ABSTRACT

HUMAN FACTORS APPROACH TOWARDS IMPROVING THE READABILITY OF BUS SCHEDULES

by
Anand Tharanathan

Due to an increasing concern over the readability of existing bus schedules of a public transportation agency the schedule format was redesigned. Two prototype schedules were designed based on the gathered information from the literature survey, focus group meetings and data from other public transportation agencies' schedules. One of the prototypes was designed by giving primary importance to the direction of travel and was named the directional prototype schedule. The other prototype was designed by giving primary importance to the day of the week, and was named weekday / weekend prototype schedule. A time based laboratory experiment and a subjective survey with twenty-six participants were conducted to test the representational modifications against the existing ones. The analysis of the experimental data showed statistical significance only in the zone representation. Zones are used for calculation of the fares for travel. They have been represented differently in the new prototypes, and was preferred over the current one. Participants more often than not assigned rank three to the current schedule as compared to rank one or two. Another observation was that the average number of errors committed in the test by the participants having just a high school level of education was over 35%. The performance of the participants kept improving along with the increase in the level of education. This is an issue of concern because large percentage of people who use the bus schedules of the public transportation agency are people with just high school level of education or even lower.

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by
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HUMAN FACTORS APPROACH TOWARDS IMPROVING READABILITY OF BUS SCHEDULES

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Gayatri Mantra

ॐ भूर्भुवः स्वः
ॐ तत्सवितुर्वरेण्यं भर्गो देवस्य
धीमहि धियो यो नः प्रचोदयात्।

"A prayer to the Almighty Supreme God, the Creator of entire cosmos, the essence of our life existence, who removes all our sins, pains and sufferings and grants happiness; beseeching His divine grace to inculcate within us His Divinity and Brilliance which may purify us and guide our wisdom on the righteous path."

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CHAPTER 1

INTRODUCTION

Hardcopy timetables are more popular and sought after more than the timetables available on the Internet. The use of the Internet to present and retrieve bus schedule information is a growing trend in the current era. Most transportation agencies have a web-based schedule system where users can enter the location to which they are traveling, the boarding location, dates of travel and time frames. Once this information is entered, a list of buses meeting the criteria is displayed. Some transportation agencies have systems where maps and schedule information can be viewed, downloaded and manipulated. Public transportation users and potential customers who do not have readily available access to a computer, however, either depend on others for information or use hardcopy schedules. Consequently, even with the widespread use and knowledge of computers, there still remains a considerable dependency on hardcopy schedules.

The current bus schedules of the public transportation agency in the State of New Jersey have evolved from staff recommendations, legal and liability issues, policy/procedural changes and schedule updates. Initially the reports were developed based on certain guidelines and staff recommendations. When the current schedules were out in the market, they received several complaints from users regarding its readability. The transportation agency prints approximately twenty million hard copies of bus schedules every year and unless the schedules are readable and used by the public, they would render unnecessary expenses. Hence a research study was initiated to explore the readability issues related to bus schedules and how they could be improved.

1.1 Readability

In designing displays, which are more readable, the goal is to present information in such a manner that it can be read rapidly and accurately. In addition, certain critical items of information should be recognized automatically, with a minimal requirement to invest conscious processing. At any level of perceptual processing, it should be apparent that the accuracy and speed of recognition would be greatest if the displayed stimuli were presented in a physical format that is maximally compatible with the visual representation of the unit in the memory (Wickens and Holland, 2000). Most obviously, print should not be too fine in order to guarantee its readability. Fine print and very narrow stroke widths are very dangerous choices. Similarly, one should maximize contrast by printing black letters on white background. The choice of fonts and the case also makes a difference on how fast users can comprehend the information (Wickens et. al, 2004). Therefore, improving readability of any display is to optimally improve the inbuilt design features, so that the users can comprehend the information faster and more accurately.

From a human factors standpoint, reading and deciphering bus schedules consists of a highly complex set of tasks involving many phases of human information processing. According to a well-known human information processing model (Wickens and Hollands, 1999), the initial searching task requires short-term sensory storage for visual information input while scanning the busy timetable, recognition of symbols and abbreviations on the map from both working and long-term memory, decision making for determining the right bus schedule at the right bus stop, and working memory for memorizing the bus route, bus schedule, and bus stops for getting on and off the bus.

These mental processing steps are even more challenging if the user is elderly, has poor vision or is not accustomed to reading and processing busy timetables.

1.2 Current Bus Schedule

The transportation agency's bus schedules have several features, including a map, timetable and text notes. The reduced version of the current schedule has been included in the appendix A. The map is not to scale and includes the names of selected streets and towns served. The map also indicates connecting bus routes and passenger rail lines. The timetable consists of selected bus stop locations, or "time point locations", which are shown in white text on a black background. Bus arrival/departure times or "time points" for the corresponding time point locations are listed below the time point locations. In general, weekdays, Saturdays and Sundays are displayed on separate tables for each direction. Several other pieces of information, including notices, phone numbers and fare information are also provided on bus schedules. The width of the schedule document is consistently 9 inches for all routes. The lengths vary between 15 inches and 27 inches depending on the level of complexity. When folded, bus schedules are approximately 9" x 3". All bus schedules are printed on standard white paper in black and white.

For this study, several sources were referred to in order to obtain information about design features for improving readability. The objective of this research was to corner out the facts, which improve readability of timetables, and to test whether the incorporation of those features into the current timetable of the public transportation agency would have an effect, under the given set of constraints.

1.3 Organization of the Thesis

In the second chapter, the literature review is presented and studies conducted in the field of printed display and related areas are described. Studies were also conducted exclusively on timetables regarding the positioning of the time-points and the effect it has on the readability of schedules. Topics related to font sizes, stroke width and importance of cases are explained. A study on the effect of highlighting is also quoted, since highlighting has been done in the newly developed prototypes. Overall, research studies based on printed displays, information processing capabilities, cognition, timetables and text, are included in the literature survey.

