaviours should be carried out to gain a better understanding of the subject matter that relates to sustainable urban environment. From then onwards, new methods will arise from the surveys that will accommodate users with specific disabilities rather than the general perception of disability as shown in this research work.

At the moment, the research work has concentrated on a general predetermined public space like a shopping mall or a bus station. Additional features that could be added like entities carrying shopping bags, travelling in a group, pushing a wheelchair or a baby's pram and others are not included in this research. An example could be an elderly person pushing another's wheelchair as the latter may be oversized and has a heavier weight to push. Another feature can be introducing new mathematical functions that can predict the weight of a disabled person, which can influence the speed of the wheelchair in which he is travelling.

In common with most previous research the simulation is two-dimensional. i.e. it is aimed at the very common situation of single level transport situations such as often found in railway stations. However, there is also inevitably a three-dimensional element in most situations be it using subways to get to train platforms or accessing the shops on the higher levels of a shopping centre. This clearly has significant design implications caused for example by crowding at the entrance to lifts or queuing for elevators, but is also likely to have very significant effects on the behaviour of the elderly and disabled who are those that are typically most inconvenienced.

Further research can enhance the design of new public spaces with respect to the involvement of people in a sustainable urban environment by optimising new research options as described above.

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Appendices

Appendix 1 (Simulation Results for the Normal Adult, Teenager and Children & Toddlers)

Movement Characteristics (AA) Vs. Percentage of Normal Adult in Case Study

Movement Characteristics (IPT) Vs. Percentage of Normal Adult in Case Study

Movement Characteristics (PTT) Vs. Percentage of Normal Adult in Case Study

Movement Characteristics (PM) Vs. Percentage of Teenager in Case Study

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Movement Characteristics (TAL) Vs. Percentage of Teenager in Case Study

Movement Characteristics (AA) Vs. Percentage of Teenager in Case Study

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Movement Characteristics (IPT) Vs. Percentage of Teenager in Case Study

Movement Characteristics (PTT) Vs. Percentage of Teenager in Case Study

Movement Characteristics (PM) Vs. Percentage of Children & Toddler in Case Study

Movement Characteristics (TAL) Vs. Percentage of Children & Toddler in Case Study

Movement Characteristics (AA) Vs. Percentage of Children & Toddler in Case Study

Movement Characteristics (IPT) Vs. Percentage of Children & Toddler in Case Study

Movement Characteristics (PTT) Vs. Percentage of Children & Toddler in Case Study

A – 1: Flow chart for simulation

menu

```
                    ( A )
                      │
                      ▼
              ◇ DEFAULT =1 ◇──YES──▶ ▱ RUNTIME = 1800 ▱
                      │                        │
                      │                        ▼
                      │              ▱ INPUT - ENTITIES ▱ ◀────────NO────────┐
                      │                        │                             │
                      NO                       ▼                             │
                      │              ◇ ENTITIES =0 ◇──YES──▶ ◇ LOOP = 3 TIMES ◇
                      │                        │                   │
                      │                        NO                  YES
                      │                        ▼                   ▼
                      │              ┌──────────────────┐  ┌──────────────────┐
                      │              │ MAKESURE THE     │  │ ENTITIES =       │
                      │              │ AMOUNT ENTER     │  │ RANDOM (99)      │
                      │              │ POSITIVE         │  └──────────────────┘
                      │              │ & NOT MORE THAN  │            │
                      │              │ 99               │            │
                      │              └──────────────────┘            │
                      │                        │                     │
                      │                        ▼                     │
                      │              ┌──────────────────┐            │
                      │              │ STORE THE        │            │
                      │              │ ENTITIES TO      │            │
                      │              │ THE MEMORY       │            │
                      │              │ BANK             │            │
                      │              └──────────────────┘            │
                      │                        │                     │
                      ▼                        ▼                     │
                    ( ◯ )◀──────────────────( ◯ )◀──────────────────┘
                      │
                      ▼
              ◇ DEFAULT =0 ◇──YES──▶ ▱ INPUT - TIME PERIOD ▱ ◀──┐
                      │                        │                 │
                      │                        ▼                YES
                      │              ◇ PERIOD <> 1 & <>2 ◇───────┘
                      NO                       │
                      │                        NO
                      │                        ▼
                      │              ▱ INPUT - RUNTIME ▱ ◀────────NO────────┐
                      │                        │                            │
                      │                        ▼                            │
                      │              ◇ RUNTIME < 60 ◇──YES──▶ ◇ LOOP = 3 TIMES ◇
                      │                        │                   │
                      │                        NO                  YES
                      │                        │                   ▼
                      │                        │          ┌──────────────────┐
                      │                        ▼          │ RUNTIME = 1800   │
                      │                      ( ◯ )◀───────└──────────────────┘
                      │                        │
                      │                        ▼
                      │              ┌──────────────────┐
                      │              │ STORE THE        │
                      │              │ RUNTIME TO       │
                      │              │ THE MEMORY       │
                      │              │ BANK             │
                      │              └──────────────────┘
                      ▼                        ▼
                    ( B )                    ( C )
```

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```
                          ┌─────┐
                          │  C  │
                          └──┬──┘
                             │
                             ▼
                        ◇─────────◇                    ╱──────────╱
                       ╱  PERIOD =1 ╲──YES──▶        ╱  INPUT -  ╱◀──NO──┐
                        ╲           ╱                ╱ ENTITIES (1-30)╱       │
                          ◇───┬───◇                  ╱──────┬───╱           │
                             │                              │                │
                            NO                              ▼                │
                             │                          ◇─────────◇          │
                             │                         ╱ ENTITIES =0╲──YES──▶◇ LOOP = 3 TIMES ◇
                             │                          ◇───┬───◇
                             │                             │                │
                             │                            NO                ▼
                             │                             ▼          ┌──────────────┐
                             │                    ┌──────────────┐    │  ENTITIES =  │
                             │                    │ MAKESURE THE │    │  RANDOM (30) │
                             │                    │ AMOUNT ENTER │    └──────┬───────┘
                             │                    │   POSITIVE   │           │
                             │                    │ & NOT MORE THAN│         │
                             │                    │      30      │           │
                             │                    └──────┬───────┘           │
                             │                           │                   │
                             │                           ▼                   │
                             │                    ┌──────────────┐           │
                             │                    │  STORE THE   │           │
                             │                    │  ENTITIES TO │           │
                             │                    │  THE MEMORY  │           │
                             │                    │     BANK     │           │
                             │                    └──────┬───────┘           │
                             ▼                           ▼                   │
                           (○)◀───────────────────────(○)◀──────────────────┘
                             │
                             ▼
                    ┌──────────────┐
                    │    THUS      │
                    │  PERIOD =2   │
                    └──────┬───────┘
                           │
                           ▼
                    ╱──────────────╱
                   ╱   INPUT -     ╱◀──NO──┐
                  ╱  ENTITIES (31-99)╱      │
                   ╱──────┬────────╱        │
                          │                 │
                          ▼                 │
                     ◇─────────◇            │
                    ╱ ENTITIES <31╲──YES──▶◇ LOOP = 3 TIMES ◇
                     ◇───┬───◇
                        │                    │
                       NO                    ▼
                        ▼             ┌──────────────┐
                 ┌──────────────┐     │  ENTITIES = 30 + │
                 │ MAKESURE THE │     │  RANDOM (69)  │
                 │ AMOUNT ENTER │     └──────┬───────┘
                 │   POSITIVE   │            │
                 │ & NOT MORE THAN│          │
                 │      99      │            │
                 └──────┬───────┘            │
                        │                    │
                        ▼                    │
                 ┌──────────────┐            │
                 │  STORE THE   │            │
                 │  ENTITIES TO │            │
                 │  THE MEMORY  │            │
                 │     BANK     │            │
                 └──────┬───────┘            │
                        ▼                    │
                      ┌─────┐                │
                      │  D  │◀───────────────┘
                      └─────┘
```

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```
        ( B )                    ( D )                                          ┌─────────────────┐
          │                        │                                            │  CATEGORIES     │
          │                        │                                            │  • CHIILDREN    │
          ▼                        ▼                                            │  • TEENAGER     │
         ( )◄──NO──◄  ENTERED AMOUNT <  ────YES───►                             │  • ADULT        │
          │            ENTITIES                                                 │  • ELDERLY      │
          ▼                                                                     │  • DISABLED     │
    ┌──────────────┐                                                           └─────────────────┘
    │ WARN THE     │                                                                   │
    │ USER TO BACK │                                                                   ▼
    │ UP THE CSV   │                                                           ┌─────────────────┐
    │ FILE         │                                                           │ INPUT -         │
    └──────────────┘                                                           │ AMOUNT OF       │
          │                                                                    │ EACH            │
          ▼                                                                    │ CATEGORIES      │
    ┌──────────────┐                                                           └─────────────────┘
    │ COUNT DOWN   │                                                                   │
    │ THE TIME     │                                                                   ▼
    │ BEFORE       │                                                           ┌─────────────────┐
    │ CONTINUOUS   │                                                           │ MAKESURE THE    │
    └──────────────┘                                                           │ AMOUNT ENTER    │
          │                          ┌──────────────┐                         │ POSITIVE        │
          ▼                          │ PAUSE THE    │                         │ & NOT MORE THAN │
     PRESSED SPACE ──YES──►          │ COUNT DOWN   │                         │ ENTITIES        │
       BAR                           └──────────────┘                         └─────────────────┘
          │                                 │                                         │
          NO                                ▼                        NO               ▼
          ▼                          PRESSED ANY KEY ────────────────►        ┌─────────────────┐
         ( )◄──────YES───◄                                                    │ STORE THE AMOUNT│
          │                                                                   │ OF EACH         │
          ▼                                                                   │ CATEGORIES INTO │
     WORLD =1 ───────YES──────►  ┌──────────────┐                             │ MEMORY          │
          │                      │ EXECUTE FILE │                             └─────────────────┘
          NO                     │ ESS.EXE      │
          ▼                      └──────────────┘
     WORLD =2 ──YES──►  ┌──────────────┐     │
          │             │ EXECUTE FILE │     ▼
          NO            │ SMS.EXE      │    ( )
          ▼             └──────────────┘     │
    ┌──────────────┐          │              ▼
    │ THUS WORLD =3│────────► ┌──────────────┐
    └──────────────┘          │ EXECUTE FILE │    ( )
                              │ BBS.EXE      │     │
                              └──────────────┘     ▼
    ┌──────────────┐                        ┌──────────────┐
    │ THANK YOU FOR│◄───────────────────────│ WAIT AFTER   │
    │ USING THE    │                        │ EXECUTE FILE │
    │ SIMULATION   │                        │ CLOSE        │
    └──────────────┘                        └──────────────┘
          │
          ▼
    ┌──────────────┐
    │ WAIT FOR 1.5S│
    └──────────────┘
          │
          ▼
      (  END  )
```

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A – 2: Flow chart for ESS

```
          ┌──────────┐
          │  START   │
          └────┬─────┘
               │
      ┌────────────────┐
      │ READ THE DATA  │
      │  FROM THE      │
      │ MEMORY BANK    │
      └────────┬───────┘
               │
          ◇ ENTITIES = 0 ◇──YES──▷ ╱ REQUEST THE USER ENTER THE ENTITIES AT THE MENU ╱ ──────▷ ( G )
               │
              NO
               │
      • SETTING THE CAMERA
      • SETTING THE BACKGROUND AND BOUNDARIES
      • CREATE "ANALYSIS OF THE EMPTY SPACE SIMULATOR.CSV"
      • OPEN CONSOLE
               │
      ┌────────────────┐
      │    CREATE      │
      │   ENTITIES     │
      └────────┬───────┘
               │
     ◇ DEFAULT = 0 ◇──YES──▷ ◇ CHILDREN <>0 ◇──YES──▷ ◇ FINISH CREATE CHILDREN? ◇──NO──▷ CREATEENTITIES CHILDREN
               │                    │                          │
               │                   NO                         YES
               │                    │
               │            ◇ TEENAGER <>0 ◇──YES──▷ ◇ FINISH CREATE TEENAGER? ◇──NO──▷ CREATEENTITIES TEENAGER
               │                    │                          │
               │                   NO                         YES
               │                    │
               │            ◇ ADULT <>0 ◇──YES──▷ ◇ FINISH CREATE ADULT? ◇──NO──▷ CREATEENTITIES ADULT
               │                    │                          │
               │                   NO                         YES
             ( B )                ( A )
```

```
        B                    A

                    ELDERLY <>0 ──YES──▶ FINISH CREATE ──NO──▶ CREATEENTITIES
   CREATEENT                               ELDERLY?                ELDERLY
     ITIES                      │
                               NO              YES
                                │
                                ▼
                                ○◀─────────────────────────────┘

                    DISABLED <>0 ──YES──▶ FINISH CREATE ──NO──▶ CREATEENTITIES
                               │          DISABLED?                 DISABLED
                              NO              YES
                               │
                               ▼
                               ○◀──────────────────────────────┘

                    SET THE CONDITION FOR ALL THE
                    ENTITIES
                    •   HIDE OBJECT
                    •   AI SET ENTITY VIEW ARC I,90,170
                    •   STARTTIME=0
                    •   ENDTIME=0
                    •   TRAVELTIME=0

        └──────▶ ○ ◀──────────┘

        SET THE STARTING
        POSITION OF ALL THE
        ENTITIES

        STARTPOINTF

        LOOP THE EXE
        UNTIL THE USER  ◀───────────────────────────  F
        QUIT

        PRESS '1' ──YES──▶ PMODE=0 ──YES──▶ AI DEBUG HIDE
                                                PATHS
                              │
                             NO
                              │
                              ▼
                     AI DEBUG SHOW
                        PATHS

          C ◀──────        ○ ◀──────────────────┘
```

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```
         ( C )
           │
           ▼
    ◇ PRESS '2' ◇──YES──▶ ◇ AMODE=0 ◇──YES──▶ ┌─────────────────┐
           │                    │               │ AI DEBUG HIDE   │
           │                    NO              │ AVOIDANCE       │
          NO                    │               │ ANGLES          │
           │                    ▼               └─────────────────┘
           │            ┌─────────────────┐              │
           │            │ AI DEBUG SHOW   │              │
           │            │ AVOIDANCE       │              │
           │            │ ANGLES          │              │
           │            └─────────────────┘              │
           ▼                    │                         │
          ( )◀──────────────── ( )◀──────────────────────┘
           │
           ▼
    ◇ PRESS '3' ◇──YES──▶ ◇ VMODE=0 ◇──YES──▶ ┌─────────────────┐
           │                    │               │ AI DEBUG HIDE   │
           │                    NO              │ VIEW ARCS       │
          NO                    │               └─────────────────┘
           │                    ▼                         │
           │            ┌─────────────────┐              │
           │            │ AI DEBUG SHOW   │              │
           │            │ VIEW ARCS       │              │
           │            └─────────────────┘              │
           ▼                    │                         │
          ( )◀──────────────── ( )◀──────────────────────┘
           │
           ▼
    ◇ PRESS 'F1' ◇──YES──▶ ◇ F1PRESSED=1 ◇──YES──▶ ╱─────────────────────────────╱
           │                       │                │ SHOW THE GUIDE TO USE THE   │
           │                       NO               │ SIMULATION                  │
          NO                       │                │ • [1] TOGGLE ENTITY PATH"   │
           │                       ▼                │ • [2] TOGGLE AVOIDANCE ANGLES"│
           │              ╱─────────────────╱       │ • [3] TOGGLE VIEW ARCS"     │
           │              │ PRESS F1 FOR SOME│      │ • FPS:                      │
           │              │ GUIDE            │      ╱─────────────────────────────╱
           │              ╱─────────────────╱                  │
           ▼                       │                           │
          (C)◀──────────────────── ( )◀─────────────────────────┘
           │
           ▼
    ◇ ENTITIES ON THE ◇──────YES──────▶ ┌─────────────────┐
    ◇ STAGE          ◇                   │ SHOW ENTITIES   │
           │                             └─────────────────┘
          NO                                      │
           ▼                                      │
    ┌─────────────────┐                          │
    │ HIDE ENTITIES   │──────────▶ ( )◀──────────┘
    └─────────────────┘            │
                                   ▼
                          ┌─────────────────┐
                          │ CALCULATE THE   │
                          │ ENTITIES ON     │
                          │ THE STAGES      │
                          └─────────────────┘
                                   │
                                   ▼
                                  ( D )
```

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```
        ( E )              ( F )              ( G )
          |                  ^                  |
          v                  |                  |
   / SHOW THE    /           |                  |
  /  CLOCK ON   /            |                  |
 / BOTTOM RIGHT/             |                  |
          |                  |                  |
          v                  |                  |
  +--------------+           |                  |
  | SET TIMER FOR|           |                  |
  |  20 MINUTE   |           |                  |
  +--------------+           |                  |
          |                  |                  |
          v                  |                  v
      /       \              |                ( O )
     /  TIMER  \    YES       ------------------>
    < =>20 MIN  >----------------------->
     \         /              
      \       /               
          |
          | NO
          v
   / SHOW THE    /
  /  TIMER ABOVE/
 /    CLOCK    /
          |
          v
  / SHOW THE AMOUNT OF /
 / ENTITIES ON STAGES &/
/   TOTAL ENTITIES    /
          |
          v
   / SHOW THE        /
  / REPRESENTATIVE  /
 /  OF THE COLOR   /
          |
          v
      /       \
     / CLOSING \      NO
    < THE       >---------------->
     \SIMULATION/
      \       /
          |
          | YES
          v
    (  END  ) <-------------------------------------
```

```
                    ┌─────────────────┐
                    │  CREATEENTITIES │
                    └────────┬────────┘
                             │
                    ┌────────┴────────┐
                    │  CATEGORIES =   │
                    │     RND(7)      │
                    └────────┬────────┘
                             │
```

CREATEENTITIES

CATEGORIES = RND(7)

CATEGORIES = 0 —YES→ CREATE CHILDREN →
CREATE ENTITIES IN SPHERE
- SIZE 9
- COLOR YELLOW
- SPEED 16
- VIEW RANGE 18

NO

CATEGORIES = 1 —YES→ CREATE TEENAGER →
CREATE ENTITIES IN SPHERE
- SIZE 10
- COLOR PINK
- SPEED 15
- VIEW RANGE 20

NO

CATEGORIES = 2 OR 3 OR 6 OR 7 —YES→ CREATE ADULT →
CREATE ENTITIES IN SPHERE
- SIZE 12
- COLOR RED
- SPEED 13.5
- VIEW RANGE 24

NO

CATEGORIES = 4 —YES→ CREATE ELDERLY →
CREATE ENTITIES IN SPHERE
- SIZE 15
- COLOR GREEN
- SPEED 11.3
- VIEW RANGE 30

NO

CREATE DISABLED →
CREATE ENTITIES IN SPHERE
- SIZE 16
- COLOR BLUE
- SPEED 10
- VIEW RANGE 32

SET THE CONDITION FOR ALL THE ENTITIES
- HIDE OBJECT
- AI SET ENTITY VIEW ARC I,90,170
- STARTTIME=0
- ENDTIME=0
- TRAVELTIME=0

ENDFUNCTION

```
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────┐
│  CREATEENTITIE  │      │  CREATEENTITIE  │      │  CREATEENTITIE  │
│    SCHILDREN    │      │    STEENAGER    │      │     SADULT      │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
         │                        │                        │
┌────────▼────────┐      ┌────────▼────────┐      ┌────────▼────────┐
│     CREATE      │      │     CREATE      │      │                 │
│    CHILDREN     │      │    TEENAGER     │      │  CREATE ADULT   │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
         │                        │                        │
┌────────▼────────┐      ┌────────▼────────┐      ┌────────▼────────┐
│ CREATE ENTITIES │      │ CREATE ENTITIES │      │ CREATE ENTITIES │
│    IN SPHERE    │      │    IN SPHERE    │      │    IN SPHERE    │
│ • SIZE 9        │      │ • SIZE 10       │      │ • SIZE 12       │
│ • COLOR YELLOW  │      │ • COLOR PINK    │      │ • COLOR RED     │
│ • SPEED 16      │      │ • SPEED 15      │      │ • SPEED 13.5    │
│ • VIEW RANGE 18 │      │ • VIEW RANGE 20 │      │ • VIEW RANGE 24 │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
         │                        │                        │
┌────────▼────────┐      ┌────────▼────────┐      ┌────────▼────────┐
│   ENDFUNCTION   │      │   ENDFUNCTION   │      │   ENDFUNCTION   │
└─────────────────┘      └─────────────────┘      └─────────────────┘
```

```
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────┐
│  CREATEENTITIE  │      │  CREATEENTITIE  │      │   STARTPOINTF   │
│    SELDERLY     │      │    SDISABLED    │      │                 │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
         │                        │                        │
┌────────▼────────┐      ┌────────▼────────┐      ┌────────▼────────┐
│     CREATE      │      │     CREATE      │      │  STARTPOINT =   │
│     ELDERLY     │      │    DISABLED     │      │    RND(1)+1     │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
         │                        │                        │
┌────────▼────────┐      ┌────────▼────────┐               │
│ CREATE ENTITIES │      │ CREATE ENTITIES │        ◇──────▼──────◇
│    IN SPHERE    │      │    IN SPHERE    │       STARTPOINT = 1
│ • SIZE 15       │      │ • SIZE 16       │        ◇─────────────◇
│ • COLOR GREEN   │      │ • COLOR BLUE    │   NO            YES
│ • SPEED 11.3    │      │ • SPEED 10      │
│ • VIEW RANGE 30 │      │ • VIEW RANGE 32 │
└────────┬────────┘      └────────┬────────┘
         │                        │
┌────────▼────────┐      ┌────────▼────────┐
│   ENDFUNCTION   │      │   ENDFUNCTION   │
└─────────────────┘      └─────────────────┘
```

STARTPOINT = 1

YES →

┌──────────────────────────────┐
│ • ENTITIES LOCATED AT   │
│   EXIT1 (BOTTOM)   │
│   │
│ • ENTITIES GO TO EXIT2   │
│   (ABOVE)   │
└──────────────────────────────┘

NO

┌──────────────────────────────┐
│ • ENTITIES LOCATED AT   │
│   EXIT2 (ABOVE)   │
│   │
│ • ENTITIES GO TO EXIT1   │
│   (BOTTOM)   │
└──────────────────────────────┘

┌─────────────────┐
│   ENDFUNCTION   │
└─────────────────┘

A – 3: Flow chart for SMS

```
    B              A                                    FINISH CREATE              CREATEENTITIES
                                                        ELDERLY?        ──NO──▶     ELDERLY
  CREATEENT        ELDERLY <>0 ──YES──▶
    ITIES                                                     │
                       │                                     YES
                      NO                                      │
                       │        ◀────────────────────────────┘
                       ●

                       │
                       ▼
                  DISABLED <>0 ──YES──▶  FINISH CREATE    ──NO──▶  CREATEENTITIES
                                          DISABLED?                  DISABLED
                       │
                      NO                       │
                       │                      YES
                       ●    ◀──────────────────┘

                       │
                       ▼
         SET THE CONDITION FOR ALL THE
         ENTITIES
         •   HIDE OBJECT
         •   AI SET ENTITY VIEW ARC I,90,170
         •   STARTTIME=0
         •   ENDTIME=0
         •   TRAVELTIME=0

              ●
              │
              ▼
         SET THE STARTING
         POSITION OF ALL THE
         ENTITIES
              │
              ▼
         STARTPOINTF
              │
              ▼
         LOOP THE EXE                                              G
         UNTIL THE USER  ◀───────────────────────────────────────
         QUIT
              │
              ▼
         PRESS '1' ──YES──▶  PMODE=0  ──YES──▶  AI DEBUG HIDE
                                                    PATHS
              │                  │
              │                 NO
              │                  │
              │                  ▼
              │             AI DEBUG SHOW
              │                PATHS
              │                  │
              ▼                  ▼
              C    ◀─────────────●
```