In the third chapter, the research plan is outlined and explained. An exclusive human factors approach was adopted for the whole study starting from the initial study of the schedule to the final time based testing and analysis of results. The research plan depicts the major interests of this research study and what the expected mode of approach is, to obtain reliable results.

The experimental methods adopted for this study are explained in chapter four. The experimental methods adopted include a literature survey, focus group meetings, gathering information from other public transportation agencies, internal brain storming session, prototype design and development, time-based laboratory experiment and the final analysis and interpretation of the results.

Chapter five contains of the results of the experimental methods. The design parameters that were adopted from each part of the input data pool consisting of the literature survey, focus group meetings, and information from other public transportation agencies are laid out. The design features that finally went in to the design and

development of the two prototypes are also included. The results of the time-based laboratory experiments are shown with the help of tables of analysis of variance and bar charts. The results of the subjective survey are illustrated with bar charts and related facts and figures.

Finally in chapter six, the substantiations and explanations of the results along with future possible extensions of study have been included. There were certain limitations and indispensable constraints in the study, which could have affected the validation of certain results. They are clearly listed and the possible solutions are mentioned.

CHAPTER 2

LITERATURE SURVEY

Reading and comprehending bus schedules involves a complex set of tasks, which includes different stages of the information-processing model. It is a series, which starts from the initial perception of the printed display till the final response. The information is perceived, after which the short-term memory and attention come into play. At this stage, there is a load on the cognitive capabilities of the user. After cognition, the user responds to the situation.

Intuition, as well as a body of research suggest that the effect of visual displays depends upon both physiological and cognitive aspects. Visual displays must be readily visible and the design must make it possible for the viewer to correctly perceive the meaning of the display. Displays designed for specific work situations, of course may require some level of worker training, but the design should capitalize on those display features that enable people to correctly perceive what they sense. (McCormick and Sanders, 1993).

Attracting the user's attention is also very important in any visual display. In certain typical situations, since substantial information may be presented to users for the normal performance of their work, exceptional conditions or time-dependant information must be presented so as to attract attention (Wickens, 1992). In general multiple techniques exist for getting attention (1) Intensity: use two levels only, with high intensity to draw attention. (2) Marking: underline, enclose in a box, point to with an arrow, or use an indicator such as an asterisk, bullet, dash, plus or "X". (3) Size: use up to four sizes,

with larger sizes attracting more attention. (4) Choice of fonts: use up to three fonts. (Schneiderman, 1998).

Researchers have also identified four important characteristics of display formats: overall density, local density, grouping and layout complexity. When objective measurement techniques for these characteristics were proposed and applied to two different display formats, the results suggested that these measures could provide the basis for objectively evaluating a display without collecting performance data (Tullis, 1983).

Recently, researchers have shown that on the average, subjects are quicker to find a target option in a highlighted display than in a display without highlighting. However, other related research has demonstrated that subjects are slower to find a target in a highlighted display than in a display without highlighting. In an attempt to resolve this paradox, a set of experiments was performed. The results suggested that to determine whether highlighting will be of benefit, one must know the type of highlighting, the level of highlighting validity, and the probability that subjects attend first to the highlighted options. The mode of highlighting might be different for different kinds of representations and designing has to be done accordingly (Fisher and Tan, 1989).

Pictures were also found to play an active role in conveying the intended message. If performance speed is important, then pictures are generally preferable to textual instructions; however, if memory of the instructions is important and recognition is critical, textual representation was determined to be more advantageous (Fisk, Kobylak and Serbo, 1986).

Researchers found that complex cognitive tasks can be accomplished using one of several different strategies. Experiments conducted in the domains of bus schedules, medication instructions, and text-editing all led to the same basic conclusion: alternative representations of the same information have clear and often dramatic effects on cognition. This was found to be true for the following comparison conditions:

1. The amount of information to be learned is relatively heavy (bus schedules) or light (text editing)

2. The domain occurs in everyday situations (*bus schedules*, medication instructions) or more specialized settings (text editing)

3. A list representation is compared with another type of list (*bus schedules*), a matrix (medications), or a spatial format (text editing)

4. The cognitive processes examined were memory (*bus schedules*, medications, text editing), comprehension (medications, text editing), or problem solving (text editing)

Despite all these differences, some representations always facilitate performance while others hindered it (Day and Ruth, 1989).

Critical determinants of performance in visual scanning include location and reading of digits. The time to perform such a task is constant for differing vertical locations of the target numerals and the initial fixation point within the display screen. When the size of displacement of fixation is increased with the display at a fixed distance, there is a significant increase in reaction time. However if viewing distance is altered, reaction time does not depend upon the resulting angular separation of the fixation point and the target. Rather the physical separation of the two determines the performance, over the range of viewing distance examined. The increased time required to look between and respond to widely separated data fields cannot be compensated by increasing viewing distance. This may be the result of a trade-off between the effects of

scan angle and of peripheral acuity (Swanstson and Walley, 1984). As per the principle of compatibility of proximity, when a task requires integration of information, the display should present the data in close proximity. Similarly, when the task does not require the integration of information or necessitates selective attention to a subset of the information, nonintegrated displays will be optimal. Information displays should match the mental representation of the information particularly in tasks that rely heavily on large amounts of data (Goettl, Kramer and Wickens, 1986). Regarding the map in the schedules, if the presence of a school or church can be shown, it would help the user to process information faster as they compare it with their existing mental models. And the proximity of the timetable to the map would also improve the speed of reading the schedule, especially if they need to read both to plan a trip.