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```
                        ( C )
                          │
                          ▼
        ┌─────────────┐        ┌─────────────┐        ┌──────────────┐
        │  PRESS '2'  │──YES──▶│  AMODE=0    │──YES──▶│ AI DEBUG HIDE│
        └─────────────┘        └─────────────┘        │  AVOIDANCE   │
               │                      │               │   ANGLES     │
               NO                     NO              └──────────────┘
               │                      ▼                      │
               │               ┌─────────────┐               │
               │               │ AI DEBUG SHOW│              │
               │               │  AVOIDANCE   │              │
               │               │   ANGLES     │              │
               │               └─────────────┘               │
               ▼                      │                       │
              (○)◀──────────────────( ○ )◀───────────────────┘
               │
               ▼
        ┌─────────────┐        ┌─────────────┐        ┌──────────────┐
        │  PRESS '3'  │──YES──▶│  VMODE=0    │──YES──▶│ AI DEBUG HIDE│
        └─────────────┘        └─────────────┘        │  VIEW ARCS   │
               │                      │               └──────────────┘
               NO                     NO                      │
               │                      ▼                       │
               │               ┌─────────────┐                │
               │               │ AI DEBUG SHOW│               │
               │               │  VIEW ARCS   │               │
               │               └─────────────┘                │
               ▼                      │                        │
              (○)◀──────────────────( ○ )◀────────────────────┘
               │
               ▼
        ┌─────────────┐
        │   CAMERA    │
        │  CONTROLS   │
        └─────────────┘
               │
               ▼
        ┌─────────────┐        ┌──────────────┐
        │   PRESS     │──YES──▶│ CAMERA MOVE  │
        │ 'DOWNKEY'   │        │    DOWN      │
        └─────────────┘        └──────────────┘
               │                      │
               NO                     │
               ▼                      │
              (○)◀────────────────────┘
               │
               ▼
        ┌─────────────┐        ┌──────────────┐
        │ PRESS 'UPKEY'│─YES──▶│ CAMERA MOVE  │
        └─────────────┘        │     UP       │
               │               └──────────────┘
               NO                     │
               ▼                      │
              (○)◀────────────────────┘
               │
               ▼
        ┌─────────────┐        ┌──────────────┐
        │   PRESS     │──YES──▶│ CAMERA MOVE  │
        │ 'LEFTKEY'   │        │    LEFT      │
        └─────────────┘        └──────────────┘
               │                      │
               NO                     │
               ▼                      │
              ( D )◀──────────────────┘
```

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```
        ( D )
          │
          ▼
     ╱PRESS╲      YES    ┌──────────────┐
    ╱'RIGHTKEY'╲─────────▶│ CAMERA MOVE  │
    ╲          ╱          │    RIGHT     │
     ╲        ╱           └──────────────┘
          │ NO                   │
          ▼                      │
         (○)◀────────────────────┘
          │
          ▼
     ╱ PRESS ╲     YES    ┌──────────────┐
    ╱ 'PGUP'  ╲──────────▶│   ZOOM IN    │
    ╲         ╱           └──────────────┘
          │ NO                   │
          ▼                      │
         (○)◀────────────────────┘
          │
          ▼
     ╱ PRESS ╲     YES    ┌──────────────┐
    ╱ 'PGDN'  ╲──────────▶│   ZOOM OUT   │
    ╲         ╱           └──────────────┘
          │ NO                   │
          ▼                      │
         (○)◀────────────────────┘
          │
          ▼
     ╱ PRESS ╲     YES    ┌──────────────┐
    ╱ 'HOME'  ╲──────────▶│   ALL THE    │
    ╲         ╱           │   CAMERA     │
          │ NO            │ SETTING BACK │
          │               │  TO ORIGIN   │
          │               └──────────────┘
          ▼                      │
         (○)◀────────────────────┘
          │
          ▼
     ╱ PRESS ╲   YES    ╱F1PRESSED=1╲  YES    ╱ SHOW THE GUIDE TO USE THE
    ╱ 'F1'    ╲────────▶╲           ╱────────▶  SIMULATION
    ╲         ╱          ╲         ╱           • [1] TOGGLE ENTITY PATH"
          │ NO               │ NO             • [2] TOGGLE AVOIDANCE ANGLES"
          │                  ▼                • [3] TOGGLE VIEW ARCS"
          │          ┌──────────────┐         • FPS:
          │          │PRESS F1 FOR  │         • CAMERA CONTROLS
          │          │ SOME GUIDE   │
          │          └──────────────┘
          ▼                  │
         (○)◀────────────── (○)◀─────────────────
          │
          ▼
    ╱ENTITIES ON THE╲   YES    ┌──────────────┐
    ╲    STAGE       ╲────────▶│ SHOW ENTITIES│
     ╲              ╱          └──────────────┘
          │ NO                        │
          ▼                           │
    ┌──────────────┐                  │
    │HIDE ENTITIES │──────▶(○)◀───────┘
    └──────────────┘         │
                             ▼
                    ┌──────────────┐
                    │CALCULATE THE │
                    │ ENTITIES ON  │
                    │  THE STAGES  │
                    └──────────────┘
                             │
                             ▼
                           ( E )
```

```
         ┌───┐
         │ E │
         └─┬─┘
           │
    ╱─────────────╲                                                    ┌──────────────────────┐
   ╱  ENTITIES      ╲                  ┌──────────────┐                │ RESET THE CONDITION  │
  ╱    REACH          ╲──YES─────────▶ │ STORE THE    │                │ OF THE ENTITIES      │
  ╲  DESTINATION      ╱                │ DATA TO THE  │          YES    │   • STARTTIME=0      │
   ╲                 ╱                 │ CSV FILE     │           │     │   • ENDTIME=0        │
    ╲───────────────╱                  └──────┬───────┘           │     │   • TRAVELTIME=0     │
           │                                  │                   │     └──────────┬───────────┘
           NO                                 ▼                   │                │
           │                          ┌──────────────┐     ╱───────────╲          ▼
           │                          │ SHOW THE DATA│    ╱             ╲   ┌──────────────┐
           │                          │ ON THE       │───╱  INSIDE SHOP  ╲  │ GO OUT THE   │
           ▼                          │ CONSOLE      │   ╲               ╱  │ SHOP         │
         ┌─○─┐◀─────────────────────  └──────────────┘    ╲─────────────╱  └──────┬───────┘
           │                                                     │                │
           │                                                     NO               ▼
           ▼                                                     │         ┌──────────────┐
    ╱─────────────╲       ┌──────────────┐                       ▼         │ ENDPOINT(I) =│
   ╱   ENTITIES    ╲      │ REBORN THE   │                ┌──────────────┐ │ RND(3)+1     │
  ╱    DELETED      ╲─YES▶│ ENTITIES     │                │ KILL ENTITIES│ └──────┬───────┘
   ╲               ╱      └──────┬───────┘                └──────┬───────┘        │
    ╲─────────────╱              │                               │                ▼
           │                     │                               ▼         ┌──────────────┐
           NO                    ▼                             ┌─○─┐◀────── │ ENDPOINTF    │
           │              ╱─────────────╲      ┌───────────┐               └──────────────┘
           │             ╱  DEFAULT =0   ╲─YES╱IS CHILDREN?╲─YES─▶┌──────────────┐
           │             ╲               ╱     ╲          ╱       │ CREATEENT    │
           │              ╲─────────────╱       ╲────────╱        │ ITIESCHILDR  │────┐
           │                     │                  │             │ EN           │    │
           │                     NO                 NO            └──────────────┘    │
           │                     ▼                  ▼                                 │
           │              ┌──────────────┐    ╱──────────╲        ┌──────────────┐    │
           │              │ CREATEENT    │   ╱IS TEENAGER?╲─YES──▶ │ CREATEENT    │   ┌─○─┐
           │              │ ITIES        │   ╲            ╱        │ ITIESTEENA   │──▶│   │
           │              └──────┬───────┘    ╲──────────╱        │ GER          │   └─┬─┘
           │                     │                  │             └──────────────┘     │
           │                     │                  NO                                 │
           │                     │                  ▼            ┌──────────────┐      │
           │                     │            ╱──────────╲       │ CREATEENT    │    ┌─○─┐
           │                     │           ╱ IS ADULT?  ╲─YES─▶ │ ITIESADULT   │──▶│   │
           │                     │           ╲            ╱       └──────────────┘   └─┬─┘
           │                     │            ╲──────────╱                             │
           │                     │                  │                                  │
           │                     │                  NO                                 │
           │                     │                  ▼            ┌──────────────┐      │
           │                     │            ╱──────────╲       │ CREATEENT    │    ┌─○─┐
           │                     │           ╱ IS ELDERLY ╲─YES─▶ │ ITIESELDER   │──▶│   │
           │                     │           ╲            ╱       │ LY           │   └─┬─┘
           │                     │            ╲──────────╱        └──────────────┘     │
           │                     │                  │                                  │
           │                     │                  NO                                 │
           │                     │                  ▼            ┌──────────────┐      │
           │                     │            ┌──────────────┐   │              │    ┌─○─┐
           │                     │            │ CREATEENT    │───┼──────────────┼──▶ │   │
           │                     │            │ ITIESDISABL  │   │              │    └─┬─┘
           │                     │            │ ED           │   │              │      │
           │                     │            └──────────────┘   └──────────────┘      │
           │                     │                              ┌──────────────────────────┐
           │                     │                              │ SET THE CONDITION FOR ALL│
           NO                    ▼            ┌──────────────┐   │ THE ENTITIES             │
           │                   ┌─○─┐          │ STARTPOIN    │◀──│  • HIDE OBJECT           │
           ▼                   │   │          │ TF           │   │  • AI SET ENTITY VIEW    │
         ┌───┐◀────────────────┤   │◀─────────│              │   │    ARC I,90,170          │
         │ F │                 └───┘          └──────────────┘   │  • STARTTIME=0           │
         └───┘                                                   │  • ENDTIME=0             │
                                                                 │  • TRAVELTIME=0          │
                                                                 └──────────────────────────┘
```

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```
                        CREATEENTITIES

                             │
                             ▼
                    ┌─────────────────┐
                    │  CATEGORIES =   │
                    │     RND(7)      │
                    └─────────────────┘
                             │
                             ▼
                        ◇ CATEGORIES = 0 ◇ ──YES──▶ ┌──────────┐    ┌─────────────────────────┐
                                                     │  CREATE  │    │ CREATE ENTITIES IN      │
                                                     │ CHILDREN │───▶│        SPHERE           │──▶ ○
                                                     └──────────┘    │  • SIZE 9               │
                             │                                       │  • COLOR YELLOW         │
                             NO                                      │  • SPEED 27             │
                             ▼                                       │  • VIEW RANGE 18        │
                                                                     └─────────────────────────┘
                        ◇ CATEGORIES = 1 ◇ ──YES──▶ ┌──────────┐    ┌─────────────────────────┐
                                                     │  CREATE  │    │ CREATE ENTITIES IN      │
                                                     │ TEENAGER │───▶│        SPHERE           │──▶ ○
                                                     └──────────┘    │  • SIZE 10              │
                             │                                       │  • COLOR PINK           │
                             NO                                      │  • SPEED 27             │
                             ▼                                       │  • VIEW RANGE 20        │
                                                                     └─────────────────────────┘
                   ◇ CATEGORIES = 2 OR 3 ◇ ──YES──▶ ┌──────────┐    ┌─────────────────────────┐
                   ◇   OR 6 OR 7         ◇           │  CREATE  │    │ CREATE ENTITIES IN      │
                                                     │  ADULT   │───▶│        SPHERE           │──▶ ○
                                                     └──────────┘    │  • SIZE 12              │
                             │                                       │  • COLOR RED            │
                             NO                                      │  • SPEED 25             │
                             ▼                                       │  • VIEW RANGE 24        │
                                                                     └─────────────────────────┘
                        ◇ CATEGORIES = 4 ◇ ──YES──▶ ┌──────────┐    ┌─────────────────────────┐
                                                     │  CREATE  │    │ CREATE ENTITIES IN      │
                                                     │ ELDERLY  │───▶│        SPHERE           │──▶ ○
                                                     └──────────┘    │  • SIZE 15              │
                             │                                       │  • COLOR GREEN          │
                             NO                                      │  • SPEED 20             │
                             ▼                                       │  • VIEW RANGE 30        │
                                                     ┌──────────┐    └─────────────────────────┘
                                                     │  CREATE  │    ┌─────────────────────────┐
                                                     │ DISABLED │───▶│ CREATE ENTITIES IN      │
                                                     └──────────┘    │        SPHERE           │──▶ ○
                                                                     │  • SIZE 16              │
                                                                     │  • COLOR BLUE           │
                                                                     │  • SPEED 18             │
                                                                     │  • VIEW RANGE 32        │
                                                                     └─────────────────────────┘
```

```
┌────────────────────────────────────────┐
│ SET THE CONDITION FOR ALL THE          │
│ ENTITIES                               │
│  • HIDE OBJECT                         │◀───
│  • AI SET ENTITY VIEW ARC I,90,170     │
│  • STARTTIME=0                         │
│  • ENDTIME=0                           │
│  • TRAVELTIME=0                        │
└────────────────────────────────────────┘
                  │
                  ▼
            ENDFUNCTION
```

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```
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│ CREATEENTITIE   │     │ CREATEENTITIE   │     │ CREATEENTITIE   │
│ SCHILDREN       │     │ STEENAGER       │     │ SADULT          │
└─────────────────┘     └─────────────────┘     └─────────────────┘
        │                       │                       │
        ▼                       ▼                       ▼
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│ CREATE          │     │ CREATE          │     │ CREATE ADULT    │
│ CHILDREN        │     │ TEENAGER        │     │                 │
└─────────────────┘     └─────────────────┘     └─────────────────┘
        │                       │                       │
        ▼                       ▼                       ▼
```

CREATE ENTITIES IN SPHERE	CREATE ENTITIES IN SPHERE	CREATE ENTITIES IN SPHERE
• SIZE 9	• SIZE 10	• SIZE 12
• COLOR YELLOW	• COLOR PINK	• COLOR RED
• SPEED 27	• SPEED 27	• SPEED 25
• VIEW RANGE 18	• VIEW RANGE 20	• VIEW RANGE 24

```
        │                       │                       │
        ▼                       ▼                       ▼
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│  ENDFUNCTION    │     │  ENDFUNCTION    │     │  ENDFUNCTION    │
└─────────────────┘     └─────────────────┘     └─────────────────┘


        ┌─────────────────┐          ┌─────────────────┐
        │ CREATEENTITIE   │          │ CREATEENTITIE   │
        │ SELDERLY        │          │ SDISABLED       │
        └─────────────────┘          └─────────────────┘
                │                            │
                ▼                            ▼
        ┌─────────────────┐          ┌─────────────────┐
        │ CREATE          │          │ CREATE          │
        │ ELDERLY         │          │ DISABLED        │
        └─────────────────┘          └─────────────────┘
                │                            │
                ▼                            ▼
```

CREATE ENTITIES IN SPHERE	CREATE ENTITIES IN SPHERE
• SIZE 15	• SIZE 16
• COLOR GREEN	• COLOR BLUE
• SPEED 20	• SPEED 18
• VIEW RANGE 30	• VIEW RANGE 32

```
                │                            │
                ▼                            ▼
        ┌─────────────────┐          ┌─────────────────┐
        │  ENDFUNCTION    │          │  ENDFUNCTION    │
        └─────────────────┘          └─────────────────┘
```

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```
                    ┌─────────────────┐
                    │  STARTPOINTF    │
                    └────────┬────────┘
                             │
                             ▼
                    ┌─────────────────┐
                    │  STARTPOINT =   │
                    │   RND(1)+1      │
                    └────────┬────────┘
                             │
                             ▼
                        ◇─────────◇
                    ◇  STARTPOINT = 1  ◇───YES──▶ ┌─────────────────┐
                        ◇─────────◇              │ ENTITIES LOCATED AT │
                             │                    │  EXIT1 (BOTTOM)    │
                            NO                    └────────┬────────┘
                             │                             │
                             ▼                             ▼
                    ┌─────────────────┐          ┌─────────────────┐
                    │     THUS        │          │ ENDPOINT =RND(3)+1 │◀──┐
                    │  STARTPOINT =2  │          └────────┬────────┘    │
                    └────────┬────────┘                   │             │
                             │                             ▼             │
                             ▼                        ◇─────────◇     YES
                    ┌─────────────────┐           ◇ ENDPOINT =1 ◇─────┘
                    │ ENTITIES LOCATED AT │          ◇─────────◇
                    │  EXIT2 (ABOVE)    │               │
                    └────────┬────────┘                │
                             │                          │
                             ▼                          │
                    ┌─────────────────┐                │
                    │ ENDPOINT =RND(3)+1 │◀──┐          │
                    └────────┬────────┘    │          │
                             │             │          │
                             ▼            YES         │
                        ◇─────────◇        │          │
                    ◇ ENDPOINT =2 ◇────────┘          │
                        ◇─────────◇                   │
                             │                          │
                             ▼                          │
                           ( ○ )◀──────────────────────┘
                             │
                             ▼
                    ┌─┬─────────────┬─┐
                    │ │  ENDPOINTF  │ │
                    └─┴──────┬──────┴─┘
                             │
                             ▼
                    ┌─────────────────┐
                    │  ENDFUNCTION    │
                    └─────────────────┘
```

```
                    ┌─────────────┐
                    │  ENDPOINTF  │
                    └─────────────┘
                           │
                           ▼
                      ◇ ENDPOINT =1 ◇ ──YES──▶ ┌─────────────────┐
                           │                    │ ENTITIES GO TO  │
                           NO                   │ EXIT1 (BOTTOM)  │
                           │                    └─────────────────┘
                           ▼
                      ◇ ENDPOINT =2 ◇ ──YES──▶ ┌─────────────────┐
                           │                    │ ENTITIES GO TO  │ ──▶ ◯
                           NO                   │ EXIT2 (ABOVE)   │
                           │                    └─────────────────┘
                           ▼
                      ◇ ENDPOINT =3 ◇ ──YES──▶ ┌─────────────────┐
                           │                    │ SHOP =RND(7)+1  │
                           NO                   └─────────────────┘
                           │                           │
                           ▼                           ▼
                  ┌─────────────────┐      ┌─────────────────────────┐
                  │ THUS ENDPOINT   │      │ • ENTITIES GO TO        │
                  │ =4              │      │   SHOP AT LEFT SIDE     │ ──▶ ◯
                  └─────────────────┘      │ • SHOP NUMBER           │
                           │               │   INCREASE FROM         │
                           ▼               │   THE BOTTOM            │
                  ┌─────────────────┐      └─────────────────────────┘
                  │ SHOP =RND(7)+9  │
                  └─────────────────┘
                           │
                           ▼
                  ┌─────────────────────────┐
                  │ • ENTITIES GO TO        │
                  │   SHOP AT RIGHT SIDE    │ ──▶ ◯
                  │ • SHOP NUMBER           │
                  │   INCREASE FROM         │
                  │   THE BOTTOM            │
                  └─────────────────────────┘
                                                      │
                                                      ▼
                                               ┌─────────────┐
                                               │ ENDFUNCTION │
                                               └─────────────┘
```

A – 4: Flow chart for BBS

```
  ( B )                          ( A )

                                                                    ┌────────────────────┐
┌───────────────┐          ◇ ELDERLY <>0 ◇──YES──▶◇ FINISH CREATE ◇──NO──▶│ CREATEENTITIES     │
│  CREATEENT    │                │                 │ ELDERLY?       │      │ ELDERLY            │
│  ITIES        │                │                 ◇                │      └────────────────────┘
└───────────────┘               NO                       YES
      │                          │                         │
      │                          ▼                         │
      │                         ( ● )◀────────────────────┘
      │                          │
      │                          ▼
      │                                              ┌────────────────────┐
      │                ◇ DISABLED <>0 ◇──YES──▶◇ FINISH CREATE ◇──NO──▶│ CREATEENTITIES     │
      │                          │              │ DISABLED?       │      │ DISABLED           │
      │                         NO              ◇                 │      └────────────────────┘
      │                          │                    YES
      │                          ▼                      │
      │                         ( ● )◀─────────────────┘
      │                          │
      │                          ▼
      │          ┌──────────────────────────────────────┐
      │          │ SET THE CONDITION FOR ALL THE        │
      │          │ ENTITIES                             │
      │          │   • HIDE OBJECT                      │
      │          │   • AI SET ENTITY VIEW ARC I,90,170  │
      │          │   • STARTTIME=0                      │
      │          │   • ENDTIME=0                        │
      │          │   • TRAVELTIME=0                     │
      │          └──────────────────────────────────────┘
      │                          │
      └─────────▶( ● )◀──────────┘
                    │
                    ▼
          ┌──────────────────────┐
          │ SET THE STARTING     │
          │ POSITION OF ALL THE  │
          │ ENTITIES             │
          └──────────────────────┘
                    │
                    ▼
          ┌──────────────────────┐
          │  STARTPOINTF         │
          └──────────────────────┘
                    │
                    ▼
          ┌──────────────────────┐
          │ LOOP THE EXE         │◀──────────────────────( H )
          │ UNTIL THE USER       │
          │ QUIT                 │
          └──────────────────────┘
                    │
                    ▼
                                                          ┌──────────────────┐
          ◇ PRESS '1' ◇──YES──▶◇ PMODE=0 ◇──YES──▶│ AI DEBUG HIDE    │
                    │                    │                │ PATHS            │
                    │                   NO                └──────────────────┘
                    │                    │                         │
                    │                    ▼                         │
                    │          ┌──────────────────┐                │
                    │          │ AI DEBUG SHOW    │                │
                    │          │ PATHS            │                │
                    │          └──────────────────┘                │
                    │                    │                         │
                    ▼                    ▼                         │
                  ( C )◀─────────────( ● )◀─────────────────────────┘
```

231

```
                    ( C )
                      │
                      ▼
           ◇ PRESS '2' ◇──YES──▶◇ AMODE=0 ◇──YES──▶┌──────────────────┐
                  │                    │            │ AI DEBUG HIDE    │
                  │                    │            │ AVOIDANCE        │
                  │                    NO           │ ANGLES           │
                  NO                   │            └──────────────────┘
                  │                    ▼                    │
                  │            ┌──────────────────┐         │
                  │            │ AI DEBUG SHOW    │         │
                  │            │ AVOIDANCE        │         │
                  │            │ ANGLES           │         │
                  │            └──────────────────┘         │
                  │                    │                    │
                  ▼                    ▼                    │
                 ( )◀──────────────── ( )◀─────────────────┘
                  │
                  ▼
           ◇ PRESS '3' ◇──YES──▶◇ VMODE=0 ◇──YES──▶┌──────────────────┐
                  │                    │            │ AI DEBUG HIDE    │
                  │                    │            │ VIEW ARCS        │
                  │                    NO           └──────────────────┘
                  NO                   │                    │
                  │                    ▼                    │
                  │            ┌──────────────────┐         │
                  │            │ AI DEBUG SHOW    │         │
                  │            │ VIEW ARCS        │         │
                  │            └──────────────────┘         │
                  │                    │                    │
                  ▼                    ▼                    │
                 ( )◀──────────────── ( )◀─────────────────┘
                  │
                  ▼
          ┌──────────────────┐
          │ CAMERA           │
          │ CONTROLS         │
          └──────────────────┘
                  │
                  ▼
           ◇ PRESS      ◇──YES──▶┌──────────────────┐
           ◇ 'DOWNKEY' ◇         │ CAMERA MOVE      │
                  │              │ DOWN             │
                  NO             └──────────────────┘
                  ▼                    │
                 ( )◀─────────────────┘
                  │
                  ▼
           ◇ PRESS 'UPKEY' ◇──YES──▶┌──────────────────┐
                  │                 │ CAMERA MOVE      │
                  │                 │ UP               │
                  NO                └──────────────────┘
                  ▼                    │
                 ( )◀─────────────────┘
                  │
                  ▼
           ◇ PRESS      ◇──YES──▶┌──────────────────┐
           ◇ 'LEFTKEY'  ◇        │ CAMERA MOVE      │
                  │              │ LEFT             │
                  NO             └──────────────────┘
                  ▼                    │
                 ( D )◀───────────────┘
```

232