Research was also conducted on the spatial characteristics of successive lines of printed text. The spatial characteristics of these patterns were measured and were found to be similar to those of patterns that induce discomfort, anomalous visual effects and even seizures. Researchers argued that the inherent striped property of horizontal text provokes "eye-strain" and seizures to the reader. It was further argued that by covering the lines of text above and below those being read would reduce the occurrence of headaches and seizures.

Subjects were also asked to judge the clarity of text. It was shown that judgments of clarity are affected by the spatial characteristics of the text pattern and in particular, the spacing between the lines. It was found that the average area of the page occupied by a letter (i.e. the product of the separation between the lines and the mean horizontal spacing between the centers of letters) accounted for less variance in clarity than the separation

between the lines of text. It was concluded that within the constraints of conventional typography and without increasing costs the clarity of text could be improved by reducing the typical spacing between the letters in order to increase the spacing between the lines. (Nimmo-Smith and Wilkins, 1987). It shows how we can manipulate the clarity and readability of a printed display with the available space and existing constraints.

2.1 Typography and Topography

Typographical and topographical aspects are important in designing displays that represent schedule stop locations, times and routes. Better typography and topography can improve the quality of any information display. There needs to be minimum congestion, which can make it easier for people to read and understand the route in one search, rather than in multiple searches. Casual examination of several mathematical or statistical tables will reveal great variation in the typographical arrangements employed. From table to table the reader may find variation in type size, type face, use of additional leading at periodical intervals, number of decimal places employed, etc. To a reader with some background in scientific topography, it is obvious that some of these factors should influence the readability of tables. In some tables, economy of space seems to be the sole consideration with no attention to readability factors. Where readability is mentioned, choice of typography depends upon opinion rather than upon experimental findings (Tinker, 1954).

The legibility of displayed letters depends upon their size, or more accurately, their subtended visual angle at any viewing distance (Smith, 1979). The term typography refers to the various features of alphanumeric characters, individually and collectively.

For everyday practical purposes, most of the variations in topography adequately fulfill the human factors criteria like visibility, legibility and readability. However there are four types of circumstances in which it may be important to use "preferred" forms of topography: (1) when viewing conditions are unfavorable (as with poor illumination or viewing time), (2) when the information is important or critical (as when emergency labels or instructions are to be read), (3) when viewing occurs at a distance, and (4) poor vision of users. Representation of maps has space constraints on many occasions, but the rule of thumb is that there should be minimum congestion and the coding should be used in such a way that it becomes easier for the user to read and understand the map. The presence of arrows and other signs should be able to convey the intended message and needs to be well justified. The maps should not be overloaded with information.

Regarding typography, the following primary conditions apply:

2.1.1 Stroke Width

The stroke width of an alphanumeric character usually is expressed as the ratio of the thickness of the stroke to the height of the letter or numeral. A phenomenon called irradiation causes white features on a black background to appear to spread into adjacent dark areas, but the reverse is not true. Thus, in general, black text on a white background should be thicker (have lower width to height ratios) than white letters on black backgrounds. With reasonably good illumination, the following width to height ratios are satisfactory for printed material: black text on white background, 1:6 to 1:8 and white text on black background, 1:8 to 1:10. As illumination is reduced, thick letters become relatively more readable than thin ones (this is true for both black-on-white and white-on-black letters). With low levels of illumination or low contrast or low contrast with

background, printed letters preferably should be boldface type with a low stroke width-to-height ratio (such as 1:5). For highly luminous letters, ratios could be reduced to 1:12 to 1:20. For black letters on a highly luminous background, very thick strokes are needed. The relationship between the width and height of a complete alphanumeric character is described as the width-height ratio and is expressed, as a proportion (such as 0.60). A width to height ratio of 3:5 has come into fairly common use and in general is well supported by research.

2.1.2 Styles of Type

Style types fall into four major classes: Ariel, Roman, Gothic, Script and Block lettering. Some styles can also vary based on the use of serifs or small segments added to each letter. Ariel text, however, does not have serifs and is hence referred to as "sans serifs" from the French word "sans", which means "without".

2.1.3 Size

Text size is defined by the term "point" which corresponds to hundredths of inches. So, for example, "9 point" text would measure 9 one-hundredths or 0.09 inches, 11 point would measure 0.11 inches and so on. Appropriate sizes are generally selected for a corresponding reading distance. In the case of close-up reading, if we accept that the commonly used 9- to 11-pt print sizes of newspaper and magazines are suitable, then such sizes (0.09 to 0.11 in; 2.3 to 2.8 mm; 22 to 27 min of visual angle) would be acceptable as a basis for general use printed alphanumeric material.

2.1.4 Case

Philips (1979) suggests that for certain tasks, such as looking for a particular label on a control panel, the important aspect of the word is not the overall shape, but rather the initial letter. If the initial letter were larger than the other letters, the word would be found more quickly (McCormick and Sanders, 1993). Therefore, when type is being designed to help the reader search quickly, the designer should first try to avoid lower case in order to make a typographical distinction. For example, to distinguish on a map country names from city names, the use of small capitals with a large initial capital is recommended since this retains emphasis on the capital letter. Secondly, when setting proper names with more than one word, it is perhaps only necessary to use a capital on the first word as normally it is only this first initial which is processed in a search task (Philips, 1979).

2.1.5 Grouping

The great variation in typographical arrangements found in published tables in the field suggests that such factors as convenience, amount of space taken and specific use for which the table was designed have led to arbitrary choice of the printing arrangement employed. In many cases, economy of space seems to be the sole consideration in determining the topographical arrangement with little or no attention to legibility. A study was conducted on the type size, arrangement of numerals in columns, and space versus space plus rules between columns. The study measured the speed and accuracy at which the correct numbers were located and tabulated. It was found that when the numbers were grouped in columns, they were located more easily as grouping helps users in directing their line of vision. In general, grouping numbers by fives were more effective than grouping in tens (Tinker, 1960).

2.2 Timetable Design

Comparatively few studies have been conducted on timetable design, with the significant ones being in the seventies and early eighties. More studies have been conducted on other kinds of tables such as currency conversion tables, spreadsheets and shopping lists. These study findings may be applied to timetables because the pertinent criterion is the optimal information representation and display. The speed and accuracy with which people obtain information from numerical tables were examined for a variety of presentation formats. It was found that people were slower and more error prone when they had to make four successive binary decisions than when making two decisions, each time selecting among four alternatives. People also made more errors when the presentation format required them to combine decisions along two different special dimensions compared to one-dimensional representation (Wright, 1977).

Another factor, which affects the speed of finding the target, is the visual field. There exists a relationship between the size of the visual fields of the observer and the time required to locate the target on static displays. People with large visual fields can find targets more rapidly than observers with small fields (Johnston, 1965). Speed of search also depends on the visual lobe area (Bellamy and Courtney, 1981).

In one study, a hypothesis concerning the appropriateness of alternative forms of graphical display for the presentation of particular properties of data was tested. It was found that there are significant differences between the alternative forms of presentation in terms of effectiveness for communicating major features of data. Representation of data in spreadsheet form was included in the study as a reference point for establishing the additional contribution that graphical representation offers. As per these findings,

there is no single form of data display, which has proved to be the most appropriate in displaying numerical data along two dimensions (Sparrow, 1989).

Compared to bar charts and pie charts, spreadsheets can be used very effectively to convey specifics, trends and accumulation. This is because of freedom within the format of comparisons by educated perceivers. It is however especially poor at drawing attention to conjunction and will need augmentation if this data aspect is to be conveyed. It is clear that different basic forms of representation influence the recall of information abstracted from data sets. The same data, if represented in a different manner, tends to convey a different meaning. There is always an optimal way of representation, which will best suit specific needs (Sparrow, 1989). Regarding the selection of the time system, studies have been conducted on the twelve-hour and twenty-four hour systems. It has been proved that the twelve-hour system is more efficient and productive than the latter (Bartram, Crawshaw, and Sprent, 1980).

In spite of the variety of circumstances in which tabulated information is used, little is known about the relative effectiveness of different formats. However it has been found from studies that some types of tables are incomprehensible to many people, and that aspects of presentation, which were intended to help the user can in fact turn out to be a detriment. There has to be an optimal design for tabulated information. There are certain guidelines given with respect to factors within columns, between columns and on total display style, which might be helpful in properly designing any table for public use. For instance, within columns, grouping should be done by using spacing or ruled lines, i.e. splitting columns into blocks of approximately five items. Another factor is the left-

right arrangement of columns; so that information is read off to the right of the item looked up (Fox and Wright, 1970).

There are two typical styles of timetables: one (which is used extensively) represents the route vertically and is known as the standard format; the other (which occurs less frequently) represents the route horizontally and is known as the reflected format. These styles of representations were assessed in their basic versions and were then modified with the intention of making them easier to use. It was found that the reflected format was better than the standard format and evidence suggested that the main reason for the superiority of the reflected format is that it is easier to scan. An intuitively attractive feature of the reflected design is that the "super ordinate" route dimension is represented in the orientation, which corresponds to probably the most powerful population stereotype of direction of motion or progression-horizontally, from left to right (Bartram, Crawshaw and Sprent, 1983).

Comparisons between matrices and tables were made in one study, which produced interesting results. The reported findings are undoubtedly little more than tentative explorations of the problems that arise when people are required to use tabulated information. There is no proof that a given type of information can be easily handled by a certain proportion of the population, and furthermore that this population can be increased by suitable training; nevertheless there appears to be a sizeable subgroup who have difficulties when trying to use certain types of tables. Considering the factor of locating the information, it might be expected that matrices will be more difficult to handle than tables that are basically a list of pairs of values, since a matrix involves locating two entry points (vertical and horizontal) (Wright, 1968).

With respect to performance with currency conversion tables based on two alternative principles of tabulation, in a simulated shopping situation there was an initial speed advantage for the table, which explicitly listed all pairs of equivalent prices. The other table, which gave conversions of shilling separately from the conversion of pence, was not only slower to use, it was more often incorrectly used. Data from a modified market survey technique showed that many incorrectly used this more difficult 'implicit' format even when given an illustrative example. Presenting school children with both numerical and non-numerical tables indicated that the difficulty of the implicit format was not caused by the mental arithmetic involved, although it was associated with combining separate items of information. Juxtaposition of the items was more easily achieved than a synthesis. The idea is that the table should be simple to use and not complicated. All information should be available in one search, rather than combined searches (Fox and Wright, 1972).

It is important that the representation of the words and numerals has an optimum blend of graphical elegance, text representation and information display for better understanding and visual quality. Graphical elegance is often found in simplicity of design and complexity of data. What can be suggested, though, are some guidelines for enhancing the visual quality of the more routine, workday designs.

Attractive displays of information:

1. Have a properly chosen format and design.
2. Use words, numbers and drawings together.
3. Display an accessible complexity of detail.
4. Are drawn in a professional manner, with the technical details of production done with care.

5. Avoid content-free decoration including chart junk (Tufte, 1983).

Lines in data graphics should be thin. One reason eighteenth and nineteenth century graphics look so good is that they were engraved on copper plates, with a characteristic hair-thin line. The drafting pens of the twentieth century mechanical drawing thickened line work, making it clumsy and unattractive. Likewise, data graphics can be enhanced by the perpendicular intersections of lines of different weights. The contrast in line weight represents contrast in meaning, with greater meaning given to the greater line weight; thus the data line should receive greater weight than the connecting verticals. The logic here is reinstatement, in different language, of the principle of data-ink maximization. This is an important tool during the phase of the general table outlay design (Tufte, 1983). Researchers have proposed that graphical efficacy may be determined, in part, by the nature of perceptual interactions that exist between attributes used to create graphical displays. One extreme type of interaction is integrability, in which two or more physical dimensions are represented as a single psychological dimension to the observer. An alternative type of interaction is configurality, in which a global emergent dimension is available to the observer in addition to the component attributes.