```
          ( D )
            │
            ▼
      ┌───────────┐
     ╱   PRESS     ╲──YES──▶┌──────────────┐
    ◀  'RIGHTKEY'   ▶       │ CAMERA MOVE  │
     ╲             ╱        │    RIGHT     │
      └───────────┘         └──────┬───────┘
            │ NO                   │
            ▼                      │
           (○)◀────────────────────┘
            │
            ▼
      ┌───────────┐
     ╱   PRESS     ╲──YES──▶┌──────────────┐
    ◀   'PGUP'      ▶       │   ZOOM IN    │
     ╲             ╱        └──────┬───────┘
      └───────────┘                │
            │ NO                    │
            ▼                       │
           (○)◀─────────────────────┘
            │
            ▼
      ┌───────────┐
     ╱   PRESS     ╲──YES──▶┌──────────────┐
    ◀   'PGDN'      ▶       │   ZOOM OUT   │
     ╲             ╱        └──────┬───────┘
      └───────────┘                │
            │ NO                    │
            ▼                       │
           (○)◀─────────────────────┘
            │
            ▼
      ┌───────────┐        ┌──────────────┐
     ╱   PRESS     ╲──YES─▶│   ALL THE    │
    ◀   'HOME'      ▶       │   CAMERA     │
     ╲             ╱        │ SETTING BACK │
      └───────────┘         │  TO ORIGIN   │
            │ NO            └──────┬───────┘
            ▼                      │
           (○)◀────────────────────┘
```

SHOW THE GUIDE TO USE THE SIMULATION
- [1] TOGGLE ENTITY PATH"
- [2] TOGGLE AVOIDANCE ANGLES"
- [3] TOGGLE VIEW ARCS"
- FPS:
- CAMERA CONTROLS

PRESS 'F1' — YES — F1PRESSED=1 — YES

NO

PRESS F1 FOR SOME GUIDE

NO

ENTITIES ON THE STAGE — YES — SHOW ENTITIES

NO

HIDE ENTITIES

CALCULATE THE ENTITIES ON THE STAGES

(E)

233

E

ENTITIES ENPOINT AT COUNTER

YES → COUNTERF

NO

ENTITIES ENTER LINE UP ZONE

YES → ENTITIES SCAN THE DISTANCE BETWEEN THE ENTITIES IN FRONT → QUEUE DISTANCE > BOTH OF THEIR SIZE

YES

NO

NO → ENTITIES STOP

ENTITIES REACH DESTINATION AND GO OUT THE STAGE

YES → STORE THE DATA TO THE CSV FILE

NO

SHOW THE DATA ON THE CONSOLE

KILL ENTITIES

F

```
                    ( F )
                      │
                      ▼
              ◇ ENTITIES ◇ ──YES──┐
              ◇ DELETED  ◇         │
                 │                 ▼
                 │          ┌──────────────┐
                 │          │ REBORN THE   │
                 │          │ ENTITIES     │
                 │          └──────────────┘
                 │                 │
                 │                 ▼
                 │          ◇ DEFAULT =0 ◇──YES──►◇ IS CHILDREN? ◇──YES──►│ CREATEENT     │──┐
                 │                 │                   │                  │ ITIESCHILDR   │  │
                 │                 │                   │                  │ EN            │  │
                 │                NO                  NO                  └───────────────┘  │
                 │                 │                   │                                     │
                 │                 ▼                   ▼                                     │
                 │          │ CREATEENT │     ◇ IS TEENAGER? ◇──YES──►│ CREATEENT     │──►( )│
                 │          │ ITIES     │            │                │ ITIESTEENA    │      │
                 │          └───────────┘            │                │ GER           │      │
                 │                                  NO                └───────────────┘      │
                 │                                   │                                       │
                 │                                   ▼                                       │
                 │                            ◇ IS ADULT? ◇──YES──►│ CREATEENT     │──►( )   │
                 │                                   │             │ ITIESADULT    │         │
                 │                                   │             └───────────────┘         │
                NO                                  NO                                       │
                 │                                   │                                       │
                 │                                   ▼                                       │
                 │                            ◇ IS ELDERLY ◇──YES──►│ CREATEENT     │──►( )  │
                 │                                   │              │ ITIESELDER    │        │
                 │                                   │              │ LY            │        │
                 │                                  NO              └───────────────┘        │
                 │                                   │                                       │
                 │                                   ▼                                       │
                 │                            │ CREATEENT     │──────────────►( )            │
                 │                            │ ITIESDISABL   │                              │
                 │                            │ ED            │                              │
                 │                            └───────────────┘                             │
                 │                                                                           │
                 │                ┌──────────────────────────────────────┐                  │
                 │                │ SET THE CONDITION FOR ALL THE         │                  │
                 │                │ ENTITIES                              │                  │
                 │         ( )◄───│ • HIDE OBJECT                         │◄─────────────────┘
                 │          │     │ • AI SET ENTITY VIEW ARC I,90,170     │
                 │          │     │ • STARTTIME=0                         │
                 │          │     │ • ENDTIME=0                           │
                 │          │     │ • TRAVELTIME=0                        │
                 │          │     │ • COUNTER WAIT TIME =0                │
                 │          │     │ • CST =0                              │
                 │          │     └──────────────────────────────────────┘
                 │          ▼
                 ▼   ┌──────────────┐
               ( G )◄┤ STARTPOIN    │
                     │ TF           │
                     └──────────────┘
```

SET THE CONDITION FOR ALL THE ENTITIES
- HIDE OBJECT
- AI SET ENTITY VIEW ARC I,90,170
- STARTTIME=0
- ENDTIME=0
- TRAVELTIME=0
- COUNTER WAIT TIME =0
- CST =0

235

```
      ( G )                      ( H )                    ( I )
        |                          ^                        |
        v                          |                        |
  ┌───────────────┐                |                        |
 /  SHOW THE      /                |                        |
 /  CLOCK ON      /                |                        |
 /  BOTTOM RIGHT  /                |                        |
 └───────────────┘                |                        |
        |                          |                        |
        v                          |                        |
  ┌───────────────┐                |                        |
  │ SET TIMER FOR │                |                        |
  │ 20 MINUTE     │                |                        |
  └───────────────┘                |                        |
        |                          |                        |
        v                          |                        |
      /\                           |                        |
     /  \        YES               |                        |
    < TIMER =>20 MIN >─────────────────────────────────────> O
     \  /                          |                        |
      \/                           |                        |
        |                          |                        |
       NO                          |                        |
        v                          |                        |
  ┌───────────────┐                |                        |
 /  SHOW THE      /                |                        |
 /  TIMER ABOVE   /                |                        |
 /  CLOCK         /                |                        |
 └───────────────┘                |                        |
        |                          |                        |
        v                          |                        |
  ┌──────────────────┐             |                        |
 / SHOW THE AMOUNT   /             |                        |
 / OF ENTITIES ON    /             |                        |
 / STAGES & TOTAL    /             |                        |
 / ENTITIES          /             |                        |
 └──────────────────┘              |                        |
        |                          |                        |
        v                          |                        |
  ┌──────────────────┐             |                        |
 / SHOW THE          /             |                        |
 / REPRESENTATIVE    /             |                        |
 / OF THE COLOR      /             |                        |
 └──────────────────┘              |                        |
        |                          |                        |
        v                          |                        |
      /\                           |                        |
     /  \          NO              |                        |
    < CLOSING THE >────────────────┘                        |
    < SIMULATION  >                                         |
     \  /                                                   |
      \/                                                    |
        |                                                   |
      YES                                                   |
        v                                                   |
   (  END  )<───────────────────────────────────────────────┘
```

236

```
CREATEENTITIES

        │
        ▼
CATEGORIES =
RND(7)

        │
        ▼
CATEGORIES = 0  ──YES──▶  CREATE       ──▶  CREATE ENTITIES IN      ──▶  ◯
                          CHILDREN           SPHERE
        │                                    • SIZE 9
       NO                                    • COLOR YELLOW
        │                                    • SPEED 27
        ▼                                    • VIEW RANGE 18

CATEGORIES = 1  ──YES──▶  CREATE       ──▶  CREATE ENTITIES IN      ──▶  ◯
                          TEENAGER           SPHERE
        │                                    • SIZE 10
       NO                                    • COLOR PINK
        │                                    • SPEED 27
        ▼                                    • VIEW RANGE 20

CATEGORIES = 2 OR 3  ──YES──▶  CREATE ADULT  ──▶  CREATE ENTITIES IN  ──▶  ◯
OR 6 OR 7                                          SPHERE
        │                                          • SIZE 12
       NO                                          • COLOR RED
        │                                          • SPEED 25
        ▼                                          • VIEW RANGE 24

CATEGORIES = 4  ──YES──▶  CREATE       ──▶  CREATE ENTITIES IN      ──▶  ◯
                          ELDERLY            SPHERE
        │                                    • SIZE 15
       NO                                    • COLOR GREEN
        │                                    • SPEED 20
        │                                    • VIEW RANGE 30
        │
        └──────────────▶  CREATE       ──▶  CREATE ENTITIES IN      ──▶  ◯
                          DISABLED           SPHERE
                                             • SIZE 16
                                             • COLOR BLUE
                                             • SPEED 18
                                             • VIEW RANGE 32


SET THE CONDITION FOR ALL THE
ENTITIES
• HIDE OBJECT
• AI SET ENTITY VIEW ARC I,90,170
• STARTTIME=0
• ENDTIME=0
• TRAVELTIME=0
• COUNTER WAIT TIME =0
• CST =0

        │
        ▼
ENDFUNCTION
```

237

CREATEENTITIE SCHILDREN

CREATE CHILDREN

CREATE ENTITIES IN SPHERE
- SIZE 9
- COLOR YELLOW
- SPEED 27
- VIEW RANGE 18

ENDFUNCTION

CREATEENTITIE STEENAGER

CREATE TEENAGER

CREATE ENTITIES IN SPHERE
- SIZE 10
- COLOR PINK
- SPEED 27
- VIEW RANGE 20

ENDFUNCTION

CREATEENTITIE SADULT

CREATE ADULT

CREATE ENTITIES IN SPHERE
- SIZE 12
- COLOR RED
- SPEED 25
- VIEW RANGE 24

ENDFUNCTION

CREATEENTITIE SELDERLY

CREATE ELDERLY

CREATE ENTITIES IN SPHERE
- SIZE 15
- COLOR GREEN
- SPEED 20
- VIEW RANGE 30

ENDFUNCTION

CREATEENTITIE SDISABLED

CREATE DISABLED

CREATE ENTITIES IN SPHERE
- SIZE 16
- COLOR BLUE
- SPEED 18
- VIEW RANGE 32

ENDFUNCTION

```
          ┌─────────────────┐
          │  STARTPOINTF    │
          └─────────────────┘
                  │
                  ▼
          ┌─────────────────┐
          │  STARTPOINT =   │
          │  RND(3)+1       │
          └─────────────────┘
                  │
                  ▼
                                                              ┌── YES ──┐
          ◇ STARTPOINT = 1 ◇──YES──┐  ┌──────────────┐  ┌──────────┐  ▼    ◇
                  │                │  │ ENTITIES     │  │ ENDPOINT=│  │ ENDPOINT =1 ◇──┐
                 NO               └─▶│ LOCATED AT    │─▶│ RND(4)   │─▶│              │  │
                  │                   │ EXIT1 (BOTTOM)│  └──────────┘  ◇           │  │
                  ▼                   └──────────────┘                            │  │
                                                               ┌── YES ──┐        │  │
          ◇ STARTPOINT = 2 ◇──YES──┐  ┌──────────────┐  ┌──────────┐  ▼    ◇      │  │
                  │                │  │ ENTITIES     │  │ ENDPOINT=│  │ ENDPOINT=2 ◇─NO─○
                 NO               └─▶│ LOCATED AT    │─▶│ RND(4)   │─▶│           │
                  │                   │ EXIT2 (ABOVE) │  └──────────┘  ◇
                  ▼                   └──────────────┘
                                                               ┌── YES ──┐
          ◇ STARTPOINT = 3 ◇──YES──┐  ┌──────────────┐  ┌──────────┐  ▼    ◇
                  │                │  │ ENTITIES     │  │ ENDPOINT=│  │ ENDPOINT=3 ◇─NO─○
                 NO               └─▶│ LOCATED AT    │─▶│ RND(4)   │─▶│ OR 4      │
                  │                   │ BUS BAY1     │  └──────────┘  ◇
                  ▼                   │ (BOTTOM RIGHT)│
          ┌─────────────────┐        └──────────────┘ ┌── YES ──┐
          │ THUS            │   ┌──────────────┐  ┌──────────┐  ▼    ◇
          │ STARTPOINT =4   │──▶│ ENTITIES     │─▶│ ENDPOINT=│─▶│ ENDPOINT=3 ◇─NO─○
          └─────────────────┘   │ LOCATED AT    │  │ RND(4)   │  │ OR 4      │
                                │ BUS BAY2     │  └──────────┘  ◇
                                │ (ABOVE RIGHT)│
                                └──────────────┘
                  ┌───────────────┐
                  ▼
          ┌─────────────────┐
          ║  ENDPOINTF     ║
          └─────────────────┘
                  │
                  ▼
          ┌─────────────────┐
          │  ENDFUNCTION    │
          └─────────────────┘
```

239

```
                    ┌──────────────┐
                    │  ENDPOINTF   │
                    └──────┬───────┘
                           │
                           ▼
                        ╱ENDPOINT╲        YES    ┌──────────────────┐
                       ╱   =1     ╲──────────────│  ENTITIES GO TO  │
                       ╲          ╱              │  EXIT1 (BOTTOM)  │
                        ╲        ╱               └──────────────────┘
                          NO │
                           ▼
                        ╱ENDPOINT╲        YES    ┌──────────────────┐
                       ╱   =2     ╲──────────────│  ENTITIES GO TO  │────◯
                       ╲          ╱              │  EXIT2 (ABOVE)   │
                        ╲        ╱               └──────────────────┘
                          NO │
                           ▼
                        ╱ENDPOINT╲        YES    ┌──────────────────┐
                       ╱   =3     ╲──────────────│  ENTITIES GO TO  │────◯
                       ╲          ╱              │  BUS BAY1        │
                        ╲        ╱               │  (BOTTOM RIGHT)  │
                          NO │                   └──────────────────┘
                           ▼
                        ╱ENDPOINT╲        YES    ┌──────────────────┐
                       ╱   =4     ╲──────────────│  ENTITIES GO TO  │────◯
                       ╲          ╱              │  BUS BAY2        │
                        ╲        ╱               │  (ABOVE RIGHT)   │
                             │                   └──────────────────┘
                           ▼
                    ┌──────────────┐     ┌──────────────────┐
                    │    THUS      │─────│  ENTITIES GO TO  │────◯
                    │  ENPOINT = 0 │     │  END OF THE      │
                    └──────────────┘     │  QUEUE BARRIER   │
                                         │  (BOTTOM LEFT)   │
                                         └──────────────────┘
                    ┌──────────────┐
                    │ ENDFUNCTION  │◄────────────
                    └──────────────┘
```

```
                    ┌──────────────┐
                    │  COUNTERF    │
                    └──────┬───────┘
                           │
                    ┌──────▼───────┐
                    │ ZONE 1 = END │
                    │ OF THE QUEUE │
                    │   BARRIER    │
                    └──────┬───────┘
                           │
                      ◇─────────◇         ┌──────────────────────┐
                      ENTITIES IN ─YES──► │ ENTITIES MOVE TOWARD  │
                        ZONE 1            │   TICKET COUNTER      │
                      ◇─────────◇         └──────────┬───────────┘
                           │                         │
                          NO                         │
                    ┌──────▼───────┐                 │
                    │  ZONE 3 = IN │◄────────────────┘
                    │ FRONT OF THE │
                    │TICKET COUNTER│
                    └──────┬───────┘
                           │
                      ◇─────────◇      ◇──────────◇       ┌────────────┐
                      ENTITIES IN ─YES─ COUNTER WAIT ─YES─►│ STORE THE  │
                        ZONE 3          TIME >5            │ DATA TO THE│
                      ◇─────────◇      ◇──────────◇        │  CSV FILE  │
                           │                │             └─────┬──────┘
                          NO               NO                   │
                                     ┌──────▼──────┐      ┌──────▼──────┐
                                     │ENTITIES STOP│      │ SHOW THE DATA│
                                     └──────┬──────┘      │   ON THE     │
                                            │             │  CONSOLE     │
                                            │             └──────┬───────┘
                                            │                    │
                                            │        ┌───────────▼──────────────┐
                                            │        │RESET THE CONDITION FOR THE│
                                            │        │ENTITIES                   │
                                            │        │ • STARTPOINT(I)=ENDPOINT(I)│
                                            │        │ • CAPTURE STARTTIME        │
                                            │        │ • ENDTIME=0                │
                                            │        │ • TRAVELTIME=0             │
                          NO                │        │ • COUNTER WAIT TIME =0     │
                                            │        │ • CST =0                   │
                                            │        └───────────┬───────────────┘
                                            │                    │
              ┌──────────────┐             │                    │
              │ ENDFUNCTION  │◄──────○◄─────┘         ┌──────────▼───────────┐
              └──────────────┘                        │      ENDPOINTF       │
                                                       └──────────────────────┘
```

Appendix 3 (HIMs's Source Code)

B – 1: Simulation menu source code

```
REM Project: INDEX
REM Created: 2/25/2009 5:10:05 PM
REM
REM ***** Main Source File *****
REM

CLS
SYNC
SYNC ON : SYNC RATE 0
SET TEXT FONT "VERDANA" : SET TEXT SIZE 15
MAP SHARED MEM TO BANK "MYBANK", 1, 40960
PRINT " ============================================ "
PRINT "  WELCOME TO HUMAN WALKING BEHAVIOUR SIMULATOR"
PRINT " ============================================ "
PRINT ""
PRINT "  THIS IS A SIMULATOR THAT SIMULATES A VARIANCE OF HUMAN "
PRINT "  WALKING BEHAVIOURS IN DIFFERENT SITUATIONS "
PRINT "  PLEASE CHOOSE ANY WORLD TO EXPOSE TO & GOOD LUCK  ^_^"
PRINT ""
PRINT "  WORLD 1 - AN EMPTY SPACE "
PRINT "  WORLD 2 - SHOPPING CENTRE "
PRINT "  WORLD 3 - BUS DEPARTURE BAY "
PRINT ""
PRINT " ============================================ "
PRINT ""
SYNC
INPUT "NOW PLEASE ENTER THE WORLD OF YOUR CHOICE: ",WORLD
PRINT ""

WHILE WORLD >3 OR WORLD <1
  INPUT "PLEASE RE-ENTER THE WORLD YOU WOULD LIKE TO ENTER TO: ",WORLD
  PRINT ""
  SYNC
ENDWHILE

IF WORLD =1 OR WORLD=2 OR WORLD =3

  REM DESIGN OF DIFFERENT WORLDS
  REM SMS
  IF WORLD=2
    CLS
    SYNC
    PRINT " ============================================== "
    PRINT "   SHOPPING CENTRE SIMULATOR"
    PRINT " ============================================== "
    PRINT ""
    PRINT "  YOU HAVE 6 CHOICE HERE"
    PRINT ""
    PRINT "  DESIGN 0 - NO EXTRA CONDITION"
    PRINT "  DESIGN 1 - SOUVENIR KIOSK SPHERE SHAPE"
    PRINT "  DESIGN 2 - THE 3 INTERSECTS BLOCK OF KIOSK"
    PRINT "  DESIGN 3 - THE 'CURVE OUTWARD' SHAPE LOCATION OF KIOSK"
    PRINT "  DESIGN 4 - THE 'CURVE INWARD' SHAPE LOCATION OF KIOSK"
    PRINT "  DESIGN 5 - RANDOM LOCATION OF KIOSK"
```

```
      PRINT " ========================================= "
      PRINT ""
      SYNC
      INPUT "NOW PLEASE SELECT THE CONDITION OF YOUR CHOICE: ",CONDITION
      PRINT ""
      WHILE CONDITION >5 OR CONDITION <0
        INPUT "PLEASE RE-ENTER THE CONDITION YOU WOULD LIKE TO ENTER TO:
",CONDITION
        PRINT ""
        SYNC
      ENDWHILE
      WRITE BANK INTEGER 1,28672,CONDITION
    ENDIF

    REM BBSS
    IF WORLD=3
      CLS
      SYNC
      PRINT " ========================================= "
      PRINT "   BUS DEPARTURE BAY SIMULATOR"
      PRINT " ========================================= "
      PRINT ""
      PRINT "  YOU HAVE 6 CHOICE HERE"
      PRINT ""
      PRINT "  DESIGN 0 - NO EXTRA CONDITION"
      PRINT "  DESIGN 1 - TREE DESIGN BARRIER"
      PRINT "  DESIGN 2 - VERTICAL DESIGN BARRIER"
      PRINT "  DESIGN 3 - SMOOTH FLOW DESIGN BARRIER"
      PRINT "  DESIGN 4 - ROUND DESIGN BARRIER"
      PRINT "  DESIGN 5 - CONE DESIGN BARRIER"
      PRINT " ========================================= "
      PRINT ""
      SYNC
      INPUT "NOW PLEASE SELECT THE CONDITION OF YOUR CHOICE: ",CONDITION
      PRINT ""
      WHILE CONDITION >5 OR CONDITION <0
        INPUT "PLEASE RE-ENTER THE CONDITION YOU WOULD LIKE TO ENTER TO:
",CONDITION
        PRINT ""
        SYNC
      ENDWHILE
      WRITE BANK INTEGER 1,28672,CONDITION
    ENDIF

    REM CHOOSE THE SETTING
    SYNC
    CLS
    PRINT " ========================================= "
    PRINT "   OPTIONAL SETTING"
    PRINT " ========================================= "
    PRINT ""
    PRINT " 0 - CUSTOM SETTING"
    PRINT " 1 - SKIP OPTION"
    PRINT " ========================================= "
    PRINT ""
    SYNC
    INPUT "PLEASE ENTER THE CHOICE: ",DEFAULT
    PRINT ""
    SYNC
```

```
WHILE DEFAULT<>0 AND DEFAULT<>1
  SYNC
  INPUT "PLEASE RE-ENTER THE CHOICE (0 OR 1): ",DEFAULT
  PRINT ""
  SYNC
ENDWHILE
WRITE BANK INTEGER 1,4096,DEFAULT

IF DEFAULT =1
REM INPUT SCREEN
SYNC
PRINT " THE SIMULATION RUN TIME IS SET FOR 30 MINUTES "
RUNTIME = 30*60
WRITE BANK INTEGER 1,32768,RUNTIME
SYNC
PRINT ""
WAIT 1000
PRINT "PLEASE ENTER THE NUMBER OF ENTITIES (MAX 99): "
INPUT "==> ",ENTITIES
SYNC

COUNT = 3
WHILE ENTITIES =0
  PRINT ""
  PRINT "PLEASE RE-ENTER THE NUMBER OF ENTITIES (MAX 99)<",COUNT,">: "
  INPUT "==> ",ENTITIES
  COUNT = COUNT - 1
  SYNC
  IF COUNT =0
    PRINT " THE PROGRAM WILL RANDOMLY CHOOSE THE NUMBER OF ENTITIES
FOR YOU "
    ENTITIES = RND(99)
  ENDIF
  SYNC
ENDWHILE

IF ENTITIES<0
  ENTITIES=-ENTITIES
ENDIF
IF ENTITIES>99
    ENTITIES=99
ENDIF

WRITE BANK INTEGER 1,0,ENTITIES
ENDIF REM FINISH DEFAULT =1

IF DEFAULT =0
  REM PEAK OR OFF-PEAK HOUR
  SYNC
  CLS
  PRINT " =========================================== "
  PRINT "   TIME PERIOD SETTING"
  PRINT " =========================================== "
  PRINT ""
  PRINT "  PLEASE SELECT THE TIME PERIOD: "
  PRINT ""
  PRINT " 1 - OFF-PEAK HOUR"
  PRINT " 2 - PEAK HOUR"
  PRINT " =========================================== "
  PRINT
```

```
    INPUT "==> ",PERIOD
    SYNC
    PRINT ""
    SYNC
    WHILE PERIOD<>1 AND PERIOD<>2
      SYNC
      INPUT "PLEASE RE-ENTER THE TIME PERIOD (1 OR 2): ",PERIOD
      PRINT ""
      SYNC
    ENDWHILE

    REM RUN TIME
    SYNC
    INPUT "PLEASE ENTER SIMULATION RUNNING TIME IN SECONDS(>60S): ",RUNTIME
    PRINT ""
    SYNC

    COUNT = 3
    WHILE RUNTIME <60
      PRINT ""
      PRINT "PLEASE RE-ENTER SIMULATION RUNNING TIME IN SECONDS(>60S):
<",COUNT,">: "
      INPUT "==> ",RUNTIME
      COUNT = COUNT - 1
      SYNC
      IF COUNT =0
        PRINT " THE SIMULATION RUN TIME IS SET TO 30 MINUTES "
        RUNTIME = 30*60
        PRINT ""
      ENDIF
      SYNC
    ENDWHILE
    WRITE BANK INTEGER 1,32768,RUNTIME
    REM FINISH RUN TIME SETUP

    REM OFF-PEAK
    IF PERIOD=1
      REM INPUT SCREEN
      SYNC
      PRINT "YOU HAVE ENTER OFF-PEAK HOUR"
      PRINT "THE MAX ENTITIES WOULD BE 30"
      PRINT "PLEASE ENTER THE NUMBER OF ENTITIES (1-30): "
      INPUT "==> ",ENTITIES
      SYNC

      COUNT = 3
      WHILE ENTITIES =0
        PRINT ""
        PRINT "PLEASE RE-ENTER THE NUMBER OF ENTITIES (1-30)<",COUNT,">: "
        INPUT "==> ",ENTITIES
        COUNT = COUNT - 1
        SYNC
        IF COUNT =0
          PRINT " THE PROGRAM WILL RANDOMLY CHOOSE THE NUMBER OF ENTITIES
FOR YOU "
          ENTITIES = RND(30)
        ENDIF
        SYNC
      ENDWHILE
```

```
      IF ENTITIES<0
        ENTITIES=-ENTITIES
      ENDIF
      IF ENTITIES>30
          ENTITIES=30
      ENDIF

      WRITE BANK INTEGER 1,0,ENTITIES
    ENDIF

    REM PEAK
    IF PERIOD=2
      REM INPUT SCREEN
      SYNC
      PRINT "YOU HAVE ENTER PEAK HOUR"
      PRINT "THE MIN ENTITIES WOULD BE AT 31"
      PRINT "THE MAX ENTITIES WOULD BE AT 99"
      PRINT "PLEASE ENTER THE NUMBER OF ENTITIES (31-99): "
      INPUT "==> ",ENTITIES
      SYNC

      COUNT = 3
      WHILE ENTITIES <31
        PRINT ""
        PRINT "PLEASE RE-ENTER THE NUMBER OF ENTITIES (31-99) <",COUNT,">: "
        INPUT "==> ",ENTITIES
        COUNT = COUNT - 1
        SYNC
        IF COUNT =0
          PRINT " THE PROGRAM WILL RANDOMLY CHOOSE THE NUMBER OF ENTITIES
FOR YOU "
          ENTITIES = 30+RND(69)
        ENDIF
        SYNC
      ENDWHILE

      IF ENTITIES>99
          ENTITIES=99
      ENDIF

      WRITE BANK INTEGER 1,0,ENTITIES
    ENDIF

    REM NUMBER OF CHILDREN
    SYNC
    PRINT "PLEASE ENTER THE NUMBER OF CHILDREN (MAX:",ENTITIES,"): "
    INPUT "==> ",CHILDREN
    SYNC

    IF CHILDREN<0
      CHILDREN=-CHILDREN
    ENDIF

    IF CHILDREN >ENTITIES
      CHILDREN =ENTITIES
    ENDIF
    WRITE BANK INTEGER 1,8192,CHILDREN

    REM NUMBER OF TEENAGER
    IF ENTITIES-CHILDREN > 0
```

```
    SYNC
    PRINT "PLEASE ENTER THE NUMBER OF TEENAGER (MAX:",ENTITIES-
CHILDREN,"): "
    INPUT "==> ",TEENAGER
    SYNC

    IF TEENAGER<0
      TEENAGER=-TEENAGER
    ENDIF

    IF TEENAGER >ENTITIES-CHILDREN
      TEENAGER = ENTITIES-CHILDREN
    ENDIF
  ENDIF
  WRITE BANK INTEGER 1,12288,TEENAGER
  REM NUMBER OF ADULT
  IF ENTITIES-CHILDREN-TEENAGER>0
    SYNC
    PRINT "PLEASE ENTER THE NUMBER OF ADULT (MAX:",ENTITIES-CHILDREN-
TEENAGER,"): "
    INPUT "==> ",ADULT
    SYNC

    IF ADULT<0
      ADULT=-ADULT
    ENDIF

    IF ADULT >ENTITIES-CHILDREN-TEENAGER
      ADULT = ENTITIES-CHILDREN-TEENAGER
    ENDIF
  ENDIF
  WRITE BANK INTEGER 1,16384,ADULT
  REM NUMBER OF ELDERLY
  IF ENTITIES-CHILDREN-TEENAGER-ADULT>0
    SYNC
    PRINT "PLEASE ENTER THE NUMBER OF ELDERS (MAX:",ENTITIES-CHILDREN-
TEENAGER-ADULT,"): "
    INPUT "==> ",ELDERLY
    SYNC

    IF ELDERLY<0
      ELDERLY=-ELDERLY
    ENDIF

    IF ELDERLY >ENTITIES-CHILDREN-TEENAGER-ADULT
      ELDERLY = ENTITIES-CHILDREN-TEENAGER-ADULT
    ENDIF
  ENDIF
  WRITE BANK INTEGER 1,20480,ELDERLY

  REM NUMBER OF DISABLED
  DISABLED = ENTITIES-CHILDREN-TEENAGER-ADULT-ELDERLY
  IF DISABLED <> 0
    SYNC
    PRINT "NUMBER OF DISABLED: ",DISABLED
    SYNC
  ENDIF
  SLEEP 2500
  WRITE BANK INTEGER 1,24576,DISABLED
  SYNC
```

```
  ENDIF REM FINISH DEFAULT=0

 A=TIMER()/1000
 DO
   CLS
   PRINT "PLEASE SAVE THE PREVIOUS ANALYSIS FILE IN OTHER DIRECTORY"
   PRINT "THE FILE WILL BE OVERWRITE AS THE SIMULATION BEGIN"
   PRINT ""
   PRINT "PRESS 'SPACE BAR' TO PAUSE THE TIME & SAVE PREVIOUS FILE"
   B=A+8-TIMER()/1000
   PRINT ""
   PRINT "TIME REMAINING <",B,"> SECONDS ..."
   SYNC
   IF B=0 OR SCANCODE()=57 THEN EXIT
 LOOP

 IF SCANCODE()=57
   CLS
   CENTER TEXT SCREEN WIDTH()/2,10,"YOU ARE ABLE TO FIND THE ANALYSIS FILE
AT"
   CENTER TEXT SCREEN WIDTH()/2,40, GET DIR$()
   CENTER TEXT SCREEN WIDTH()/2,70, "PRESS ANY KEY TO CONTINUE"
   SYNC
   WAIT KEY
 ENDIF
ENDIF

IF WORLD=1
 EXECUTE FILE "WORLDS/ESS/ESS.EXE","","",1
ENDIF

IF WORLD=2
 EXECUTE FILE "WORLDS/SMS/SMS.EXE","","",1
ENDIF

IF WORLD=3
 EXECUTE FILE "WORLDS/BBS/BBS.EXE","","",1
ENDIF

CLS
SYNC
CENTER TEXT SCREEN WIDTH()/2,60,"THANK YOU FOR USING THE SIMULATION..."
SYNC
WAIT 1500
```

B – 2: Empty Space Simulation source code

```
REM Project: ESS
REM Created: 2/25/2009 9:34:08 PM
REM
REM ***** Main Source File *****
REM

CLS
SYNC ON : SYNC RATE 0 : AUTOCAM OFF
SET TEXT FONT "VERDANA" : SET TEXT SIZE 15
AI START
AI SET RADIUS 8

MAP SHARED MEM TO BANK "MYBANK", 1, 40960
ENTITIES = BANK INTEGER(1,0)
DEFAULT = BANK INTEGER (1,4096)
CHILDREN = BANK INTEGER (1,8192)
TEENAGER = BANK INTEGER (1,12288)
ADULT = BANK INTEGER (1,16384)
ELDERLY = BANK INTEGER (1,20480)
DISABLED = BANK INTEGER (1,24576)
RUNTIME = BANK INTEGER (1,32768)

REM TO MAKE SURE USERS ARE ENTER FROM THE MAIN MENU
IF ENTITIES = 0
  SYNC
  CENTER TEXT SCREEN WIDTH()/2,20, " WARNING !! "
  CENTER TEXT SCREEN WIDTH()/2,40, " YOU MAY NOT ENTER THE NUMBER OF ENTITIES YET"
  CENTER TEXT SCREEN WIDTH()/2,60, " PLEASE GO BACK TO MENU OF THE SIMULATION"
   SYNC
   SLEEP 4000
ENDIF
IF ENTITIES <>0
REM DIMENSION
DIM CATEGORIES(ENTITIES)
DIM SPEED(ENTITIES)
DIM SIZE(ENTITIES)
DIM STARTPOINT(ENTITIES)
DIM ENDPOINT(ENTITIES)
DIM STARTTIME(ENTITIES)
DIM ENDTIME(ENTITIES)
DIM TRAVELTIME(ENTITIES)
DIM ENTITIESON(ENTITIES)
WIDTH#=800 `X
HEIGHT#=100 `Y
DEPTH#=800 `Z

REM CAMERA
REM *** W X H X D *** 800 X 100 X 800 ***
POSITION CAMERA 0,800,-(DEPTH#/2)
POINT CAMERA 0,0,0

REM FLOOR
MAKE OBJECT BOX ENTITIES+1,WIDTH#,2,DEPTH#
POSITION OBJECT ENTITIES+1,0,-1,0
COLOR OBJECT ENTITIES+1,RGB(255,255,255)

REM MAKE BOUNDARY OBSTACLE, ENCLOSES THE SPACE TO KEEP THE ENTITY IN
```

```
AI START NEW OBSTACLE
REM ADD POINTS IN A ANTI-CLOCKWISE DIRECTION TO CREATE A BOUNDARY (USE
CLOCKWISE TO CREATE AN OBSTACLE)
AI ADD OBSTACLE VERTEX -WIDTH#/2,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2,(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX -WIDTH#/2,(DEPTH#/2+65)
REM FINISH CREATING OUR BOUNDARY
AI END NEW OBSTACLE 0,1
AI COMPLETE OBSTACLES

REM DATASE - OPEN FILE & THE TITLE
OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE EMPTY SPACE SIMULATION.csv"
WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE EMPTY AREA"
DATALINE$="MAX NUMBER OF ENTITIES = "+STR$(ENTITIES)
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,"WORLD 1 - EMPTY AREA"
DATALINE$="CATEGORIES,DIFF. LEVEL OF HUMAN,COLOR,SIZE,SPEED;dm/s"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="0,CHILDREN,YELLOW,9,16"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="1,TEENAGER,PINK,10,15"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="2 3 6 7,ADULT,RED,12,13.5"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="4,ELDERLY,GREEN,15,11.3"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="5,DISABLED,BLUE,16,10"
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,""
WRITE DATAFILE STRING 1,"ENTITIES ID,CATEGORIES,STARTPOINT,ENDPOINT,START
TIME,END TIME,TIME TAKEN"
OPEN CONSOLE
PRINT CONSOLE "ID CATEGORIES STARTPOINT ENDPOINT TIME TAKEN"
PRINT CONSOLE
PRINT CONSOLE "== ========== ========== ======== =========="
PRINT CONSOLE

IF DEFAULT=0
  IF CHILDREN <>0
    FOR I=1 TO CHILDREN
      REM BORN THE ENTITIES
      CREATEENTITIESCHILDREN(I)
    NEXT I
  ENDIF

  IF TEENAGER <>0
    FOR I=CHILDREN+1 TO CHILDREN+TEENAGER
      REM BORN THE ENTITIES
      CREATEENTITIESTEENAGER(I)
    NEXT I
  ENDIF

  IF ADULT <>0
    FOR I=CHILDREN+TEENAGER+1 TO CHILDREN+TEENAGER+ADULT
      REM BORN THE ENTITIES
      CREATEENTITIESADULT(I)
    NEXT I
  ENDIF
```

```
    IF ELDERLY <>0
      FOR I=CHILDREN+TEENAGER+ADULT+1 TO CHILDREN+TEENAGER+ADULT+ELDERLY
        REM BORN THE ENTITIES
        CREATEENTITIESELDERLY(I)
      NEXT I
    ENDIF

    IF DISABLED <>0
      FOR I=CHILDREN+TEENAGER+ADULT+ELDERLY+1 TO
CHILDREN+TEENAGER+ADULT+ELDERLY+DISABLED
        REM BORN THE ENTITIES
        CREATEENTITIESDISABLED(I)
      NEXT I
    ENDIF

    FOR I=1 TO ENTITIES
      HIDE OBJECT I
      AI SET ENTITY VIEW ARC I,90,170
      STARTTIME(I)=0
      ENDTIME(I)=0
      TRAVELTIME(I)=0
      REM SET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    NEXT I
ENDIF REM FINISH DEFAULT=0

IF DEFAULT=1
  FOR I=1 TO ENTITIES
    REM BORN THE ENTITIES
    CREATEENTITIES(I)
    REM SET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  NEXT I
ENDIF REM FINISH DEFAULT=1

REM SIMULATION TIMER
RUNTIMESTART=TIMER()/1000

DO
  REM HANDLE DEBUGGING OUTPUT
  REM ***COPYRIGHT DBP***

  IF KEYSTATE(2)=1 AND PTIMER<TIMER()
    PTIMER = TIMER()+300
    PMODE = 1-PMODE

    IF ( PMODE=0 ) THEN AI DEBUG HIDE PATHS ELSE AI DEBUG SHOW PATHS 2.5
  ENDIF

  IF KEYSTATE(3)=1 AND ATIMER<TIMER()
    ATIMER = TIMER()+300
    AMODE = 1-AMODE

    IF ( AMODE=0 ) THEN AI DEBUG HIDE AVOIDANCE ANGLES ELSE AI DEBUG SHOW
AVOIDANCE ANGLES 2.5
  ENDIF

  IF KEYSTATE(4)=1 AND VTIMER<TIMER()
    VTIMER = TIMER()+300
```

```
    VMODE = 1-VMODE

  IF ( VMODE=0 ) THEN AI DEBUG HIDE VIEW ARCS ELSE AI DEBUG SHOW VIEW ARCS 2.5
ENDIF

IF ( KEYSTATE(59)=1 AND F1TIMER<TIMER() )
  F1TIMER = TIMER()+300

  F1PRESSED=1-F1PRESSED
ENDIF

IF ( F1PRESSED )
  REM DISPLAY INFO
  FPS$="FPS: "+STR$(SCREEN FPS())
  SET CURSOR 0,DEPTH#/2+40
  PRINT
  PRINT "ENTITIES FOLLOW PRESET PATHS, AVOIDING OTHER ENTITIES"
  PRINT
  PRINT
  PRINT
  PRINT
  PRINT
  PRINT
  TEXT 0,SCREEN HEIGHT()-120,"DEBUG CONTROLS:"
  TEXT 0,SCREEN HEIGHT()-100,"[1]    TOGGLE ENTITY PATH"
  TEXT 0,SCREEN HEIGHT()-80,"[2]    TOGGLE AVOIDANCE ANGLES"
  TEXT 0,SCREEN HEIGHT()-60,"[3]    TOGGLE VIEW ARCS"
  TEXT 0,SCREEN HEIGHT()-40,FPS$
  SET CURSOR 0,DEPTH#/2+40
ELSE
  CENTER TEXT SCREEN WIDTH()/2, 30, "-- PRESS F1 FOR HELP --"
ENDIF
REM ***COPYRIGHT DBP***

REM RESET THE ENTITIES ON THE STAGE
ENTITIESON=0

REM ACTION - HIDE, KILL OBJECTS
FOR I= 1 TO ENTITIES
  REM MAKE SURE KILLED EMERMY WILL NOT "EXIST"
  IF AI ENTITY EXIST(I)=1
    REM HIDE THE OBJECTS  -- B4 ENTERING & AFTER LEAVING THE STAGE
    IF AI GET ENTITY Z (I)>(DEPTH#/2)
      HIDE OBJECT I
      ENTITIESON(I)=0
    ENDIF
    IF AI GET ENTITY Z (I)<(-DEPTH#/2)
      HIDE OBJECT I
      ENTITIESON(I)=0
    ENDIF
    REM SHOW THE OBJECT  -- WHEN ON THE STAGE
    IF AI GET ENTITY Z (I)<(DEPTH#/2) AND AI GET ENTITY Z (I)>(-DEPTH#/2)
      IF STARTTIME(I)=0 THEN STARTTIME(I)=TIMER()/1000
      SHOW OBJECT I
      ENTITIESON(I)=1
    ENDIF

    REM ARRIVE DESTINATION AND DELETE OBEJCT
    REM DESTINATION IS 1
    IF ENDPOINT(I)=1 REM AND AI ENTITY EXIST(I)=1
```

```
      IF AI GET ENTITY Z (I)<(-DEPTH#/2)
        IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
        TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
        DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
        WRITE DATAFILE STRING 1, DATALINE$
        IF I=>10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        AI KILL ENTITY I
        DELETE OBJECT I
        ENTITIESON(I)=0
      ENDIF
    ENDIF
    REM DESTINATION IS 2
    IF ENDPOINT(I)=2 REM AND AI ENTITY EXIST(I)=1
      IF AI GET ENTITY Z (I)>(DEPTH#/2)
        IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
        TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
        DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
        WRITE DATAFILE STRING 1, DATALINE$
        IF I=>10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        AI KILL ENTITY I
        DELETE OBJECT I
        ENTITIESON(I)=0
      ENDIF
    ENDIF
  ENDIF REM ENDIF ENERMY EXIST =1
  REM TO REBORN THE KILLED ENERMY

  IF AI ENTITY EXIST(I)=0 AND DEFAULT=0
    IF CATEGORIES(I)=0
      REM BORN THE ENTITIES
      CREATEENTITIESCHILDREN(I)
    ENDIF

    IF CATEGORIES(I)=1
      REM BORN THE ENTITIES
      CREATEENTITIESTEENAGER(I)
    ENDIF
```

```
      IF CATEGORIES(I)=2
        REM BORN THE ENTITIES
        CREATEENTITIESADULT(I)
      ENDIF

      IF CATEGORIES(I)=4
        REM BORN THE ENTITIES
        CREATEENTITIESELDERLY(I)
      ENDIF

      IF CATEGORIES(I)=5
        REM BORN THE ENTITIES
        CREATEENTITIESDISABLED(I)
      ENDIF
      HIDE OBJECT I
      AI SET ENTITY VIEW ARC I,90,170
      STARTTIME(I)=0
      ENDTIME(I)=0
      TRAVELTIME(I)=0
      REM RESET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    ENDIF REM FINISH REBORN ENEMY

    REM TO REBORN THE KILLED ENEMY IN DEFAULT SETTING
    IF AI ENTITY EXIST(I)=0 AND DEFAULT=1
      REM REBORN THE ENTITIES
      CREATEENTITIES(I)
      REM RESET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    ENDIF REM FINISH REBORN ENEMY IN DEFAULT SETTING

    REM CALCULATE THE NUMBER OF ENTITIES ON THE STAGE
    ENTITIESON= ENTITIESON+ENTITIESON(I)
  NEXT I

  REM TIME
  HR$=LEFT$(GET TIME$(),2)
  HR=VAL(HR$)
  IF HR=>12
    IF HR> 12 THEN HR=HR-12
    POST$=" PM"
  ELSE
    POST$=" AM"
  ENDIF
  TIME$=STR$(HR)+RIGHT$(GET TIME$(),6)+POST$

  REM PRINT THE TIME AT THE BOTTOM OF THE SCREEN
  TEXT 7*SCREEN WIDTH()/8,SCREEN HEIGHT()-20,TIME$

  REM SIMULATION TIMER
  SET TEXT SIZE 12
  IF TIMER()/1000>RUNTIMESTART+RUNTIME THEN EXIT
  TEXT 7*SCREEN WIDTH()/8+5,SCREEN HEIGHT()-35,"TIMER:
"+STR$(RUNTIMESTART+RUNTIME-TIMER()/1000)

  SET TEXT SIZE 15
  CENTER TEXT SCREEN WIDTH()/2, 30, "-- PRESS F1 FOR HELP --"
  SET CURSOR 0,0
  PRINT "NO. OF ENTITIES: ",ENTITIESON," / ",ENTITIES
  PRINT ""
```

```
    PRINT "CATEGORIES:- "
    PRINT " CHILDREN- YELLOW"
    PRINT " TEENAGER - PINK"
    PRINT " ADULT - RED"
    PRINT " ELDERLY - GREEN"
    PRINT " DISABLED - BLUE"
    AI UPDATE
    SYNC
  LOOP
ENDIF REM FOR THE ENTITIES <>0
END REM FINISH THE SIMULATION

REM CREATE DIFF CATEGORIES OF ENTITIES
FUNCTION CREATEENTITIES(I)
  CATEGORIES(I)=RND(7)
  REM CHILDREN
  IF CATEGORIES(I)=0
    SIZE(I)=9
    SPEED(I)=16
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM TEENAGER
  IF CATEGORIES(I)=1
    SIZE(I)=10
    SPEED(I)=15
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM NORMAL ADULT
  IF CATEGORIES(I)=2 OR CATEGORIES(I)=3 OR CATEGORIES(I)=6 OR CATEGORIES(I)=7
    SIZE(I)=12
    SPEED(I)=13.5
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB (255,0,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,25
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM ELDERLY
  IF CATEGORIES(I)=4
    SIZE(I)=15
    SPEED(I)=11.3
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,20
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM DISABLED PEOPLE
```

```
  IF CATEGORIES(I)=5
    SIZE(I)=16
    SPEED(I)=10
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,18
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF
  AI SET ENTITY SPEED I,SPEED(I)
  HIDE OBJECT I
  AI SET ENTITY VIEW ARC I,90,170
  STARTTIME(I)=0
  ENDTIME(I)=0
  TRAVELTIME(I)=0
  SYNC
ENDFUNCTION

REM CEATE ENTITIES UNDER USER DETERMINED
FUNCTION CREATEENTITIESCHILDREN(I)
  REM CHILDREN
  CATEGORIES(I)=0
  SPEED(I)=16
  SIZE(I)=9
  MAKE OBJECT SPHERE I, SIZE(I)
  COLOR OBJECT I,RGB(255,255,0)
  AI ADD ENEMY I
  AI SET ENTITY SPEED I,SPEED(I)
  AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESTEENAGER(I)
  REM TEENAGER
  CATEGORIES(I)=1
  SPEED(I)=15
  SIZE(I)=10
  MAKE OBJECT SPHERE I, SIZE(I)
  COLOR OBJECT I,RGB(255,0,255)
  AI ADD ENEMY I
  AI SET ENTITY SPEED I,SPEED(I)
  AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  SYNC
ENDFUNCTION