In one study, thirteen stimulus sets, each consisting of attributes commonly used for design of graphs, were submitted to the performance-based diagnostics of integrality and configurality. The analysis showed a continuum of configurality among the present stimulus sets with little evidence for integral graphical attributes. The configural pattern of the result was more common when two identical dimensions were paired (homogenous stimuli) than when two different dimensions were paired (heterogeneous stimuli).

However, there seems to be no evidence that pairs of dimensions belonging to a single object (object integration) were any more configural than dimensions belonging to different objects. Object integration however consistently relates to inefficient performance in tasks requiring the filtering of one of the two component dimensions. (Carswell and Wickens, 1990).

Proper alignment of the data within the table can improve the overall visual quality. One of the five vital points for data display as suggested by Smith and Moiser (1986) is that the format should be familiar to the operator and this objective is served by rules for neat columns of data, left justification for alphanumeric data, right justification of integers, lining up of decimal points, proper spacing, use of comprehensible labels and appropriate measurement units and number of decimal digits (Schneiderman, 1998). More generally, tables and graphics can be classified as friendly and unfriendly. There are specific differences between friendly and unfriendly graphics:

Friendly:

1. Words are spelled out, mysterious and elaborate encoding avoided.
2. Words run from left to right, the usual direction for reading occidental languages.
3. Brief messages help explain data.
4. Elaborately encoded shadings, cross hatching, and colors are avoided; instead labels are placed on the graphic itself; no legend is required.
5. Graphic attracts the viewer and provokes curiosity.
6. Type is clear, precise and modest lettering maybe done by hand.
7. Type is upper and lower case with serifs.

Unfriendly:

1. Abbreviations abound, requiring the viewer to sort through text to decode abbreviations.

2. Words run vertically, particularly along the Y-axis; words run in several different directions.

3. Graphic is cryptic, requires repeated references to scattered text.

4. Obscure coding requires going back and forth between legend and graphic

5. Graphic is repellant, filled with chartjunk.

6. Type is clotted, overbearing.

7. Type is all capitals, sans serif (Tufte, 1983).

CHAPTER 3

RESEARCH APPROACH

3.1 Research objectives

The research objectives of the study were the following.

1. Search different sources to find out the most efficient design features that could enhance readability of printed schedules.

2. To capture the shortcomings in design features in the current schedule with respect to readability.

3. Develop prototypes, with improved design features incorporated in them.

4. Conduct a time based laboratory test with human participants to substantiate the incorporated design features in the newly developed bus schedules.

5. Conduct a subjective survey to capture the preferences of the users with respect to certain design features in the prototypes.

6. Propose ideas and research approach towards designing future bus timetables and making them more readable and user friendly.

3.2 Research Activities

An exclusive "human factors" approach was used for this research study. The research activities that were carried out during the study are following.

1. The reasons for the poor readability of the current schedules were analyzed. Different sources of information like the literature survey; focus group meetings and information from other public transportation agencies' schedules were used as inputs.

2. Two prototypes were developed with improved features. The respective information from the literature search, focus group meetings and data from the schedules of other public transportation agencies were used in this section as well to aid the development of the two prototypes. An internal brainstorming session was also a significant contributor and organizer of the input data pool. Considering all the constraints from the different perspectives, the necessary design features were incorporated into the newly developed prototypes. The two prototypes differed with

respect to the importance assigned to the design parameters. One of the schedules was named the directional prototype schedule, because this schedule gave primary importance to the direction of travel, irrespective of the day of the week. The other prototype was named the weekday / weekend prototype schedule, since this schedule gave primary importance to the day of the week, irrespective of the direction of travel.

3. The two prototypes along with the current schedule were used for a time based laboratory experiment with human participants. The time based laboratory experiment was carefully designed to capture the positive and negative design features of the current schedule and the newly developed prototypes. The design of the experiment, recruitment of participants and the time based laboratory test are described in the appropriate section. A subjective questionnaire was also designed to capture the preferences of the human participants with respect to their expectation of an easily readable bus schedule.

4. The objective performance and the subjective preferences of the participants were analyzed to understand the underlying readability problems of the current bus schedule. Depending on the findings from the experimental data and the subjective questionnaire, certain techniques and ideas have been discussed towards the designing timetables, which are more readable, and user friendly.

CHAPTER 4

EXPERIMENTAL METHODS

4.1 Literature Survey

An extensive literature search was conducted on the topics of guidelines and principles of information display, human factors in display designs, optimal display of information, cognitive behavior, and understanding and interpreting of information in printed displays. This information was used as a guide during the design of the prototypes for a time based laboratory experiment. Although there probably has not been any research study where objective performance and subjective preferences were combined to draw the final conclusions, several ideas regarding the testing set up were derived from the literature.

4.2 Selection of the Bus Route

Over two hundred bus routes are operated by the public transportation agency in the State of New Jersey. Among the schedules for theses routes, some cover combined routes, while some are stand-alone. To have a controlled research approach to the study, a particular route and the respective bus schedule was selected for detailed review, and "prototype" development. The selected bus schedule was a busy one with many time points and frequent stops. The map printed on the schedule was also confusing.