FUNCTION CREATEENTITIESADULT(I)
  REM NORMAL ADULT
  CATEGORIES(I)=2
  SPEED(I)=13.5
  SIZE(I)=12
  MAKE OBJECT SPHERE I, SIZE(I)
  COLOR OBJECT I,RGB (255,0,0)
  AI ADD ENEMY I
  AI SET ENTITY SPEED I,SPEED(I)
  AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESELDERLY(I)
```

```
  REM ELDERLY
  CATEGORIES(I)=4
  SPEED(I)=11.3
  SIZE(I)=15
  MAKE OBJECT SPHERE I, SIZE(I)
  COLOR OBJECT I,RGB(0,255,0)
  AI ADD ENEMY I
  AI SET ENTITY SPEED I,SPEED(I)
  AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESDISABLED(I)
  REM DISABLED PEOPLE
  CATEGORIES(I)=5
  SPEED(I)=10
  SIZE(I)=16
  MAKE OBJECT SPHERE I, SIZE(I)
  COLOR OBJECT I,RGB(0,0,255)
  AI ADD ENEMY I
  AI SET ENTITY SPEED I,SPEED(I)
  AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  SYNC
ENDFUNCTION

REM STARTING POINT AND WHERE TO GO
FUNCTION STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  STARTPOINT(I) =RND(1)+1
  REM AT EXIT 1
  IF STARTPOINT(I)=1
    POSITION OBJECT I, RND(WIDTH#)-WIDTH#/2, 10,-(RND(40)+DEPTH#/2+25)
    REM GO TO EXIT 2
    AI ENTITY GO TO POSITION I,(RND(WIDTH#)-WIDTH#/2),(RND(40)+DEPTH#/2+25)
    ENDPOINT(I)=2
  ENDIF

  REM AT EXIT 2
  IF STARTPOINT(I)=2
    POSITION OBJECT I, RND(WIDTH#)-WIDTH#/2, 10,(RND(DEPTH#/4)+DEPTH#/2)
    REM GO TO EXIT 1
    AI ENTITY GO TO POSITION I,(RND(WIDTH#)-WIDTH#/2),-(RND(DEPTH#/4)+DEPTH#/2)
    ENDPOINT(I)=1
  ENDIF
  SYNC
ENDFUNCTION
```

```
REM Project: SMS
REM Created: 3/15/2009 1:41:00 PM
REM
REM ***** Main Source File *****
REM

CLS
SYNC ON : SYNC RATE 0 : AUTOCAM OFF
SET TEXT FONT "VERDANA" : SET TEXT SIZE 15
AI START
AI SET RADIUS 8

MAP SHARED MEM TO BANK "MYBANK", 1, 40960
ENTITIES = BANK INTEGER(1,0)
DEFAULT = BANK INTEGER (1,4096)
CHILDREN = BANK INTEGER (1,8192)
TEENAGER = BANK INTEGER (1,12288)
ADULT = BANK INTEGER (1,16384)
ELDERLY = BANK INTEGER (1,20480)
DISABLED = BANK INTEGER (1,24576)
CONDITION = BANK INTEGER (1,28672)
RUNTIME = BANK INTEGER (1,32768)

REM TO MAKE SURE USERS ARE ENTER FROM THE MAIN MENU
IF ENTITIES = 0
  SYNC
  CENTER TEXT SCREEN WIDTH()/2,20, " WARNING !! "
  CENTER TEXT SCREEN WIDTH()/2,40, " YOU MAY NOT ENTER THE NUMBER OF ENTITIES YET"
  CENTER TEXT SCREEN WIDTH()/2,60, " PLEASE GO BACK TO MENU OF THE SIMULATION"
   SYNC
  SLEEP 4000
ENDIF

IF ENTITIES <> 0
REM DIMENSION
DIM CATEGORIES(ENTITIES)
DIM SPEED(ENTITIES)
DIM SIZE(ENTITIES)
DIM STARTPOINT(ENTITIES)
DIM ENDPOINT(ENTITIES)
DIM STARTTIME(ENTITIES)
DIM ENDTIME(ENTITIES)
DIM TRAVELTIME(ENTITIES)
DIM ENTITIESON(ENTITIES)
DIM SHOP(ENTITIES)
DIM STATUSOUT(ENTITIES) REM TO CHECK EITHER THE ENTITIES GO OUT THE SHOP O NOT
WIDTH#=800  `X
HEIGHT#=100  `Y
DEPTH#=800  `Z
CAMERAX=-70
CAMERAY=800
CAMERAZ=20




REM CAMERA
REM *** W X H X D *** 800 X 100 X 800 ***
COLOR BACKDROP RGB(128,64,0)
```

```
POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
POINT CAMERA CAMERAX,0,CAMERAZ
SET CAMERA RANGE 100,1100

REM FLOOR
MAKE OBJECT BOX ENTITIES+1,WIDTH#,2,DEPTH#
POSITION OBJECT ENTITIES+1,0,-2,0
COLOR OBJECT ENTITIES+1,RGB(255,255,255)

REM WALL BETWEEN SHOPS ON RIGHT
FOR I=ENTITIES+2 TO ENTITIES+10
  MAKE OBJECT BOX I,WIDTH#/4,50,10
  POSITION OBJECT I,3*WIDTH#/8,25,4*DEPTH#/8-(DEPTH#/8*(I-ENTITIES-2))
  COLOR OBJECT I,RGB(64,128,128)
  AI ADD STATIC OBSTACLE I
NEXT I

REM WALL BETWEEN SHOPS ON LEFT
FOR I=ENTITIES+11 TO ENTITIES+19
  MAKE OBJECT BOX I,WIDTH#/4,50,10
  POSITION OBJECT I,-3*WIDTH#/8,25,4*DEPTH#/8-(DEPTH#/8*(I-ENTITIES-11))
  COLOR OBJECT I,RGB(64,128,128)
  AI ADD STATIC OBSTACLE I
NEXT I

REM WALL AT BOTH LEFT AND RIGHT SIDE
FOR I=ENTITIES+20 TO ENTITIES+21
  MAKE OBJECT BOX I,10,50,DEPTH#
  POSITION OBJECT I,WIDTH#/2+5-(I-ENTITIES-20)*(WIDTH#+10),25,0
  COLOR OBJECT I,RGB(64,128,128)
  AI ADD STATIC OBSTACLE I
NEXT I

REM NARROW THE ENTRANCE OF RIGHT SHOPS
FOR I=ENTITIES+22 TO ENTITIES+28
  MAKE OBJECT BOX I,10,50,50
  POSITION OBJECT I,2*WIDTH#/8,25,3*DEPTH#/8-(DEPTH#/8*(I-ENTITIES-22))
  COLOR OBJECT I,RGB(64,128,128)
  AI ADD STATIC OBSTACLE I
NEXT I

REM NARROW THE ENTRANCE OF LEFT SHOPS
FOR I=ENTITIES+29 TO ENTITIES+35
  MAKE OBJECT BOX I,10,50,50
  POSITION OBJECT I,-2*WIDTH#/8,25,3*DEPTH#/8-(DEPTH#/8*(I-ENTITIES-29))
  COLOR OBJECT I,RGB(64,128,128)
  AI ADD STATIC OBSTACLE I
NEXT I

REM BOTTOM RIGHT
MAKE OBJECT BOX ENTITIES+36,10,50,30
POSITION OBJECT ENTITIES+36,2*WIDTH#/8,25,-depth#/2+10
COLOR OBJECT ENTITIES+36,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+36

REM UPPER RIGHT
MAKE OBJECT BOX ENTITIES+37,10,50,30
POSITION OBJECT ENTITIES+37,2*WIDTH#/8,25,depth#/2-10
COLOR OBJECT ENTITIES+37,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+37
```

```
REM BOTTOM LEFT
MAKE OBJECT BOX ENTITIES+38,10,50,30
POSITION OBJECT ENTITIES+38,-2*WIDTH#/8,25,-depth#/2+10
COLOR OBJECT ENTITIES+38,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+38

REM UPPER LEFT
MAKE OBJECT BOX ENTITIES+39,10,50,30
POSITION OBJECT ENTITIES+39,-2*WIDTH#/8,25,depth#/2-10
COLOR OBJECT ENTITIES+39,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+39

REM DISPLAY SHOP NAME
REM SHOP NAME AT LEFT
CLS
CENTER TEXT 50,0,"Curry's Digital™"
GET IMAGE 1,0,0,100,17,1
MAKE OBJECT PLAIN ENTITIES+40,90,25,1
XROTATE OBJECT ENTITIES+40,90
TEXTURE OBJECT ENTITIES+40,1
YROTATE OBJECT ENTITIES+40,-90
POSITION OBJECT ENTITIES+40,-WIDTH#/2+5+22,50,-7*DEPTH#/16

CLS
CENTER TEXT 40,0,"WHSmith™"
GET IMAGE 2,0,0,80,17,1
MAKE OBJECT PLAIN ENTITIES+41,90,25,1
XROTATE OBJECT ENTITIES+41,90
TEXTURE OBJECT ENTITIES+41,2
YROTATE OBJECT ENTITIES+41,-90
POSITION OBJECT ENTITIES+41,-WIDTH#/2+5+22,50,-5*DEPTH#/16

CLS
CENTER TEXT 30,0,"NEXT™"
GET IMAGE 3,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+42,90,25,1
XROTATE OBJECT ENTITIES+42,90
TEXTURE OBJECT ENTITIES+42,3
YROTATE OBJECT ENTITIES+42,-90
POSITION OBJECT ENTITIES+42,-WIDTH#/2+5+22,50,-3*DEPTH#/16

CLS
CENTER TEXT 30,0,"GAME™"
GET IMAGE 4,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+43,90,25,1
XROTATE OBJECT ENTITIES+43,90
TEXTURE OBJECT ENTITIES+43,4
YROTATE OBJECT ENTITIES+43,-90
POSITION OBJECT ENTITIES+43,-WIDTH#/2+5+22,50,-1*DEPTH#/16

CLS
CENTER TEXT 30,0,"Boots™"
GET IMAGE 5,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+44,90,25,1
XROTATE OBJECT ENTITIES+44,90
TEXTURE OBJECT ENTITIES+44,5
YROTATE OBJECT ENTITIES+44,-90
POSITION OBJECT ENTITIES+44,-WIDTH#/2+5+22,50,1*DEPTH#/16
```

```
CLS
CENTER TEXT 33,0,"Barratts™"
GET IMAGE 6,0,0,64,17,1
MAKE OBJECT PLAIN ENTITIES+45,90,25,1
XROTATE OBJECT ENTITIES+45,90
TEXTURE OBJECT ENTITIES+45,6
YROTATE OBJECT ENTITIES+45,-90
POSITION OBJECT ENTITIES+45,-WIDTH#/2+5+22,50,3*DEPTH#/16

CLS
CENTER TEXT 30,0,"Clarks™"
GET IMAGE 7,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+46,90,25,1
XROTATE OBJECT ENTITIES+46,90
TEXTURE OBJECT ENTITIES+46,7
YROTATE OBJECT ENTITIES+46,-90
POSITION OBJECT ENTITIES+46,-WIDTH#/2+5+22,50,5*DEPTH#/16

CLS
CENTER TEXT 30,0,"HSBC™"
GET IMAGE 8,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+47,90,25,1
XROTATE OBJECT ENTITIES+47,90
TEXTURE OBJECT ENTITIES+47,8
YROTATE OBJECT ENTITIES+47,-90
POSITION OBJECT ENTITIES+47,-WIDTH#/2+5+22,50,7*DEPTH#/16

REM SHOP NAME AT RIGHT
CLS
CENTER TEXT 30,0,"Claire's™"
GET IMAGE 9,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+48,90,25,1
XROTATE OBJECT ENTITIES+48,90
TEXTURE OBJECT ENTITIES+48,9
YROTATE OBJECT ENTITIES+48,90
POSITION OBJECT ENTITIES+48,WIDTH#/2-5-22,50,-7*DEPTH#/16

CLS
CENTER TEXT 40,0,"Thornton's™"
GET IMAGE 10,0,0,80,17,1
MAKE OBJECT PLAIN ENTITIES+49,90,25,1
XROTATE OBJECT ENTITIES+49,90
TEXTURE OBJECT ENTITIES+49,10
YROTATE OBJECT ENTITIES+49,90
POSITION OBJECT ENTITIES+49,WIDTH#/2-5-22,50,-5*DEPTH#/16

CLS
CENTER TEXT 40,0,"Vodafone™"
GET IMAGE 11,0,0,80,17,1
MAKE OBJECT PLAIN ENTITIES+50,90,25,1
XROTATE OBJECT ENTITIES+50,90
TEXTURE OBJECT ENTITIES+50,11
YROTATE OBJECT ENTITIES+50,90
POSITION OBJECT ENTITIES+50,WIDTH#/2-5-22,50,-3*DEPTH#/16

CLS
CENTER TEXT 32,0,"Tyler's™"
GET IMAGE 12,0,0,64,17,1
MAKE OBJECT PLAIN ENTITIES+51,90,25,1
XROTATE OBJECT ENTITIES+51,90
```

```
TEXTURE OBJECT ENTITIES+51,12
YROTATE OBJECT ENTITIES+51,90
POSITION OBJECT ENTITIES+51,WIDTH#/2-5-22,50,-1*DEPTH#/16

CLS
CENTER TEXT 40,0,"The Works™"
GET IMAGE 13,0,0,80,17,1
MAKE OBJECT PLAIN ENTITIES+52,90,25,1
XROTATE OBJECT ENTITIES+52,90
TEXTURE OBJECT ENTITIES+52,13
YROTATE OBJECT ENTITIES+52,90
POSITION OBJECT ENTITIES+52,WIDTH#/2-5-22,50,1*DEPTH#/16

CLS
CENTER TEXT 30,0,"Orange™"
GET IMAGE 14,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+53,90,25,1
XROTATE OBJECT ENTITIES+53,90
TEXTURE OBJECT ENTITIES+53,14
YROTATE OBJECT ENTITIES+53,90
POSITION OBJECT ENTITIES+53,WIDTH#/2-5-22,50,3*DEPTH#/16

CLS
CENTER TEXT 32,0,"TK Maxx™"
GET IMAGE 15,0,0,64,17,1
MAKE OBJECT PLAIN ENTITIES+54,90,25,1
XROTATE OBJECT ENTITIES+54,90
TEXTURE OBJECT ENTITIES+54,15
YROTATE OBJECT ENTITIES+54,90
POSITION OBJECT ENTITIES+54,WIDTH#/2-5-22,50,5*DEPTH#/16

CLS
CENTER TEXT 30,0,"Cargo™"
GET IMAGE 16,0,0,60,17,1
MAKE OBJECT PLAIN ENTITIES+55,90,25,1
XROTATE OBJECT ENTITIES+55,90
TEXTURE OBJECT ENTITIES+55,16
YROTATE OBJECT ENTITIES+55,90
POSITION OBJECT ENTITIES+55,WIDTH#/2-5-22,50,7*DEPTH#/16
REM FINISH NAMING SHOP
IF CONDITION=0
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C0.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN0"
ENDIF REM FINISH CONDITION 1

IF CONDITION=1
  REM OBSTACLES - ROUND ABOUT 1
  MAKE OBJECT SPHERE ENTITIES+56,120
  POSITION OBJECT ENTITIES+56,0,0,-3*DEPTH#/8
  COLOR OBJECT ENTITIES+56,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+56

  REM OBSTACLES - ROUND ABOUT 2
  MAKE OBJECT SPHERE ENTITIES+57,120
  POSITION OBJECT ENTITIES+57,0,0,0*DEPTH#/8
  COLOR OBJECT ENTITIES+57,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+57
```

```
    REM OBSTACLES - ROUND ABOUT 3
    MAKE OBJECT SPHERE ENTITIES+58,120
    POSITION OBJECT ENTITIES+58,0,0,3*DEPTH#/8
    COLOR OBJECT ENTITIES+58,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+58
    REM CREATE CSV&TITLE
    OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C1.csv"
    WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN1"
ENDIF REM FINISH CONDITION 1

IF CONDITION=2
    REM OBSTACLE
    MAKE OBJECT BOX ENTITIES+56, 0.7*WIDTH#/4,50,20
    POSITION OBJECT ENTITIES+56, 0,25,-5*DEPTH#/16
    COLOR OBJECT ENTITIES+56,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+56

    MAKE OBJECT BOX ENTITIES+57, 0.7*WIDTH#/4,50,20
    POSITION OBJECT ENTITIES+57, 0,25,5*DEPTH#/16
    COLOR OBJECT ENTITIES+57,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+57

    MAKE OBJECT BOX ENTITIES+58, 20,50,DEPTH#*0.35
    POSITION OBJECT ENTITIES+58, -WIDTH#/8-10,25,-2*DEPTH#/8
    COLOR OBJECT ENTITIES+58,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+58

    MAKE OBJECT BOX ENTITIES+59, 20,50,DEPTH#*0.35
    POSITION OBJECT ENTITIES+59, -WIDTH#/8-10,25,2*DEPTH#/8
    COLOR OBJECT ENTITIES+59,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+59

    MAKE OBJECT BOX ENTITIES+60, 20,50,DEPTH#*0.35
    POSITION OBJECT ENTITIES+60, WIDTH#/8+10,25,-2*DEPTH#/8
    COLOR OBJECT ENTITIES+60,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+60

    MAKE OBJECT BOX ENTITIES+61, 20,50,DEPTH#*0.35
    POSITION OBJECT ENTITIES+61, WIDTH#/8+10,25,2*DEPTH#/8
    COLOR OBJECT ENTITIES+61,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+61
    REM CREATE CSV&TITLE
    OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C2.csv"
    WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN2"
ENDIF REM FINISH CONDITION 2

IF CONDITION=3
    REM OBSTACLES1
    FOR I=ENTITIES+56 TO ENTITIES+64
        MAKE OBJECT BOX I,20,30,50
        YROTATE OBJECT I,-45
        POSITION OBJECT I,-WIDTH#/8-ABS(7.5*(5-(I-ENTITIES-56)))+40,20,-DEPTH#/2+(I-ENTITIES-
55)*DEPTH#/10
        COLOR OBJECT I,RGB(0,0,0)
        AI ADD STATIC OBSTACLE I
    NEXT I

    FOR I=ENTITIES+65 TO ENTITIES+73
```

```
    MAKE OBJECT BOX I,20,30,50
    YROTATE OBJECT I,45
    POSITION OBJECT I,WIDTH#/8+ABS(7.5*(5-(I-ENTITIES-65)))-40,20,-DEPTH#/2+(I-ENTITIES-
64)*DEPTH#/10
    COLOR OBJECT I,RGB(0,0,0)
    AI ADD STATIC OBSTACLE I
  NEXT I
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C3.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN3"
ENDIF REM FINISH CONDITION 3

IF CONDITION=4
  REM OBSTACLES1
  FOR I=ENTITIES+56 TO ENTITIES+64
    MAKE OBJECT BOX I,20,30,50
    YROTATE OBJECT I,(I-ENTITIES-55)*180/10
    POSITION OBJECT I,-WIDTH#/8+ABS((5-(I-ENTITIES-55))*WIDTH#/80),20,-DEPTH#/2+(I-
ENTITIES-55)*DEPTH#/10
    COLOR OBJECT I,RGB(0,0,0)
    AI ADD STATIC OBSTACLE I
  NEXT I

  FOR I=ENTITIES+65 TO ENTITIES+73
    MAKE OBJECT BOX I,20,30,50
    YROTATE OBJECT I,-(I-ENTITIES-64)*180/10
    POSITION OBJECT I,WIDTH#/8-ABS((5-(I-ENTITIES-64))*WIDTH#/80),20,-DEPTH#/2+(I-
ENTITIES-64)*DEPTH#/10
    COLOR OBJECT I,RGB(0,0,0)
    AI ADD STATIC OBSTACLE I
  NEXT I
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C4.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN4"
ENDIF REM FINISH CONDITION 4

IF CONDITION=5
  REM OBSTACLES1
  FOR I=ENTITIES+56 TO ENTITIES+63
    MAKE OBJECT BOX I,35,30,70
    YROTATE OBJECT I,RND(180)
    POSITION OBJECT I,-WIDTH#/8+RND(2*WIDTH#/8),20,-DEPTH#/2+(I-ENTITIES-55)*DEPTH#/9
    COLOR OBJECT I,RGB(0,0,0)
    AI ADD STATIC OBSTACLE I
  NEXT I
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE SHOPPING MALL SIMULATOR C5.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE SHOPPING MALL-DESIGN5"
ENDIF REM FINISH CONDITION 5

REM MAKE BOUNDARY OBSTACLE, ENCLOSES THE SPACE TO KEEP THE ENTITY IN
REM ADD POINTS IN A ANTI-CLOCKWISE DIRECTION TO CREATE A BOUNDARY (USE
CLOCKWISE TO CREATE AN OBSTACLE)
AI START NEW OBSTACLE
AI ADD OBSTACLE VERTEX -WIDTH#/2-5,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2+5,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2+5,(DEPTH#/2+65)
```

```
AI ADD OBSTACLE VERTEX -WIDTH#/2-5,(DEPTH#/2+65)
AI END NEW OBSTACLE 0,1
REM FINISH CREATING ALL BOUNDARY

AI COMPLETE OBSTACLES

REM DATASE&CONSOLE
DATALINE$="MAX NUMBER OF ENTITIES = "+STR$(ENTITIES)
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,"WORLD 2 - SHOPPING MALL"
DATALINE$="CATEGORIES,DIFF. LEVEL OF HUMAN,COLOR,SIZE,SPEED;dm/s"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="0,CHILDREN,YELLOW,9,16"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="1,TEENAGER,PINK,10,15"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="2 3 6 7,ADULT,RED,12,13.5"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="4,ELDERLY,GREEN,15,11.3"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="5,DISABLED,BLUE,16,10"
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,""
WRITE DATAFILE STRING 1,"ENTITIES ID,CATEGORIES,STARTPOINT,ENDPOINT,SHOP,START
TIME,END TIME,TIME TAKEN"
OPEN CONSOLE
PRINT CONSOLE "ID CATEGORIES STARTPOINT ENDPOINT SHOP TIME TAKEN"
PRINT CONSOLE
PRINT CONSOLE "== ========= ========= ======= ==== =========="
PRINT CONSOLE

IF DEFAULT=0
  IF CHILDREN <>0
    FOR I=1 TO CHILDREN
      REM BORN THE ENTITIES
      CREATEENTITIESCHILDREN(I)
    NEXT I
  ENDIF

  IF TEENAGER <>0
    FOR I=CHILDREN+1 TO CHILDREN+TEENAGER
      REM BORN THE ENTITIES
      CREATEENTITIESTEENAGER(I)
    NEXT I
  ENDIF

  IF ADULT <>0
    FOR I=CHILDREN+TEENAGER+1 TO CHILDREN+TEENAGER+ADULT
      REM BORN THE ENTITIES
      CREATEENTITIESADULT(I)
    NEXT I
  ENDIF

  IF ELDERLY <>0
    FOR I=CHILDREN+TEENAGER+ADULT+1 TO CHILDREN+TEENAGER+ADULT+ELDERLY
      REM BORN THE ENTITIES
      CREATEENTITIESELDERLY(I)
    NEXT I
  ENDIF
```

```
    IF DISABLED <>0
      FOR I=CHILDREN+TEENAGER+ADULT+ELDERLY+1 TO
CHILDREN+TEENAGER+ADULT+ELDERLY+DISABLED
        REM BORN THE ENTITIES
        CREATEENTITIESDISABLED(I)
      NEXT I
    ENDIF

    FOR I=1 TO ENTITIES
      HIDE OBJECT I
      AI SET ENTITY VIEW ARC I,90,170
      STARTTIME(I)=0
      ENDTIME(I)=0
      TRAVELTIME(I)=0
      REM SET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    NEXT I
ENDIF REM FINISH DEFAULT=0

IF DEFAULT=1
  FOR I=1 TO ENTITIES
    REM BORN THE ENTITIES
    CREATEENTITIES(I)
    REM SET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  NEXT I
ENDIF REM FINISH DEFAULT=1

REM SIMULATION TIMER
RUNTIMESTART=TIMER()/1000

DO
  REM HANDLE DEBUGGING OUTPUT
  REM ***COPYRIGHT DBP***
  REM
  IF KEYSTATE(2)=1 AND PTIMER<TIMER()
    PTIMER = TIMER()+300
    PMODE = 1-PMODE

    IF ( PMODE=0 ) THEN AI DEBUG HIDE PATHS ELSE AI DEBUG SHOW PATHS 2.5
  ENDIF

  IF KEYSTATE(3)=1 AND ATIMER<TIMER()
    ATIMER = TIMER()+300
    AMODE = 1-AMODE

    IF ( AMODE=0 ) THEN AI DEBUG HIDE AVOIDANCE ANGLES ELSE AI DEBUG SHOW
AVOIDANCE ANGLES 2.5
  ENDIF

  IF KEYSTATE(4)=1 AND VTIMER<TIMER()
    VTIMER = TIMER()+300
    VMODE = 1-VMODE

    IF ( VMODE=0 ) THEN AI DEBUG HIDE VIEW ARCS ELSE AI DEBUG SHOW VIEW ARCS 2.5
  ENDIF

  IF ( KEYSTATE(59)=1 AND F1TIMER<TIMER() )
    F1TIMER = TIMER()+300
```

```
    F1PRESSED=1-F1PRESSED
  ENDIF REM ***COPYRIGHT DBP***

  REM CAMERA CONTROLS
  IF DOWNKEY()=1
    CAMERAZ=CAMERAZ-2
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  IF UPKEY()=1
    CAMERAZ=CAMERAZ+2
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  IF RIGHTKEY()=1
    CAMERAX=CAMERAX+2
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  IF LEFTKEY()=1
    CAMERAX=CAMERAX-2
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  REM PAGE UP KEY-ZOOM IN
  IF KEYSTATE(201)=1
    CAMERAY=CAMERAY-5
    IF CAMERAY<350 THEN CAMERAY=350
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  REM PAGEDOWN KEY-ZOOM OUT
  IF KEYSTATE(209)=1
    CAMERAY=CAMERAY+5
    IF CAMERAY>1000 THEN CAMERAY=1000
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  REM HOME KEY -RESET TO ORI POSITION
  IF KEYSTATE(199)=1
    CAMERAX=-70
    CAMERAY=800
    CAMERAZ=20
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF

  IF ( F1PRESSED )
    REM DISPLAY INFO
    FPS$="FPS: "+STR$(SCREEN FPS())
    SET CURSOR 0,DEPTH#/2+40
    PRINT
    PRINT "ENTITIES FOLLOW PRESET PATHS, AVOIDING OTHER ENTITIES"
    PRINT
    PRINT
    PRINT
    PRINT
    PRINT
    PRINT
    TEXT 0,SCREEN HEIGHT()-120,"DEBUG CONTROLS:"
```

```
      TEXT 0,SCREEN HEIGHT()-100,"[1]    TOGGLE ENTITY PATH"
      TEXT 0,SCREEN HEIGHT()-80,"[2]    TOGGLE AVOIDANCE ANGLES"
      TEXT 0,SCREEN HEIGHT()-60,"[3]    TOGGLE VIEW ARCS"
      TEXT 0,SCREEN HEIGHT()-40,FPS$
      TEXT 300,SCREEN HEIGHT()-120,"CAMERA CONTROLS:"
      TEXT 300,SCREEN HEIGHT()-100,"   [^]"
      TEXT 300,SCREEN HEIGHT()-80,"[<][V][>]"
      TEXT 300,SCREEN HEIGHT()-90,"          CAMERA MOTION KEY"
      TEXT 300,SCREEN HEIGHT()-60,"[PGDN]    ZOOM OUT"
      TEXT 300,SCREEN HEIGHT()-40,"[PGUP]    ZOOM IN"
      TEXT 300,SCREEN HEIGHT()-20,"[HOME]    BACK TO ORI"

  ELSE
    CENTER TEXT SCREEN WIDTH()/2, 25, "-- PRESS F1 FOR HELP --"
  ENDIF

  REM RESET THE ENTITIES ON THE STAGE
  ENTITIESON=0

  REM ACTION - SHOPPING, HIDE, KILL OBJECTS
  FOR I= 1 TO ENTITIES
    REM SHOPPING ON THE LEFT SIDE
    IF ENDPOINT(I)=3
      IF AI GET ENTITY X(I) <-3*WIDTH#/8+10 AND STATUSOUT(I)=0 AND AI GET ENTITY Z(I)<
DEPTH#/2 AND AI GET ENTITY Z(I)>-DEPTH#/2
        IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
        TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
        DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
HOP(I))+","+STR$(STARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
        WRITE DATAFILE STRING 1, DATALINE$
        IF I=>10 AND SHOP(I)<10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I=>10 AND SHOP(I)=>10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10 AND SHOP(I)<10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10 AND SHOP(I)=>10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        STARTPOINT(I)=ENDPOINT(I)
        ENDTIME(I)=0
        TRAVELTIME(I)=0
        SHOP(I)=0
        STARTTIME(I)=TIMER()/1000
        AI ENTITY GO TO POSITION I, 0,0
        STATUSOUT(I)=1

      ENDIF
```

```
        IF STATUSOUT(I)=1 AND AI GET ENTITY X(I)>-2*WIDTH#/8+5
          AI ENTITY STOP I
          ENDPOINT(I)=RND(3)+1
          ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
          STATUSOUT(I)=0
        ENDIF
      ENDIF

      IF ENDPOINT(I)=4
        IF AI GET ENTITY X(I)>3*WIDTH#/8-10 AND STATUSOUT(I)=0 AND AI GET ENTITY Z(I)<
DEPTH#/2 AND AI GET ENTITY Z(I)>-DEPTH#/2
          IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
          TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
          DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
HOP(I))+","+STR$(STARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
          WRITE DATAFILE STRING 1, DATALINE$
          IF I=>10 AND SHOP(I)<10
            PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          IF I=>10 AND SHOP(I)=>10
            PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          IF I<10 AND SHOP(I)<10
            PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          IF I<10 AND SHOP(I)=>10
            PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",SHOP(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          STARTPOINT(I)=ENDPOINT(I)
          ENDTIME(I)=0
          TRAVELTIME(I)=0
          SHOP(I)=0
          STARTTIME(I)=TIMER()/1000
          AI ENTITY GO TO POSITION I, 0,0
          STATUSOUT(I)=1
        ENDIF
        IF STATUSOUT(I)=1 AND AI GET ENTITY X(I)<2*WIDTH#/8-5
          AI ENTITY STOP I
          ENDPOINT(I)=RND(3)+1
          ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
          STATUSOUT(I)=0
        ENDIF
      ENDIF
      REM MAKE SURE KILLED EMERMY WILL NOT "EXIST"
      IF AI ENTITY EXIST(I)=1
        REM HIDE THE OBJECTS  -- B4 ENTERING THE EXIT 1, 2, BUS BAY 1 AND 2
        IF AI GET ENTITY Z (I)>(DEPTH#/2)
          HIDE OBJECT I
          ENTITIESON(I)=0
        ENDIF
        IF AI GET ENTITY Z (I)<(-DEPTH#/2)
```

```
      HIDE OBJECT I
      ENTITIESON(I)=0
    ENDIF

    REM SHOW THE OBJECT  -- WHEN ON THE STAGE
    IF AI GET ENTITY Z (I)<(DEPTH#/2) AND AI GET ENTITY Z (I)>(-DEPTH#/2) AND  AI GET
ENTITY X (I) <(WIDTH#/2)
      IF STARTTIME(I)=0 THEN STARTTIME(I)=TIMER()/1000
      SHOW OBJECT I
      ENTITIESON(I)=1
    ENDIF

    REM ARRIVE DESTINATION AND DELETE OBEJCT
    REM DESTINATION IS 1
    IF ENDPOINT(I)=1 REM AND AI ENTITY EXIST(I)=1
      IF AI GET ENTITY Z (I)<(-DEPTH#/2)
        IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
        TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
        DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
HOP(I))+","+STR$(STARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
        WRITE DATAFILE STRING 1, DATALINE$
        IF I=>10 AND SHOP(I)<10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I=>10 AND SHOP(I)=>10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10 AND SHOP(I)<10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        IF I<10 AND SHOP(I)=>10
          PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
        ENDIF
        AI KILL ENTITY I
        DELETE OBJECT I
        ENTITIESON(I)=0
      ENDIF
    ENDIF
    REM DESTINATION IS 2
    IF ENDPOINT(I)=2 REM AND AI ENTITY EXIST(I)=1
      IF AI GET ENTITY Z (I)>(DEPTH#/2)
        IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
        TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
        DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
HOP(I))+","+STR$(STARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
        WRITE DATAFILE STRING 1, DATALINE$
        IF I=>10 AND SHOP(I)<10
          PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
          PRINT CONSOLE
```

```
      ENDIF
      IF I=>10 AND SHOP(I)=>10
        PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I)," ",SHOP(I),"        ",TRAVELTIME(I)
        PRINT CONSOLE
      ENDIF
      IF I<10 AND SHOP(I)<10
        PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
        PRINT CONSOLE
      ENDIF
      IF I<10 AND SHOP(I)=>10
        PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"   ",SHOP(I),"        ",TRAVELTIME(I)
        PRINT CONSOLE
      ENDIF
      AI KILL ENTITY I
      DELETE OBJECT I
      ENTITIESON(I)=0
     ENDIF
    ENDIF
  ENDIF REM END ENEMY ALIVE

  IF AI ENTITY EXIST(I)=0 AND DEFAULT=0
    IF CATEGORIES(I)=0
      REM BORN THE ENTITIES
      CREATEENTITIESCHILDREN(I)
    ENDIF

    IF CATEGORIES(I)=1
      REM BORN THE ENTITIES
      CREATEENTITIESTEENAGER(I)
    ENDIF

    IF CATEGORIES(I)=2
      REM BORN THE ENTITIES
      CREATEENTITIESADULT(I)
    ENDIF

    IF CATEGORIES(I)=4
      REM BORN THE ENTITIES
      CREATEENTITIESELDERLY(I)
    ENDIF

    IF CATEGORIES(I)=5
      REM BORN THE ENTITIES
      CREATEENTITIESDISABLED(I)
    ENDIF
    HIDE OBJECT I
    AI SET ENTITY VIEW ARC I,90,170
    STARTTIME(I)=0
    ENDTIME(I)=0
    TRAVELTIME(I)=0
    REM RESET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF REM FINISH REBORN ENEMY

  REM TO REBORN THE KILLED ENEMY IN DEFAULT SETTING
  IF AI ENTITY EXIST(I)=0 AND DEFAULT=1
    REM REBORN THE ENTITIES
```

```
      CREATEENTITIES(I)
      REM RESET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    ENDIF REM FINISH REBORN ENEMY IN DEFAULT SETTING

    REM CALCULATE THE NUMBER OF ENTITIES ON THE STAGE
    ENTITIESON= ENTITIESON+ENTITIESON(I)
  NEXT I

  REM TIME
  HR$=LEFT$(GET TIME$(),2)
  HR=VAL(HR$)
  IF HR=>12
    IF HR> 12 THEN HR=HR-12
    POST$=" PM"
  ELSE
    POST$=" AM"
  ENDIF
  TIME$=STR$(HR)+RIGHT$(GET TIME$(),6)+POST$

  REM PRINT THE TIME AT THE BOTTOM OF THE SCREEN
  TEXT 7*SCREEN WIDTH()/8,SCREEN HEIGHT()-20,TIME$

  REM SIMULATION TIMER
  SET TEXT SIZE 12
  IF TIMER()/1000>RUNTIMESTART+RUNTIME THEN EXIT
  TEXT 7*SCREEN WIDTH()/8+5,SCREEN HEIGHT()-35,"TIMER:
"+STR$(RUNTIMESTART+RUNTIME-TIMER()/1000)

  SET TEXT SIZE 15
  REM PRINT SOME RESULTS
  SET CURSOR 0,0
  PRINT "NO. OF ENTITIES: ",ENTITIESON," / ",ENTITIES
  PRINT ""
  PRINT "CATEGORIES:- "
  PRINT " CHILDREN - YELLOW"
  PRINT " TEENAGER - PINK"
  PRINT " ADULT - RED"
  PRINT " ELDERLY - GREEN"
  PRINT " DISABLED - BLUE"
  AI UPDATE
  SYNC
LOOP

ENDIF REM FOR THE ENTITIES <>0
END REM FINISH THE SIMULATOR

REM CREATE DIFF CATEGORIES OF ENTITIES
FUNCTION CREATEENTITIES(I)
  CATEGORIES(I)=RND(7)
  REM CHILDREN
  IF CATEGORIES(I)=0
    SIZE(I)=9
    SPEED(I)=16
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF
```

```
  REM TEENAGER
  IF CATEGORIES(I)=1
    SIZE(I)=10
    SPEED(I)=15
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM NORMAL ADULT
  IF CATEGORIES(I)=2 OR CATEGORIES(I)=3 OR CATEGORIES(I)=6 OR CATEGORIES(I)=7
    SIZE(I)=12
    SPEED(I)=13.5
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB (255,0,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,25
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM ELDERLY
  IF CATEGORIES(I)=4
    SIZE(I)=15
    SPEED(I)=11.3
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,20
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM DISABLED PEOPLE
  IF CATEGORIES(I)=5
    SIZE(I)=16
    SPEED(I)=10
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,18
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF
  AI SET ENTITY SPEED I,SPEED(I)
  HIDE OBJECT I
  AI SET ENTITY VIEW ARC I,90,170
  STARTTIME(I)=0
  ENDTIME(I)=0
  TRAVELTIME(I)=0
  SYNC
ENDFUNCTION

REM CEATE ENTITIES UNDER USER DETERMINED
FUNCTION CREATEENTITIESCHILDREN(I)
  REM CHILDREN
  CATEGORIES(I)=0
  SPEED(I)=16
  SIZE(I)=9
  MAKE OBJECT SPHERE I, SIZE(I)
```

```
   COLOR OBJECT I,RGB(255,255,0)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESTEENAGER(I)
   REM TEENAGER
   CATEGORIES(I)=1
   SPEED(I)=15
   SIZE(I)=10
   MAKE OBJECT SPHERE I, SIZE(I)
   COLOR OBJECT I,RGB(255,0,255)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION


FUNCTION CREATEENTITIESADULT(I)
   REM NORMAL ADULT
   CATEGORIES(I)=2
   SPEED(I)=13.5
   SIZE(I)=12
   MAKE OBJECT SPHERE I, SIZE(I)
   COLOR OBJECT I,RGB (255,0,0)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESELDERLY(I)
   REM ELDERLY
   CATEGORIES(I)=4
   SPEED(I)=11.3
   SIZE(I)=15
   MAKE OBJECT SPHERE I, SIZE(I)
   COLOR OBJECT I,RGB(0,255,0)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESDISABLED(I)
   REM DISABLED PEOPLE
   CATEGORIES(I)=5
   SPEED(I)=10
   SIZE(I)=16
   MAKE OBJECT SPHERE I, SIZE(I)
   COLOR OBJECT I,RGB(0,0,255)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION
```

```
REM STARTING POINT
FUNCTION STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  SYNC
  STARTPOINT(I)=RND(1)+1

  REM AT EXIT 1
  IF STARTPOINT(I)=1
    POSITION OBJECT I, RND(WIDTH#-100)-WIDTH#/2, 10,-(RND(40)+DEPTH#/2+25)
    REM GO TO
    ENDPOINT(I)=RND(3)+1
    REM MAKE SURE NOT BACK TO SAME POSITION
    WHILE ENDPOINT(I)=1
      ENDPOINT(I)=RND(3)+1
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF

  REM AT EXIT 2
  IF STARTPOINT(I)=2
    POSITION OBJECT I, RND(WIDTH#-100)-WIDTH#/2, 10,(RND(40)+DEPTH#/2+25)
    REM GO TO
    ENDPOINT(I)=RND(3)+1
    REM MAKE SURE NOT BACK TO SAME POSITION
    WHILE ENDPOINT(I)=2
      ENDPOINT(I)=RND(3)+1
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF
  SYNC
ENDFUNCTION

FUNCTION ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  REM EXIT 1
  IF ENDPOINT(I)=1
    AI ENTITY GO TO POSITION I, RND(WIDTH#-100)-WIDTH#/2,-(RND(40)+DEPTH#/2+25)
  ENDIF
  REM EXIT 2
  IF ENDPOINT(I)=2
    AI ENTITY GO TO POSITION I,RND(WIDTH#-100)-WIDTH#/2,(RND(40)+DEPTH#/2+25)
  ENDIF
  REM SHOP AT LEFT
  IF ENDPOINT(I)=3
    REM SHOP NUMBER START FROM BOTTOM
    SHOP(I)=RND(7)+1
    IF SHOP(I)=1
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,-7*DEPTH#/16
    ENDIF
    IF SHOP(I)=2
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,-5*DEPTH#/16
    ENDIF
    IF SHOP(I)=3
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,-3*DEPTH#/16
    ENDIF
    IF SHOP(I)=4
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,-1*DEPTH#/16
    ENDIF
    IF SHOP(I)=5
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,1*DEPTH#/16
    ENDIF
    IF SHOP(I)=6
```

```
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,3*DEPTH#/16
    ENDIF
    IF SHOP(I)=7
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,5*DEPTH#/16
    ENDIF
    IF SHOP(I)=8
      AI ENTITY GO TO POSITION I,-3*WIDTH#/8,7*DEPTH#/16
    ENDIF
    STATUSOUT(I)=0
  ENDIF
  REM SHOP AT RIGHT
  IF ENDPOINT(I)=4
    SHOP(I)=RND(7)+9
    IF SHOP(I)=9
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,-7*DEPTH#/16
    ENDIF
    IF SHOP(I)=10
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,-5*DEPTH#/16
    ENDIF
    IF SHOP(I)=11
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,-3*DEPTH#/16
    ENDIF
    IF SHOP(I)=12
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,-1*DEPTH#/16
    ENDIF
    IF SHOP(I)=13
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,1*DEPTH#/16
    ENDIF
    IF SHOP(I)=14
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,3*DEPTH#/16
    ENDIF
    IF SHOP(I)=15
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,5*DEPTH#/16
    ENDIF
    IF SHOP(I)=16
      AI ENTITY GO TO POSITION I,3*WIDTH#/8,7*DEPTH#/16
    ENDIF
    STATUSOUT(I)=0
  ENDIF
ENDFUNCTION
```

```
REM Project: BBS
REM Created: 2/25/2009 9:46:36 PM
REM
REM ***** Main Source File *****
REM

CLS
SYNC ON : SYNC RATE 0 : AUTOCAM OFF
SET TEXT FONT "VERDANA" : SET TEXT SIZE 15
AI START
AI SET RADIUS 8

MAP SHARED MEM TO BANK "MYBANK", 1, 40960
ENTITIES = BANK INTEGER(1,0)
DEFAULT = BANK INTEGER (1,4096)
CHILDREN = BANK INTEGER (1,8192)
TEENAGER = BANK INTEGER (1,12288)
ADULT = BANK INTEGER (1,16384)
ELDERLY = BANK INTEGER (1,20480)
DISABLED = BANK INTEGER (1,24576)
CONDITION = BANK INTEGER (1,28672)
RUNTIME = BANK INTEGER (1,32768)

REM TO MAKE SURE USERS ARE ENTER FROM THE MAIN MENU
IF ENTITIES = 0
  SYNC
  CENTER TEXT SCREEN WIDTH()/2,10, " WARNING !! "
  CENTER TEXT SCREEN WIDTH()/2,40, " YOU MAY NOT ENTER THE NUMBER OF ENTITIES YET"
  CENTER TEXT SCREEN WIDTH()/2,70, " PLEASE GO BACK TO MENU OF THE SIMULATION "
   SYNC
  SLEEP 4000
ENDIF

IF ENTITIES <>0

REM DIMENSION
DIM CATEGORIES(ENTITIES)
DIM SPEED(ENTITIES)
DIM SIZE(ENTITIES)
DIM STARTPOINT(ENTITIES)
DIM ENDPOINT(ENTITIES)
DIM ENTITIESON(ENTITIES)
DIM STARTTIME(ENTITIES)
DIM ENDTIME(ENTITIES)
DIM TRAVELTIME(ENTITIES)
DIM WAITCOUNTER(ENTITIES)
DIM CST(ENTITIES) REM COUNTER STARTING TIME
DIM QDISTANCE(ENTITIES) REM DISTANCE WHEN QUEUE
WIDTH#=800 `X
HEIGHT#=100 `Y
DEPTH#=800 `Z
CAMERAX=-50
CAMERAY=800
CAMERAZ=10

REM CAMERA
REM *** W X H X D *** 800 X 100 X 800 ***
```

```
COLOR BACKDROP RGB(128,128,128)
POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
POINT CAMERA CAMERAX,0,CAMERAZ
SET CAMERA RANGE 100,1100

REM FLOOR
MAKE OBJECT BOX ENTITIES+1,WIDTH#,2,DEPTH#
POSITION OBJECT ENTITIES+1,0,-2,0
COLOR OBJECT ENTITIES+1,RGB(255,255,255)


REM OBSTACLE (WALL 1)
MAKE OBJECT BOX ENTITIES+2,100,50,DEPTH#/4
POSITION OBJECT ENTITIES+2,WIDTH#/2-50,25,3*DEPTH#/8
COLOR OBJECT ENTITIES+2,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+2

REM OBSTACLE (WALL 2)
MAKE OBJECT BOX ENTITIES+3,100,50,DEPTH#/4
POSITION OBJECT ENTITIES+3,WIDTH#/2-50,25,0
COLOR OBJECT ENTITIES+3,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+3

REM OBSTACLE (WALL 3)
MAKE OBJECT BOX ENTITIES+4,100,50,DEPTH#/4
POSITION OBJECT ENTITIES+4,WIDTH#/2-50,25,-(3*DEPTH#/8)
COLOR OBJECT ENTITIES+4,RGB(64,128,128)
AI ADD STATIC OBSTACLE ENTITIES+4

REM OBSTACLE (INVISIBLE WALL 1)
MAKE OBJECT BOX ENTITIES+5,100,50,70
POSITION OBJECT ENTITIES+5,WIDTH#/2-50,25,DEPTH#/2+35
COLOR OBJECT ENTITIES+5,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+5
HIDE OBJECT ENTITIES+5

REM OBSTACLE (INVISIBLE WALL 2)
MAKE OBJECT BOX ENTITIES+6,70,50,DEPTH#/4
POSITION OBJECT ENTITIES+6,WIDTH#/2+35,25,0
COLOR OBJECT ENTITIES+6,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+6
HIDE OBJECT ENTITIES+6

REM OBSTACLE (INVISIBLE WALL 3)
MAKE OBJECT BOX ENTITIES+7,100,50,70
POSITION OBJECT ENTITIES+7,WIDTH#/2-50,25,-(DEPTH#/2+35)
COLOR OBJECT ENTITIES+7,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+7
HIDE OBJECT ENTITIES+7

REM COUNTER
MAKE OBJECT BOX ENTITIES+8,22,50,30
POSITION OBJECT ENTITIES+8,-(WIDTH#/2-12),25,DEPTH#/2-16
COLOR OBJECT ENTITIES+8,RGB(0,255,255)
AI ADD STATIC OBSTACLE ENTITIES+8

REM FIST 6 SEAT
FOR I = ENTITIES+9 TO ENTITIES+14
  MAKE OBJECT BOX I,20,10,DEPTH#/8*1.2
  POSITION OBJECT I,-WIDTH#/4+50*(I-ENTITIES-9),5,3*DEPTH#/8
```