4.3 Focus Group Meetings

Once the route was selected, focus group meetings were conducted to receive input and feedback regarding the use of the schedule. The focus group forum provided an excellent opportunity for interactive discussions regarding their opinions and use of the schedule. One focus group, named as the internal focus group consisted of seven employees of the public transportation agency, who use various bus routes operated by the agency on a regular basis. The focus group meeting was conducted in one of the rooms in the office building of the public transportation agency. The second group, which was called the external focus group, consisted of both users of the selected bus line and non-users of the bus service. There were six participants in this group and the same room was used for the meeting as the one used for the external focus group. The same basic format of the meeting was used for both groups. Discussions of the meeting covered a number of topics and issues relevant to schedule usability, format and content. Although the make up of each group was different, there were several common issues regarding the use of the schedules. These issues are described in the successive chapter.

4.4 Other Transportation Agencies' Schedules and Information

Although layouts from other transportation agencies were not intended to serve as a basis for developing the prototypes, it was interesting to note some of the layout approaches undertaken by other agencies. Obtaining and then presenting these schedules also provided an opportunity for the focus groups to identify preferences in the layout of the schedules. Several inputs were received regarding the readability, and positive and

negative features in those schedules. These inputs were pooled and incorporated in the most optimal possible way during the development of the prototypes.

4.5 Internal Brain Storming Session

After all inputs were received from the various sources, an internal brain storming session was conducted within the research team. There were specific constraints, which had to be considered during the development of the prototypes. Usage of color to highlight certain features was one of the constraints. Considering all the constraints, the internal brain storming session helped to organize and incorporate the necessary design parameters into the two prototypes.

4.6 Prototype Design and Development

Considering the indispensable constraints, printed display guidelines, literature search, information on schedule design from other public transportation agencies and focus group members' expectations, two prototype schedules were designed and developed for time based testing.

4.7 Time Based Laboratory Experiment

4.7.1 Pilot Test

A pilot test was conducted in a laboratory set up with the two prototypes and the current schedule. The study was conducted with eight subjects to nullify any shortcomings in the general design and execution of the lab-based time test. The participants were asked if they faced any difficulties in following the procedure of the test. The response was

negative without any major modifications to the suggested methodology. The shortcomings, even though negligible, were rectified accordingly and the final test was conducted.

4.7.2 Final Time Based Laboratory Test

Participants: Twenty-six people served as volunteers for this time based test. Sixteen of them were males and ten were females. A selection procedure was designed for recruiting participants for the time-based test. The distribution of participants among age categories with respect to their gender is shown in Table 4.1.

Table 4.1 Age Classification of Participants

Gender	Age				
	Under 18	18 to 35	35 to 55	Above 55	Total
Males	2	8	5	1	16
Females	1	4	4	1	10

The participants included high school students, college students, professors, janitors and office staff. The distribution of educational level among the participants is presented in Table 4.2.

Table 4.2 Educational Level Classification of Participants

Educational Level	Number of Participants
High School	5
College	13
Advanced Degree	8

The experience level of the participants with respect to their familiarity and usage of the public transportation agency's bus schedules were divided into four major categories, namely

- None
- Rarely (Less than twice in the last six months)
- Frequently (Twice a month)
- Very frequently (Twice a week)

The former two divisions were classified as infrequent uses and the latter two as frequent users. Therefore, regarding the participants, they were divided based on three major classifications, namely their age, level of education and their familiarity with the particular bus schedules.

Time-Based Test: A time-based test was designed, wherein the subjects had to answer questions based on the prototype schedule provided to them. Three schedules were used for the test, one being the existing schedule. The time test was divided into three phases; each phase for a specific schedule and a set of questions. Each set comprised of eleven questions, with the first one being a trial question, so that the participants would get familiar with the mode of questioning. The questions were printed on placards and were

placed in front of each participant. The result of the first question was not recorded or analyzed. Prior to each phase, the participants were given five minutes to become familiarized with the given schedule. Each of the ten questions was designed to test specific factors that may affect reading and interpretation of bus schedules. Even though the questions in the three question sheets were similar with respect to the design feature they tested, they were not the same destinations, departure locations or times. The locations and the times were changed, but the testing variable within the question remained the same. On the average, a particular participant took one hour and fifteen minutes to complete the whole test, including the subjective questionnaire.

Data Collection: The entire experiment was video recorded using a camcorder. A microphone, which was connected to the camcorder, was used to ensure the clarity of subjects' verbal responses. The intention was to record the responses of the participants while they performed the task. The recording also tracked the time utilized by the participant for a particular question. The recording set up was placed behind the participants so that they were not disturbed by its presence. As soon as a participant found out the answer for a question, he / she said it out loud, so that the experimenter could record the time and answer. The time utilized by each participant for every question was also noted using a stopwatch. Thereby the speed and accuracy of the participants in reading the schedule was observed.

Subjective Questionnaire: After the time-test, a subjective questionnaire was given to each subject to obtain their opinion about the different ways of representation of information in the three schedules. They were asked to rank the schedules based on ease

of use, reading and interpretation comfort. Questions based on the individual efficiency of the incorporated design features were also included.

Data Evaluation: Within-subject experimental design was used for quantitative analysis. The order of the three designs and the three question sheets were counterbalanced in order to cancel any sequential effects. A General linear model of analysis of variance (ANOVA) was used to compare the three designs on performance variables, including time in finding information from the bus schedules and their accuracy.

CHAPTER 5

RESULTS

5.1 Relevant Findings from the Literature Survey

A number of consistent themes emerged from the body of research, some of which are reflected in the layout and design features of other public transportation agency schedules. Relevant findings from the literature review and its applicability to the public transportation agency is the State of New Jersey are presented below:

1. Time-point reorientation: Bartram, Crawshaw and Sprent did a study on bus timetables and the results suggest that the locations and the time should be on the same axis, so that the users do not have to flip the schedule to read efficiently.

2. Proximity: Goettl, Kramer and Wickens (1986), conducted a study, the results of which suggested that proximity enhances productivity when a task requires integration of information. The proximity of the map to the timetable might be an important factor in making the timetable easier to read and follow.