```
  COLOR OBJECT I,RGB(255,128,0)
  AI ADD STATIC OBSTACLE I
NEXT I

REM SECOND 6 SEAT
FOR I = ENTITIES+15 TO ENTITIES+20
  MAKE OBJECT BOX I,20,10,DEPTH#/8*1.2
  POSITION OBJECT I,-WIDTH#/4+50*(I-ENTITIES-15),5,0
  COLOR OBJECT I,RGB(255,128,0)
  AI ADD STATIC OBSTACLE I
NEXT I

REM THIRD 6 SEAT
FOR I = ENTITIES+21 TO ENTITIES+26
  MAKE OBJECT BOX I,20,10,DEPTH#/8*1.2
  POSITION OBJECT I,-WIDTH#/4+50*(I-ENTITIES-21),5,-3*DEPTH#/8
  COLOR OBJECT I,RGB(255,128,0)
  AI ADD STATIC OBSTACLE I
NEXT I

REM LINE UP 1
MAKE OBJECT BOX ENTITIES+27,5,20,6*DEPTH#/8
POSITION OBJECT ENTITIES+27,-WIDTH#/2+22,10,0
COLOR OBJECT ENTITIES+27,RGB(128,0,0)
AI ADD STATIC OBSTACLE ENTITIES+27

REM LINE UP 2
MAKE OBJECT BOX ENTITIES+28,5,20,200
POSITION OBJECT ENTITIES+28,-WIDTH#/2+22,10,DEPTH#/2-50-100
COLOR OBJECT ENTITIES+28,RGB(128,0,0)
AI ADD STATIC OBSTACLE ENTITIES+28

REM COUNTER PROTECTION 1
MAKE OBJECT BOX ENTITIES+29,20,20,5
POSITION OBJECT ENTITIES+29,-WIDTH#/2+34,10,DEPTH#/2
COLOR OBJECT ENTITIES+29,RGB(128,0,0)
AI ADD STATIC OBSTACLE ENTITIES+29

REM COUNTER PROTECTION 2
MAKE OBJECT BOX ENTITIES+30,5,20,70
POSITION OBJECT ENTITIES+30,-WIDTH#/2+44,10,DEPTH#/2-35
COLOR OBJECT ENTITIES+30,RGB(128,0,0)
AI ADD STATIC OBSTACLE ENTITIES+30

REM SIGNBOARD 1
CLS
CENTER TEXT 30,0,"> > > >"
CENTER TEXT 30,20,"BUS BAY"
CENTER TEXT 30,40,"1"
GET IMAGE 1,0,0,60,60,1
MAKE OBJECT PLAIN ENTITIES+31,100,80,1
XROTATE OBJECT ENTITIES+31,90
TEXTURE OBJECT ENTITIES+31,1
POSITION OBJECT ENTITIES+31,WIDTH#/2-50,50,-(4*DEPTH#/16+40)
SET OBJECT TRANSPARENCY ENTITIES+31,0

REM SIGNBOARD 2
CLS
CENTER TEXT 30,0,"BUS BAY"
CENTER TEXT 30,20,"2"
```

```
CENTER TEXT 30,40,"> > > >"
GET IMAGE 2,0,0,60,60,1
MAKE OBJECT PLAIN ENTITIES+32,100,80,1
XROTATE OBJECT ENTITIES+32,90
TEXTURE OBJECT ENTITIES+32,2
POSITION OBJECT ENTITIES+32,WIDTH#/2-50,50,4*DEPTH#/16+40
SET OBJECT TRANSPARENCY ENTITIES+32,0
REM ENTITIES+33 UNTIL ENTITIES+35 IS EMPTY FOR DEFAULT SYSTEM

IF CONDITION=0
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C0.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN0"
ENDIF REM FINISH CONDITION 0

IF CONDITION=1
  REM BARRIER BUS BAY 1
  MAKE OBJECT BOX ENTITIES+36,120,50,4
  POSITION OBJECT ENTITIES+36,WIDTH#/2-100,25,-3*DEPTH#/16
  COLOR OBJECT ENTITIES+36,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+36

  MAKE OBJECT BOX ENTITIES+37,60,50,4
  YROTATE OBJECT ENTITIES+37,30
  POSITION OBJECT ENTITIES+37,WIDTH#/2-170,25,-3*DEPTH#/16+45
  COLOR OBJECT ENTITIES+37,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+37

  MAKE OBJECT BOX ENTITIES+38,60,50,4
  YROTATE OBJECT ENTITIES+38,-30
  POSITION OBJECT ENTITIES+38,WIDTH#/2-170,25,-3*DEPTH#/16-45
  COLOR OBJECT ENTITIES+38,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+38

  MAKE OBJECT BOX ENTITIES+39,50,50,4
  YROTATE OBJECT ENTITIES+39,60
  POSITION OBJECT ENTITIES+39,WIDTH#/2-145,25,-3*DEPTH#/16+95
  COLOR OBJECT ENTITIES+39,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+39

  MAKE OBJECT BOX ENTITIES+40,50,50,4
  YROTATE OBJECT ENTITIES+40,-60
  POSITION OBJECT ENTITIES+40,WIDTH#/2-145,25,-3*DEPTH#/16-95
  COLOR OBJECT ENTITIES+40,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+40

  REM BARRIER BUS BAY 2
  MAKE OBJECT BOX ENTITIES+41,120,50,4
  POSITION OBJECT ENTITIES+41,WIDTH#/2-100,25,3*DEPTH#/16
  COLOR OBJECT ENTITIES+41,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+41

  MAKE OBJECT BOX ENTITIES+42,60,50,4
  YROTATE OBJECT ENTITIES+42,30
  POSITION OBJECT ENTITIES+42,WIDTH#/2-170,25,3*DEPTH#/16+45
  COLOR OBJECT ENTITIES+42,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+42

  MAKE OBJECT BOX ENTITIES+43,60,50,4
```

```
YROTATE OBJECT ENTITIES+43,-30
POSITION OBJECT ENTITIES+43,WIDTH#/2-170,25,3*DEPTH#/16-45
COLOR OBJECT ENTITIES+43,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+43

MAKE OBJECT BOX ENTITIES+44,50,50,4
YROTATE OBJECT ENTITIES+44,60
POSITION OBJECT ENTITIES+44,WIDTH#/2-145,25,3*DEPTH#/16+95
COLOR OBJECT ENTITIES+44,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+44

MAKE OBJECT BOX ENTITIES+45,50,50,4
YROTATE OBJECT ENTITIES+45,-60
POSITION OBJECT ENTITIES+45,WIDTH#/2-145,25,3*DEPTH#/16-95
COLOR OBJECT ENTITIES+45,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+45

REM BARRRIER BTW SEAT 1
MAKE OBJECT BOX ENTITIES+46,50,50,4
POSITION OBJECT ENTITIES+46,0-50,25,-3*DEPTH#/16
COLOR OBJECT ENTITIES+46,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+46

MAKE OBJECT BOX ENTITIES+47,50,50,4
POSITION OBJECT ENTITIES+47,0-150,25,-3*DEPTH#/16
COLOR OBJECT ENTITIES+47,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+47

MAKE OBJECT BOX ENTITIES+48,50,50,4
POSITION OBJECT ENTITIES+48,0+50,25,-3*DEPTH#/16
COLOR OBJECT ENTITIES+48,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+48

REM BARRRIER BTW SEAT 2
MAKE OBJECT BOX ENTITIES+49,50,50,4
POSITION OBJECT ENTITIES+49,0-50,25,3*DEPTH#/16
COLOR OBJECT ENTITIES+49,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+49

MAKE OBJECT BOX ENTITIES+50,50,50,4
POSITION OBJECT ENTITIES+50,0-150,25,3*DEPTH#/16
COLOR OBJECT ENTITIES+50,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+50

MAKE OBJECT BOX ENTITIES+51,50,50,4
POSITION OBJECT ENTITIES+51,0+50,25,3*DEPTH#/16
COLOR OBJECT ENTITIES+51,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+51

REM BARRIER FOR THE LINE UP
MAKE OBJECT BOX ENTITIES+52,50,50,4
COLOR OBJECT ENTITIES+52,RGB(0,0,0)
YROTATE OBJECT ENTITIES+52,-45
POSITION OBJECT ENTITIES+52,-WIDTH#/2+80,25,-6*DEPTH#/16+5
AI ADD STATIC OBSTACLE ENTITIES+52

MAKE OBJECT BOX ENTITIES+53,50,50,4
COLOR OBJECT ENTITIES+53,RGB(0,0,0)
YROTATE OBJECT ENTITIES+53,-45
POSITION OBJECT ENTITIES+53,-WIDTH#/2+130,25,-6*DEPTH#/16+5
```

```
   AI ADD STATIC OBSTACLE ENTITIES+53

   MAKE OBJECT BOX ENTITIES+54,60,50,4
   COLOR OBJECT ENTITIES+54,RGB(0,0,0)
   YROTATE OBJECT ENTITIES+54,-45
   POSITION OBJECT ENTITIES+54,-WIDTH#/2+80,25,-6*DEPTH#/16+65
   AI ADD STATIC OBSTACLE ENTITIES+54

   MAKE OBJECT BOX ENTITIES+55,60,50,4
   COLOR OBJECT ENTITIES+55,RGB(0,0,0)
   YROTATE OBJECT ENTITIES+55,-45
   POSITION OBJECT ENTITIES+55,-WIDTH#/2+130,25,-6*DEPTH#/16+65
   AI ADD STATIC OBSTACLE ENTITIES+55

   MAKE OBJECT BOX ENTITIES+56,60,50,4
   COLOR OBJECT ENTITIES+56,RGB(0,0,0)
   YROTATE OBJECT ENTITIES+56,-45
   POSITION OBJECT ENTITIES+56,-WIDTH#/2+180,25,-6*DEPTH#/16+65
   AI ADD STATIC OBSTACLE ENTITIES+56

   MAKE OBJECT BOX ENTITIES+57,60,50,4
   COLOR OBJECT ENTITIES+57,RGB(0,0,0)
   POSITION OBJECT ENTITIES+57,-WIDTH#/2+90,25,-6*DEPTH#/16-40
   AI ADD STATIC OBSTACLE ENTITIES+57

   REM LINE UP ADDON
   MAKE OBJECT BOX ENTITIES+58,15,20,5
   COLOR OBJECT ENTITIES+58,RGB(128,0,0)
   POSITION OBJECT ENTITIES+58,-WIDTH#/2+22+5,10,-6*DEPTH#/16
   AI ADD STATIC OBSTACLE ENTITIES+58
   REM CREATE CSV&TITLE
   OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C1.csv"
   WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN1"
 ENDIF REM FINISH CONDITION 1

IF CONDITION=2
   REM BARRIER AT BUS BAY 2
   MAKE OBJECT BOX ENTITIES+33,4,50,0.7*DEPTH#/8
   POSITION OBJECT ENTITIES+33,3*WIDTH#/8-30,25,4*DEPTH#/16
   COLOR OBJECT ENTITIES+33,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+33

   MAKE OBJECT BOX ENTITIES+34,4,50,0.7*DEPTH#/8
   POSITION OBJECT ENTITIES+34,3*WIDTH#/8-30,25,2*DEPTH#/16
   COLOR OBJECT ENTITIES+34,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+34

   MAKE OBJECT BOX ENTITIES+35,4,50,1.2*DEPTH#/8
   POSITION OBJECT ENTITIES+35,3*WIDTH#/8-60,25,3*DEPTH#/16
   COLOR OBJECT ENTITIES+35,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+35

   MAKE OBJECT BOX ENTITIES+36,4,50,0.7*DEPTH#/8
   POSITION OBJECT ENTITIES+36,3*WIDTH#/8-90,25,4*DEPTH#/16
   COLOR OBJECT ENTITIES+36,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+36

   MAKE OBJECT BOX ENTITIES+37,4,50,0.7*DEPTH#/8
   POSITION OBJECT ENTITIES+37,3*WIDTH#/8-90,25,2*DEPTH#/16
```

```
COLOR OBJECT ENTITIES+37,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+37

MAKE OBJECT BOX ENTITIES+38,4,50,1.2*DEPTH#/8
POSITION OBJECT ENTITIES+38,3*WIDTH#/8-120,25,3*DEPTH#/16
COLOR OBJECT ENTITIES+38,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+38

REM BARRIER AT BUS BAY 1
MAKE OBJECT BOX ENTITIES+39,4,50,0.7*DEPTH#/8
POSITION OBJECT ENTITIES+39,3*WIDTH#/8-30,25,-4*DEPTH#/16
COLOR OBJECT ENTITIES+39,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+39

MAKE OBJECT BOX ENTITIES+40,4,50,0.7*DEPTH#/8
POSITION OBJECT ENTITIES+40,3*WIDTH#/8-30,25,-2*DEPTH#/16
COLOR OBJECT ENTITIES+40,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+40

MAKE OBJECT BOX ENTITIES+41,4,50,1.2*DEPTH#/8
POSITION OBJECT ENTITIES+41,3*WIDTH#/8-60,25,-3*DEPTH#/16
COLOR OBJECT ENTITIES+41,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+41

MAKE OBJECT BOX ENTITIES+42,4,50,0.7*DEPTH#/8
POSITION OBJECT ENTITIES+42,3*WIDTH#/8-90,25,-4*DEPTH#/16
COLOR OBJECT ENTITIES+42,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+42

MAKE OBJECT BOX ENTITIES+43,4,50,0.7*DEPTH#/8
POSITION OBJECT ENTITIES+43,3*WIDTH#/8-90,25,-2*DEPTH#/16
COLOR OBJECT ENTITIES+43,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+43

MAKE OBJECT BOX ENTITIES+44,4,50,1.2*DEPTH#/8
POSITION OBJECT ENTITIES+44,3*WIDTH#/8-120,25,-3*DEPTH#/16
COLOR OBJECT ENTITIES+44,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+44

REM BARRIER AT COUNTER
MAKE OBJECT BOX ENTITIES+45,4,50,0.5*DEPTH#/8
POSITION OBJECT ENTITIES+45,-WIDTH#/2+60,25,-5.2*DEPTH#/16
COLOR OBJECT ENTITIES+45,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+45

MAKE OBJECT BOX ENTITIES+46,4,50,0.5*DEPTH#/8
POSITION OBJECT ENTITIES+46,-WIDTH#/2+60,25,-6.8*DEPTH#/16
COLOR OBJECT ENTITIES+46,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+46

MAKE OBJECT BOX ENTITIES+47,4,50,1*DEPTH#/8
POSITION OBJECT ENTITIES+47,-WIDTH#/2+90,25,-6*DEPTH#/16
COLOR OBJECT ENTITIES+47,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+47

MAKE OBJECT BOX ENTITIES+48,4,50,0.5*DEPTH#/8
POSITION OBJECT ENTITIES+48,-WIDTH#/2+120,25,-5.2*DEPTH#/16
COLOR OBJECT ENTITIES+48,RGB(0,0,0)
AI ADD STATIC OBSTACLE ENTITIES+48
```

```
   MAKE OBJECT BOX ENTITIES+49,4,50,0.5*DEPTH#/8
   POSITION OBJECT ENTITIES+49,-WIDTH#/2+120,25,-6.8*DEPTH#/16
   COLOR OBJECT ENTITIES+49,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+49

   MAKE OBJECT BOX ENTITIES+50,4,50,1*DEPTH#/8
   POSITION OBJECT ENTITIES+50,-WIDTH#/2+150,25,-6*DEPTH#/16
   COLOR OBJECT ENTITIES+50,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+50

   MAKE OBJECT BOX ENTITIES+51,4,50,1*DEPTH#/8
   POSITION OBJECT ENTITIES+51,-WIDTH#/2+180,25,-4.9*DEPTH#/16
   COLOR OBJECT ENTITIES+51,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+51
   REM CREATE CSV&TITLE
   OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C2.csv"
   WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN2"
 ENDIF REM FINISH CONDITION 2

 IF CONDITION=3
   REM BARRIER1
   MAKE OBJECT BOX ENTITIES+33,120,50,5
   POSITION OBJECT ENTITIES+33,WIDTH#/2-60,25,-2*DEPTH#/16-1*DEPTH#/24
   COLOR OBJECT ENTITIES+33,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+33

   MAKE OBJECT BOX ENTITIES+34,120,50,5
   POSITION OBJECT ENTITIES+34,WIDTH#/2-60,25,-2*DEPTH#/16-2*DEPTH#/24
   COLOR OBJECT ENTITIES+34,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+34

   REM BARRIER2
   MAKE OBJECT BOX ENTITIES+35,120,50,5
   POSITION OBJECT ENTITIES+35,WIDTH#/2-60,25,2*DEPTH#/16+1*DEPTH#/24
   COLOR OBJECT ENTITIES+35,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+35

   MAKE OBJECT BOX ENTITIES+36,120,50,5
   POSITION OBJECT ENTITIES+36,WIDTH#/2-60,25,2*DEPTH#/16+2*DEPTH#/24
   COLOR OBJECT ENTITIES+36,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+36

   REM BARRIER3
   MAKE OBJECT BOX ENTITIES+37,5,50,80
   POSITION OBJECT ENTITIES+37,-WIDTH#/2+22+40,25,-6*DEPTH#/16
   COLOR OBJECT ENTITIES+37,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+37

   MAKE OBJECT BOX ENTITIES+38,40,50,5
   POSITION OBJECT ENTITIES+38,-WIDTH#/2+22+40-18,25,-6*DEPTH#/16-40
   COLOR OBJECT ENTITIES+38,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+38

   MAKE OBJECT BOX ENTITIES+39,5,50,80
   POSITION OBJECT ENTITIES+39,-WIDTH#/2+22+80,25,-6*DEPTH#/16
   COLOR OBJECT ENTITIES+39,RGB(0,0,0)
   AI ADD STATIC OBSTACLE ENTITIES+39

   MAKE OBJECT BOX ENTITIES+40,5,50,80
```

```
    POSITION OBJECT ENTITIES+40,-WIDTH#/2+22+120,25,-6*DEPTH#/16
    COLOR OBJECT ENTITIES+40,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+40
      REM CREATE CSV&TITLE
    OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C3.csv"
    WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN3"
ENDIF REM FINISH CONDITION 3

IF CONDITION=4
    REM BARRIER1
    FOR I=ENTITIES+33 TO ENTITIES+36
      MAKE OBJECT SPHERE I,0.65*DEPTH#/8
      POSITION OBJECT I,WIDTH#/2-125-(I-ENTITIES-33)*150,0,-3*DEPTH#/16
      COLOR OBJECT I,RGB(0,0,0)
      AI ADD STATIC OBSTACLE I
    NEXT I

    REM BARRIER2
    FOR I=ENTITIES+37 TO ENTITIES+40
      MAKE OBJECT SPHERE I,0.65*DEPTH#/8
      POSITION OBJECT I,WIDTH#/2-125-(I-ENTITIES-37)*150,0,3*DEPTH#/16
      COLOR OBJECT I,RGB(0,0,0)
      AI ADD STATIC OBSTACLE I
    NEXT I

    REM BARRIER3
    MAKE OBJECT SPHERE ENTITIES+41,80
    POSITION OBJECT ENTITIES+41,-WIDTH#/2+22+40+40,0,-6*DEPTH#/16+10
    COLOR OBJECT ENTITIES+41,RGB(0,0,0)
    AI ADD STATIC OBSTACLE ENTITIES+41

    REM LINE UP ADDON
    MAKE OBJECT BOX ENTITIES+42,15,20,5
    COLOR OBJECT ENTITIES+42,RGB(128,0,0)
    POSITION OBJECT ENTITIES+42,-WIDTH#/2+22+5,10,-6*DEPTH#/16
    AI ADD STATIC OBSTACLE ENTITIES+42
    REM CREATE CSV&TITLE
    OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C4.csv"
    WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN4"
ENDIF REM FINISH CONDITION 4

IF CONDITION=5
    REM BARRIER1
    FOR I=ENTITIES+33 TO ENTITIES+36
      MAKE OBJECT CONE I,0.8*DEPTH#/8
      ZROTATE OBJECT I,-90
      POSITION OBJECT I,WIDTH#/2-100-(I-ENTITIES-33)*150,0,-3*DEPTH#/16
      COLOR OBJECT I,RGB(0,0,0)
      AI ADD STATIC OBSTACLE I
    NEXT I

    REM BARRIER2
    FOR I=ENTITIES+37 TO ENTITIES+40
      MAKE OBJECT CONE I,0.8*DEPTH#/8
      ZROTATE OBJECT I,-90
      POSITION OBJECT I,WIDTH#/2-100-(I-ENTITIES-37)*150,0,3*DEPTH#/16
      COLOR OBJECT I,RGB(0,0,0)
      AI ADD STATIC OBSTACLE I
```

```
  NEXT I

  REM BARRIER3
  MAKE OBJECT CONE ENTITIES+41,90
  XROTATE OBJECT I,90
  POSITION OBJECT ENTITIES+41,-WIDTH#/2+22+40+30,0,-6*DEPTH#/16+20
  COLOR OBJECT ENTITIES+41,RGB(0,0,0)
  AI ADD STATIC OBSTACLE ENTITIES+41

  REM LINE UP ADDON
  MAKE OBJECT BOX ENTITIES+42,15,20,5
  COLOR OBJECT ENTITIES+42,RGB(128,0,0)
  POSITION OBJECT ENTITIES+42,-WIDTH#/2+22+5,10,-6*DEPTH#/16
  AI ADD STATIC OBSTACLE ENTITIES+42
  REM CREATE CSV&TITLE
  OPEN DATAFILE TO WRITE 1,"ANALYSIS OF THE BUS BAY SIMULATION C5.csv"
  WRITE DATAFILE STRING 1, "ANALYSIS OF HUMAN WALKING BEHAVIOUR SIMULATION IN
THE BUS BAY-DESIGN5"
ENDIF REM FINISH CONDITION 5

REM MAKE BOUNDARY OBSTACLE, ENCLOSES THE SPACE TO KEEP THE ENTITY IN
REM ADD POINTS IN AN ANTI-CLOCKWISE DIRECTION TO CREATE A BOUNDARY (USE
CLOCKWISE TO CREATE AN OBSTACLE)
AI START NEW OBSTACLE
AI ADD OBSTACLE VERTEX -WIDTH#/2,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2+65,-(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX WIDTH#/2+65,(DEPTH#/2+65)
AI ADD OBSTACLE VERTEX -WIDTH#/2,(DEPTH#/2+65)
AI END NEW OBSTACLE 0,1
REM FINISH CREATING ALL BOUNDARY

AI COMPLETE OBSTACLES

REM DATASE&CONSOLE
DATALINE$="MAX NUMBER OF ENTITIES = "+STR$(ENTITIES)
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,"WORLD 3 - BUS BAY"
DATALINE$="CATEGORIES,DIFF. LEVEL OF HUMAN,COLOR,SIZE,SPEED;dm/s"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="0,CHILDREN,YELLOW,9,16"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="1,TEENAGER,PINK,10,15"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="2 3 6 7,ADULT,RED,12,13.5"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="4,ELDERLY,GREEN,15,11.3"
WRITE DATAFILE STRING 1,DATALINE$
DATALINE$="5,DISABLED,BLUE,16,10"
WRITE DATAFILE STRING 1,DATALINE$
WRITE DATAFILE STRING 1,""
WRITE DATAFILE STRING 1,"ENTITIES ID,CATEGORIES,STARTPOINT,ENDPOINT,START
TIME,END TIME,TIME TAKEN"
OPEN CONSOLE
PRINT CONSOLE "ID CATEGORIES STARTPOINT ENDPOINT TIME TAKEN"
PRINT CONSOLE
PRINT CONSOLE "== ========= ========= ======= ========="
PRINT CONSOLE