3. Zebra Pattern: In an article by Fisher and Tan (1989), it is mentiond that proper highlighting will grab the attention of the users, and also provide them a reference line, which in turn will also help them read the schedule easily.

4. Decrease column length: According to Fox and Wright (1970), decreasing the column length will fasten up the reading process for the user. It will also decrease the error in reading, which might turn up in the case of long columns.

5. Font size: According to American Public Transportation Association (APTA) standards, the minimum font size for printed texts should be point 6, while it is point 5 in the existing schedules. Increase in the size might enhance the readability.

6. Zone distinction: A study conducted by Swanstson and Walley (1984) suggested that the separations between zones should be shown clearly. Zone separation in the bus schedule will help the user to translate the information into the bus fare faster.

5.2 Relevant Findings from the Focus Group Meetings

5.2.1 Internal Focus Group

All of the internal focus group participants were employees of the public transportation agency in the State of New Jersey and were regular users of the bus schedule. The moderator distributed two bus timetables; one of which was a stand-alone schedule, and the other one a combined schedule. The group was then asked to complete two "scenarios". The first scenario asked questions about use of the stand-alone schedule on a weekday to get to a meeting. The second asked about use of the combined schedule to get to a Giants football game at the Meadowlands Sports Complex on a Sunday.

The group did not have difficulty answering the questions. However, a question came up regarding the use of the combined schedule. Specifically, one of the focus group members pointed out a provision in the schedule that indicates the bus does not travel to the Sports Complex on sporting events. The rest of the group overlooked this. The moderator asked a series of questions about the use of the bus schedule. The following summarizes the overall responses:

1. *How critical is the schedule to making your trip*? In general, the group felt that the schedule was very critical for making trips.

2. *How often do you use the bus schedule?* Responses were somewhat varied. Some indicated that they used the schedule few times per week. Others indicated they used it less frequently.

3. *Where do you pick up the bus schedule?* As the focus group members were employees of the public transportation agency, all replied that they pick up the schedules at work.

4. *Are bus schedules readily available and convenient to pick up*? The response was yes.

The group was asked what information on the schedule was important. To help encourage discussions, a list of information items that are typically on the schedule was provided. The group was then asked to rate each of the items on a scale of "1" to "5" with "1" representing the most essential and "5" representing the least essential. A summary of responses is provided in Table 2.

Table 5.1 Group Ratings of Essential Bus Schedule Information

Information Item	Ranking (High ⟷ Low)				
	1	2	3	4	5
	Number of Responses				
Holiday Service Guide	2	2	2		1
Transportation Agency Information	3	3	1	1	
Reduced Fare Information	1	2	3	1	
Rail Riders Information			3	3	1
Frequent Riders Information			3	3	1
Customer Service	6	1			
Map Information	7				
Schedule Directions	4	2	1		
Disabilities Information		4	3		
Receipt Remarks	1	2		3	1

Overall, it was agreed that the map was the most important piece of information on the schedule. The group also indicated that fare information would be helpful. However, most customers reportedly just asked the bus driver. Customer service

numbers were also viewed as an important piece of information on the schedule. Responses to other essential items that were discussed are the following:

1. Connecting bus routes and zone lines need to be shown clearly.

2. Fares per zone should be better depicted on the schedules.

3. Information numbers are critical.

4. Web site information is also critical and would help in identifying "point to point" information as well as fare information.

5. Schedules should clearly indicate what towns are served.

6. It would be helpful to know which schedule applies. For example, sometimes it is not clear whether weekend schedules apply for a particular holiday if the holiday is not specifically listed on the schedule.

7. The schedule should clearly state whether the line is an exact fare line

8. Multiple leg routes need to be simplified.

The group discussed several features regarding the timetable layout. Handouts of sample timetables from a number of other public transportation agencies were distributed and the group was asked to comment on the following:

1. *Display of AM versus PM*: The group liked having a better distinction between AM and PM times. They liked having different fonts as well as a physical separation such as a space or a line. The group generally preferred the solid line to distinguish morning and afternoon times.

2. *The need to flip schedules to determine direction and boarding/discharge locations*: The group generally did not have a problem with the flipping of schedules but preferred the use of some type of shading or lines to follow the locations and times. The group generally expressed some difficulty where they were boarding the bus between the locations depicted on the timetable. It was also suggested that the name of the municipality be highlighted.

3. *The need to rotate schedules:* The current bus schedule typically displays the time point location on one axis and the actual time points on the perpendicular axis. The group was generally favorable to having the time point location angled.

However, there was concern regarding the amount of space that would be needed to fit this information.

The group was asked to comment on the timetable maps. The moderator distributed a number of samples from other public transportation agencies and the group was then asked to comment. The group responded that the maps from other jurisdictions were far too complicated and that the stick maps depicted on current bus schedules of the Public transportation Agency in the State of New Jersey do an excellent job in conveying the necessary information. The group stated that showing additional features, such as schools, churches, parks, etc would be helpful. All agreed that the orientation of the maps was acceptable. The group also liked having a link between the map and the timetable as depicted on the current schedule.

The group was also asked to raise any other issues regarding the bus schedules. Some indicated difficulty in folding the schedules, but it was generally agreed that the current bus schedules are easy to follow. However, the group listed the following items that could be improved:

1. Font sizes are often too small to clearly read and should be made larger where possible.

2. The towns that are served should be clearly identified not only on the front of the schedule but also on the maps and timetables.

3. Use of lines and / or shading to distinguish AM/PM and make the timetables easier to follow from the location time point to time.