IF DEFAULT=0
  IF CHILDREN <>0
```

```
      FOR I=1 TO CHILDREN
        REM BORN THE ENTITIES
        CREATEENTITIESCHILDREN(I)
      NEXT I
    ENDIF

    IF TEENAGER <>0
      FOR I=CHILDREN+1 TO CHILDREN+TEENAGER
        REM BORN THE ENTITIES
        CREATEENTITIESTEENAGER(I)
      NEXT I
    ENDIF

    IF ADULT <>0
      FOR I=CHILDREN+TEENAGER+1 TO CHILDREN+TEENAGER+ADULT
        REM BORN THE ENTITIES
        CREATEENTITIESADULT(I)
      NEXT I
    ENDIF

    IF ELDERLY <>0
      FOR I=CHILDREN+TEENAGER+ADULT+1 TO CHILDREN+TEENAGER+ADULT+ELDERLY
        REM BORN THE ENTITIES
        CREATEENTITIESELDERLY(I)
      NEXT I
    ENDIF

    IF DISABLED <>0
      FOR I=CHILDREN+TEENAGER+ADULT+ELDERLY+1 TO
CHILDREN+TEENAGER+ADULT+ELDERLY+DISABLED
        REM BORN THE ENTITIES
        CREATEENTITIESDISABLED(I)
      NEXT I
    ENDIF

    FOR I=1 TO ENTITIES
      HIDE OBJECT I
      AI SET ENTITY VIEW ARC I,90,170
      STARTTIME(I)=0
      ENDTIME(I)=0
      TRAVELTIME(I)=0
      REM SET STARTING POINT
      STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    NEXT I
ENDIF REM FINISH DEFAULT=0

IF DEFAULT=1
  FOR I=1 TO ENTITIES
    REM BORN THE ENTITIES
    CREATEENTITIES(I)
    REM SET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  NEXT I
ENDIF REM FINISH DEFAULT=1

REM SIMULATION TIMER
RUNTIMESTART=TIMER()/1000

DO
  REM HANDLE DEBUGGING OUTPUT
```

```
REM ***COPYRIGHT DBP***
REM
IF KEYSTATE(2)=1 AND PTIMER<TIMER()
  PTIMER = TIMER()+300
  PMODE = 1-PMODE

  IF ( PMODE=0 ) THEN AI DEBUG HIDE PATHS ELSE AI DEBUG SHOW PATHS 2.5
ENDIF

IF KEYSTATE(3)=1 AND ATIMER<TIMER()
  ATIMER = TIMER()+300
  AMODE = 1-AMODE

  IF ( AMODE=0 ) THEN AI DEBUG HIDE AVOIDANCE ANGLES ELSE AI DEBUG SHOW
AVOIDANCE ANGLES 2.5
ENDIF

IF KEYSTATE(4)=1 AND VTIMER<TIMER()
  VTIMER = TIMER()+300
  VMODE = 1-VMODE

  IF ( VMODE=0 ) THEN AI DEBUG HIDE VIEW ARCS ELSE AI DEBUG SHOW VIEW ARCS 2.5
ENDIF

IF ( KEYSTATE(59)=1 AND F1TIMER<TIMER() )
  F1TIMER = TIMER()+300

  F1PRESSED=1-F1PRESSED
ENDIF REM ***COPYRIGHT DBP***

REM CAMERA CONTROLS
IF DOWNKEY()=1
  CAMERAZ=CAMERAZ-2
  POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
  POINT CAMERA CAMERAX,0,CAMERAZ
ENDIF
IF UPKEY()=1
  CAMERAZ=CAMERAZ+2
  POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
  POINT CAMERA CAMERAX,0,CAMERAZ
ENDIF
IF RIGHTKEY()=1
  CAMERAX=CAMERAX+2
  POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
  POINT CAMERA CAMERAX,0,CAMERAZ
ENDIF
IF LEFTKEY()=1
  CAMERAX=CAMERAX-2
  POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
  POINT CAMERA CAMERAX,0,CAMERAZ
ENDIF
REM PAGE UP KEY-ZOOM IN
IF KEYSTATE(201)=1
  CAMERAY=CAMERAY-5
  IF CAMERAY<350 THEN CAMERAY=350
  POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
  POINT CAMERA CAMERAX,0,CAMERAZ
ENDIF
REM PAGEDOWN KEY-ZOOM OUT
IF KEYSTATE(209)=1
```

```
    CAMERAY=CAMERAY+5
    IF CAMERAY>1000 THEN CAMERAY=1000
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF
  REM HOME KEY -RESET TO ORI POSITION
  IF KEYSTATE(199)=1
    CAMERAX=-50
    CAMERAY=800
    CAMERAZ=10
    POSITION CAMERA CAMERAX,CAMERAY,CAMERAZ
    POINT CAMERA CAMERAX,0,CAMERAZ
  ENDIF

  IF ( F1PRESSED )
    REM DISPLAY INFO
    FPS$="FPS: "+STR$(SCREEN FPS())
    SET CURSOR 0,DEPTH#/2+40
    PRINT
    PRINT "ENTITIES FOLLOW PRESET PATHS, AVOIDING OTHER ENTITIES"
    PRINT
    PRINT
    PRINT
    PRINT
    PRINT
    PRINT
    TEXT 0,SCREEN HEIGHT()-120,"DEBUG CONTROLS:"
    TEXT 0,SCREEN HEIGHT()-100,"[1]    TOGGLE ENTITY PATH"
    TEXT 0,SCREEN HEIGHT()-80,"[2]    TOGGLE AVOIDANCE ANGLES"
    TEXT 0,SCREEN HEIGHT()-60,"[3]    TOGGLE VIEW ARCS"
    TEXT 0,SCREEN HEIGHT()-40,FPS$
    TEXT 300,SCREEN HEIGHT()-120,"CAMERA CONTROLS:"
    TEXT 300,SCREEN HEIGHT()-100,"   [^]"
    TEXT 300,SCREEN HEIGHT()-80,"[<][V][>]"
    TEXT 300,SCREEN HEIGHT()-90,"          CAMERA MOTION KEY"
    TEXT 300,SCREEN HEIGHT()-60,"[PGDN]    ZOOM OUT"
    TEXT 300,SCREEN HEIGHT()-40,"[PGUP]    ZOOM IN"
    TEXT 300,SCREEN HEIGHT()-20,"[HOME]    BACK TO ORI"

  ELSE
    CENTER TEXT SCREEN WIDTH()/2, 25, "-- PRESS F1 FOR HELP --"
  ENDIF

  REM RESET THE ENTITIES ON THE STAGE
  ENTITIESON=0

  REM ACTION - COUNTER, HIDE, KILL OBJECTS
  FOR I= 1 TO ENTITIES
    REM COUNTER
    IF ENDPOINT(I)=0
      COUNTERF(I,WIDTH#,HEIGHT#,DEPTH#)
    ENDIF
    REM MAKE SURE KILLED EMERMY WILL NOT "EXIST"
    IF AI ENTITY EXIST(I)=1
      REM HIDE THE OBJECTS  -- B4 ENTERING THE EXIT 1, 2, BUS BAY 1 AND 2
      IF AI GET ENTITY Z (I)>(DEPTH#/2)
        HIDE OBJECT I
        ENTITIESON(I)=0
      ENDIF
      IF AI GET ENTITY Z (I)<(-DEPTH#/2)
```

```
        HIDE OBJECT I
        ENTITIESON(I)=0
      ENDIF
      IF AI GET ENTITY X (I)>(WIDTH#/2)
        HIDE OBJECT I
        ENTITIESON(I)=0
      ENDIF

      REM SHOW THE OBJECT  -- WHEN ON THE STAGE
      IF AI GET ENTITY Z (I)<(DEPTH#/2) AND AI GET ENTITY Z (I)>(-DEPTH#/2) AND  AI GET
ENTITY X (I) <(WIDTH#/2)
        IF STARTTIME(I)=0 THEN STARTTIME(I)=TIMER()/1000
        SHOW OBJECT I
        ENTITIESON(I)=1
      ENDIF

      REM ARRIVE DESTINATION AND DELETE OBEJCT
      REM DESTINATION IS 1
      IF ENDPOINT(I)=1 REM AND AI ENTITY EXIST(I)=1
        IF AI GET ENTITY Z (I)<(-DEPTH#/2)
          IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
          TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
          DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
          WRITE DATAFILE STRING 1, DATALINE$
          IF I=>10
            PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ELSE
            PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          AI KILL ENTITY I
          DELETE OBJECT I
          ENTITIESON(I)=0
          WAITCOUNTER(I)=0
        ENDIF
      ENDIF
      REM DESTINATION IS 2
      IF ENDPOINT(I)=2 REM AND AI ENTITY EXIST(I)=1
        IF AI GET ENTITY Z (I)>(DEPTH#/2)
          IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
          TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
          DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
          WRITE DATAFILE STRING 1, DATALINE$
          IF I=>
            PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ELSE
            PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"
",ENDPOINT(I),"        ",TRAVELTIME(I)
            PRINT CONSOLE
          ENDIF
          AI KILL ENTITY I
```

```
      DELETE OBJECT I
      ENTITIESON(I)=0
      WAITCOUNTER(I)=0
     ENDIF
    ENDIF
    REM DESTINATION IS 3
    IF ENDPOINT(I)=3
     IF AI GET ENTITY X (I)>(WIDTH#/2) AND AI GET ENTITY Z (I)<(-DEPTH#/8)
      IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
      TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
      DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
      WRITE DATAFILE STRING 1, DATALINE$
      IF I=>10
       PRINT CONSOLE "",I,"        ",CATEGORIES(I),"       ",STARTPOINT(I),"
",ENDPOINT(I),"       ",TRAVELTIME(I)
        PRINT CONSOLE
      ELSE
       PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"       ",STARTPOINT(I),"
",ENDPOINT(I),"       ",TRAVELTIME(I)
        PRINT CONSOLE
       ENDIF
       AI KILL ENTITY I
       DELETE OBJECT I
       ENTITIESON(I)=0
       WAITCOUNTER(I)=0
      ENDIF
     ENDIF
    IF ENDPOINT(I)=4
     IF AI GET ENTITY X (I)>(WIDTH#/2) AND AI GET ENTITY Z (I)>(DEPTH#/8)
      IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
      TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
      DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
      WRITE DATAFILE STRING 1, DATALINE$
      IF I=>10
       PRINT CONSOLE "",I,"        ",CATEGORIES(I),"       ",STARTPOINT(I),"
",ENDPOINT(I),"       ",TRAVELTIME(I)
        PRINT CONSOLE
      ELSE
       PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"       ",STARTPOINT(I),"
",ENDPOINT(I),"       ",TRAVELTIME(I)
        PRINT CONSOLE
       ENDIF
       AI KILL ENTITY I
       DELETE OBJECT I
       ENTITIESON(I)=0
       WAITCOUNTER(I)=0
      ENDIF
     ENDIF
    ENDIF
    REM END ENEMY ALIVE

    IF AI ENTITY EXIST(I)=0 AND DEFAULT=0
     IF CATEGORIES(I)=0
      REM BORN THE ENTITIES
      CREATEENTITIESCHILDREN(I)
     ENDIF
```

```
    IF CATEGORIES(I)=1
      REM BORN THE ENTITIES
      CREATEENTITIESTEENAGER(I)
    ENDIF

    IF CATEGORIES(I)=2
      REM BORN THE ENTITIES
      CREATEENTITIESADULT(I)
    ENDIF

    IF CATEGORIES(I)=4
      REM BORN THE ENTITIES
      CREATEENTITIESELDERLY(I)
    ENDIF

    IF CATEGORIES(I)=5
      REM BORN THE ENTITIES
      CREATEENTITIESDISABLED(I)
    ENDIF
    HIDE OBJECT I
    AI SET ENTITY VIEW ARC I,90,170
    STARTTIME(I)=0
    ENDTIME(I)=0
    TRAVELTIME(I)=0
    REM RESET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF REM FINISH REBORN ENEMY

  REM TO REBORN THE KILLED ENEMY IN DEFAULT SETTING
  IF AI ENTITY EXIST(I)=0 AND DEFAULT=1
    REM REBORN THE ENTITIES
    CREATEENTITIES(I)
    REM RESET STARTING POINT
    STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF REM FINISH REBORN ENEMY IN DEFAULT SETTING

  REM CALCULATE THE NUMBER OF ENTITIES ON THE STAGE
  ENTITIESON= ENTITIESON+ENTITIESON(I)
NEXT I

REM QUEUING ACTION
AI ADD ZONE 2,-WIDTH#/2,-5.5*DEPTH#/16,-WIDTH#/2+22,DEPTH#/2-40
FOR I=1 TO ENTITIES
  IF AI GET ENTITY IN ZONE (I,2)=1

    FOR J=1 TO ENTITIES
      IF AI GET ENTITY IN ZONE (J,2)=1
        QDISTANCE(I)= AI GET ENTITY Z(I) - AI GET ENTITY Z(J)
        REM +5 IS TO MAKE THE BOUNDARY BIGGER BEFORE COLLIDE
        IF QDISTANCE(I) > -(SIZE(I)+SIZE(J)+5) AND QDISTANCE(I) <0
          AI ENTITY STOP I
          J=ENTITIES
        ENDIF
      ENDIF
    NEXT J
  ENDIF
NEXT I

REM TIME
```

```
    HR$=LEFT$(GET TIME$(),2)
    HR=VAL(HR$)
    IF HR=>12
      IF HR> 12 THEN HR=HR-12
      POST$=" PM"
    ELSE
      POST$=" AM"
    ENDIF
    TIME$=STR$(HR)+RIGHT$(GET TIME$(),6)+POST$

    REM PRINT THE TIME AT THE BOTTOM OF THE SCREEN
    TEXT 7*SCREEN WIDTH()/8,SCREEN HEIGHT()-20,TIME$

    REM SIMULATION TIMER
    SET TEXT SIZE 12
    IF TIMER()/1000>RUNTIMESTART+RUNTIME THEN EXIT
    TEXT 7*SCREEN WIDTH()/8+5,SCREEN HEIGHT()-35,"TIMER:
"+STR$(RUNTIMESTART+RUNTIME-TIMER()/1000)

    SET TEXT SIZE 15
    SET CURSOR 0,0
    PRINT "NO. OF ENTITIES: ",ENTITIESON," / ",ENTITIES
    PRINT ""
    PRINT "CATEGORIES:- "
    PRINT " CHILDREN- YELLOW"
    PRINT " TEENAGER - PINK"
    PRINT " ADULT - RED"
    PRINT " ELDERLY - GREEN"
    PRINT " DISABLED - BLUE"
    AI UPDATE
    SYNC
  LOOP

ENDIF REM FOR THE ENTITIES <>0
END REM FINISH THE SIMULATION

REM CREATE DIFF CATEGORIES OF ENTITIES
FUNCTION CREATEENTITIES(I)
  CATEGORIES(I)=RND(7)
  REM CHILDREN
  IF CATEGORIES(I)=0
    SIZE(I)=9
    SPEED(I)=16
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF

  REM TEENAGER
  IF CATEGORIES(I)=1
    SIZE(I)=10
    SPEED(I)=15
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,27
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
  ENDIF
```

```
   REM NORMAL ADULT
   IF CATEGORIES(I)=2 OR CATEGORIES(I)=3 OR CATEGORIES(I)=6 OR CATEGORIES(I)=7
     SIZE(I)=12
     SPEED(I)=13.5
     MAKE OBJECT SPHERE I, SIZE(I)
     COLOR OBJECT I,RGB (255,0,0)
     AI ADD ENEMY I
     AI SET ENTITY SPEED I,25
     AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   ENDIF

   REM ELDERLY
   IF CATEGORIES(I)=4
     SIZE(I)=15
     SPEED(I)=11.3
     MAKE OBJECT SPHERE I, SIZE(I)
     COLOR OBJECT I,RGB(0,255,0)
     AI ADD ENEMY I
     AI SET ENTITY SPEED I,20
     AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   ENDIF

   REM DISABLED PEOPLE
   IF CATEGORIES(I)=5
     SIZE(I)=16
     SPEED(I)=10
     MAKE OBJECT SPHERE I, SIZE(I)
     COLOR OBJECT I,RGB(0,0,255)
     AI ADD ENEMY I
     AI SET ENTITY SPEED I,18
     AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   ENDIF
   AI SET ENTITY SPEED I,SPEED(I)
   HIDE OBJECT I
   AI SET ENTITY VIEW ARC I,90,170
   STARTTIME(I)=0
   ENDTIME(I)=0
   TRAVELTIME(I)=0
   CST(I)=0
   SYNC
ENDFUNCTION

REM CEATE ENTITIES UNDER USER DETERMINED
FUNCTION CREATEENTITIESCHILDREN(I)
   REM CHILDREN
   CATEGORIES(I)=0
   SPEED(I)=16
   SIZE(I)=9
   MAKE OBJECT SPHERE I, SIZE(I)
   COLOR OBJECT I,RGB(255,255,0)
   AI ADD ENEMY I
   AI SET ENTITY SPEED I,SPEED(I)
   AI SET ENTITY VIEW RANGE I,SIZE(I)*2
   SYNC
ENDFUNCTION

FUNCTION CREATEENTITIESTEENAGER(I)
   REM TEENAGER
   CATEGORIES(I)=1
```

```
    SPEED(I)=15
    SIZE(I)=10
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(255,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,SPEED(I)
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
    SYNC
  ENDFUNCTION


  FUNCTION CREATEENTITIESADULT(I)
    REM NORMAL ADULT
    CATEGORIES(I)=2
    SPEED(I)=13.5
    SIZE(I)=12
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB (255,0,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,SPEED(I)
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
    SYNC
  ENDFUNCTION

  FUNCTION CREATEENTITIESELDERLY(I)
    REM ELDERLY
    CATEGORIES(I)=4
    SPEED(I)=11.3
    SIZE(I)=15
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,255,0)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,SPEED(I)
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
    SYNC
  ENDFUNCTION

  FUNCTION CREATEENTITIESDISABLED(I)
    REM DISABLED PEOPLE
    CATEGORIES(I)=5
    SPEED(I)=10
    SIZE(I)=16
    MAKE OBJECT SPHERE I, SIZE(I)
    COLOR OBJECT I,RGB(0,0,255)
    AI ADD ENEMY I
    AI SET ENTITY SPEED I,SPEED(I)
    AI SET ENTITY VIEW RANGE I,SIZE(I)*2
    SYNC
  ENDFUNCTION

  REM STARTING POINT
  FUNCTION STARTPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    SYNC
    STARTPOINT(I)=RND(3)+1
    REM AT EXIT 1
    IF STARTPOINT(I)=1
      POSITION OBJECT I, RND(WIDTH#-100)-WIDTH#/2, SIZE(I)/2,-(RND(40)+DEPTH#/2+25)
      REM GO TO
      ENDPOINT(I)=RND(4)
      REM MAKE SURE NOT BACK TO SAME POSITION
```

```
    WHILE ENDPOINT(I)=1
      ENDPOINT(I)=RND(4)
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF

  REM AT EXIT 2
  IF STARTPOINT(I)=2
    POSITION OBJECT I, RND(WIDTH#-100)-WIDTH#/2, SIZE(I)/2,(RND(40)+DEPTH#/2+25)
    REM GO TO
    ENDPOINT(I)=RND(4)
    REM MAKE SURE NOT BACK TO SAME POSITION
    WHILE ENDPOINT(I)=2
      ENDPOINT(I)=RND(4)
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF

  REM BUS BAY 1
  IF STARTPOINT(I)=3
    POSITION OBJECT I,RND(40)+WIDTH#/2+25, SIZE(I)/2,-(RND(DEPTH#/8)+DEPTH#/8)
    REM GO TO
    ENDPOINT(I)=RND(4)
    REM MAKE SURE NOT BACK TO SAME POSITION AND NEXT BUS BAY
    WHILE ENDPOINT(I)=3 OR ENDPOINT(I)=4
      ENDPOINT(I)=RND(4)
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF
  REM BUS BAY 2
  IF STARTPOINT(I)=4
    POSITION OBJECT I,RND(40)+WIDTH#/2+25, SIZE(I)/2,(RND(DEPTH#/8)+DEPTH#/8)
    REM GO TO
    ENDPOINT(I)=RND(4)
    REM MAKE SURE NOT BACK TO SAME POSITION AND NEXT BUS BAY
    WHILE ENDPOINT(I)=3 OR ENDPOINT(I)=4
      ENDPOINT(I)=RND(4)
    ENDWHILE
    ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  ENDIF
  SYNC
ENDFUNCTION

FUNCTION ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
  IF ENDPOINT(I)=1
    AI ENTITY GO TO POSITION I, RND(WIDTH#-100)-WIDTH#/2,-(RND(40)+DEPTH#/2+25)
  ENDIF
  IF ENDPOINT(I)=2
    AI ENTITY GO TO POSITION I,RND(WIDTH#-100)-WIDTH#/2,(RND(40)+DEPTH#/2+25)
  ENDIF
  IF ENDPOINT(I)=3
    AI ENTITY GO TO POSITION I,RND(40)+WIDTH#/2+25,-(RND(DEPTH#/8)+DEPTH#/8)
  ENDIF
  IF ENDPOINT(I)=4
    AI ENTITY GO TO POSITION I,RND(40)+WIDTH#/2+25,(RND(DEPTH#/8)+DEPTH#/8)
  ENDIF
  REM COUNTER
  IF ENDPOINT(I)=0
    AI ENTITY GO TO POSITION I, -WIDTH#/2+9,-6*DEPTH#/16+15
  ENDIF
```

```
ENDFUNCTION

FUNCTION COUNTERF(I,WIDTH#,HEIGHT#,DEPTH#)
  AI ADD ZONE 1,-WIDTH#/2,-6.2*DEPTH#/16,-WIDTH#/2+22,DEPTH#/2-60
  IF AI GET ENTITY IN ZONE (I ,1) = 1
`    AI SET ENTITY SPEED I,50
    AI ENTITY GO TO POSITION I,-(WIDTH#/2-9),DEPTH#/2-45
  ENDIF

  REM AREA IN FORNT OF THE COUNTER
  AI ADD ZONE 3,-WIDTH#/2,DEPTH#/2-50,-WIDTH#/2+22,DEPTH#/2-40
  IF AI GET ENTITY IN ZONE (I ,3) = 1
    IF CST(I)=0 THEN CST(I)=TIMER()/1000
    IF CST(I)>0 THEN WAITCOUNTER(I)=TIMER()/1000-CST(I)
    IF WAITCOUNTER(I)>5
      REM IN ORDER TO AVOID ENTITIES GO BACK TO EXIT 1 BY 'U' TURN THEREFORE ONLY 3
CHOICE HAVE PROVIDED
      IF ENDTIME(I)=0 THEN ENDTIME(I)=TIMER()/1000
      TRAVELTIME(I)=ENDTIME(I)-STARTTIME(I)
      DATALINE$ =
STR$(I)+","+STR$(CATEGORIES(I))+","+STR$(STARTPOINT(I))+","+STR$(ENDPOINT(I))+","+STR$(S
TARTTIME(I))+","+STR$(ENDTIME(I))+","+STR$(TRAVELTIME(I))
      WRITE DATAFILE STRING 1, DATALINE$
      IF I=>10
        PRINT CONSOLE "",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",TRAVELTIME(I)
          PRINT CONSOLE

      ELSE
        PRINT CONSOLE " ",I,"        ",CATEGORIES(I),"        ",STARTPOINT(I),"      ",ENDPOINT(I),"
",TRAVELTIME(I)
          PRINT CONSOLE
      ENDIF

      STARTPOINT(I)=ENDPOINT(I)
      ENDTIME(I)=0
      TRAVELTIME(I)=0
      CST(I)=0
      ENDPOINT(I)=RND(2)+2
      STARTTIME(I)=TIMER()/1000
      AI SET ENTITY SPEED I,SPEED(I)
      ENDPOINTF(I,WIDTH#,HEIGHT#,DEPTH#)
    ENDIF
    IF WAITCOUNTER(I)=<5
      AI ENTITY STOP I
    ENDIF
  ENDIF
ENDFUNCTION
```