5.2.2 External Focus Group:

None of the external focus group participants were employees of the public transportation agency. The group was provided with the same set of timetables and scenarios as the internal focus group, to maintain a standardized approach to the focus group discussions. Each participant indicated whether he or she is a current bus customer and has experience using the public transportation agency's buses and bus schedules. This information is presented in Table5.2:

Table 5.2 Information of the Participants of the External Focus Group

Participant Number:	Experience Using the Bus
1	Regular user of the provided combined schedule and has been using the bus for a relatively long time.
2	Not currently a bus user but has experience using the transportation agency's bus service.
3	Not currently a bus user but has experience using the transportation agency's bus service.
4	Does not own a car, and uses the public transportation agency's bus and rail services.
5	Regular user of the provided stand-alone schedule bus and uses the bus to commute back and forth to work from Newark Liberty Airport.
6	Not currently a bus user but has experience using the transportation agency's bus service, most recently, to get around after the participant was in a car accident.

Those who were not current bus customers were asked why they did not use the bus. The following reasons were given:

- Concerns over safety at bus stops (crime)
- Convenience
- Not knowing where the bus goes
- Frustration in waiting for the bus
- Lack of bus schedules

After the scenarios were given, the group had some difficulty in correctly answering the questions in the first scenario. Specifically, some indicated they did not know which direction (side of the schedule) to use. Others were confused because one scenario did not ask for a specific time point but rather a location between time points. Only four persons indicated that they used the map. The group also provided the following comments:

- The schedule needs to show from/to dates when the schedule is effective
- There is an assumption that the only locations where one could board/disembark are the time points listed on the schedule. There should be an indication that the time points represent "major stops" and that there are locations in between the time points where passengers can board and disembark.
- Several people indicated that for these scenarios, they would just call the toll free number or use the Internet. It was stated that the toll free number and web address should be more clearly indicated on the schedule. Some focus group members suggested that this information be placed on the front of the schedule or in a more obvious location.
- Participants needed to flip the schedule five or six times

Most participants indicated that they responded correctly to Situation 2. However, no one realized the bus would not go into the stadium. The moderator asked a series of questions about the bus schedule. The following summarizes the overall responses:

1. *How critical is the schedule to making your trip*? The regular users indicated that the schedule was not critical for their trip making. Others indicated that the schedules were helpful, but that they often depended on obtaining information from the driver, other passengers waiting or the toll free number.

2. *How often do you use the bus schedule?* The regular users indicated they used the schedule very infrequently. Others indicated once a week.

3. *Where do you pick up the bus schedule?* Most participants indicated that they picked up the schedules on the bus.

4. *Are bus schedules readily available and convenient to pick up*? Participants indicated that the schedules were often not available on the bus.

The group was asked about what information on the schedule is important. To help encourage discussion, a list of 14 information items that are typically found on a bus schedule were provided. The group was then asked to rank each of the items in terms of importance with "1" representing the most important and "14" representing the least important. A summary of responses is provided in the Table 5.3 below.

Table 5.3 Summary of Reponses of the External Focus Group

Schedule Information	Importance Level					
	Users			Non-Users		
Serving Towns	1	1	14	1	1	1
Map	5	5	13	2	2	5
Holiday Service Guide	3	2	12	4	6	14
Customer Service Information	2	3	2	8	3	3
Notice to Customers with Disability	11	13	11	5	7	4
Receipt for Ride	12	12	10	13	14	12
Please Note	13	10	4	12	12	8
Transportation Agency Information	4	4	1	9	4	13
Security Hot Line	7	6	3	3	9	6
Reduced Fare Information	10	11	9	10	11	7
Transportation Agency Rail Riders	8	9	8	14	10	10
Frequent Riders Information	9	7	7	11	8	11
How to Use the Schedule	6	8	6	7	5	9
Please....	14	14	5	6	13	2

Overall, it was agreed that the list of towns served was the most important piece of information on the schedule. The group also indicated that fare information would be helpful. However, most customers reportedly just ask the bus driver or use the toll free number. Customer service numbers were also viewed as an important piece of information on the schedule. Receipt information was generally viewed as the least important piece of information.

The group generally agreed that the following are also essential items of information:

- How many towns and which towns the bus travels to, or goes through
- Knowing which bus goes to which town
- Departure / arrival times and the ability to determine travel time
- Schedule effective dates
- Toll free customer service number

The group discussed several features regarding the timetable layout. Handouts of sample timetables from a number of other public transportation agencies were distributed and the group was asked to comment on the following:

- *Display of AM versus PM*: The group liked having a better distinction between AM and PM times. They liked having the bolded font, to distinguish AM and PM.

- *The need for flipping schedules to determine direction and boarding/discharge locations*: The group indicated that they had to flip the schedule often. The current schedules of the public transportation agency in the State of New Jersey display the "to destination" on one side and thus weekday and weekend/holiday schedules are displayed together on one side. It was suggested that weekday timetables all be displayed on one side and weekend/holiday schedules be displayed on the other side.

- *The need to rotate schedules*: The current schedules display the time point location on one axis and the actual time points on the perpendicular axis. The group agreed that it was preferable to display the time points horizontally, but recognized this would reduce the number of time points shown on the schedule.

The group was asked to comment on the schedule maps. Generally, it was agreed that there is adequate detail on the current maps. However, all participants agreed that the linkage between the timetable and map, as displayed on the provided stand-alone schedule was essential. The group stated that showing additional features, such as schools, churches, parks, etc. was not necessary. No one expressed concern regarding the orientation of the map (i.e. north up as a convention). The group was asked to raise any other issues regarding the bus schedules and what could be improved overall. The group indicated the following:

- The font size on the provided combined schedule was too small and should be increased.

- Weekday timetables should be on one side and weekend / holiday schedules should be shown on the other.

- There should be connection points between the map and the time points (as on the stand-alone schedule).
- The schedules should include an "effective to" date as well as the "effective from" date.
- Schedule changes should be highlighted
- Phone numbers and web site information should be displayed on the front of the schedule.
- There should be a better distinction between AM and PM
- The towns that are served and the towns through which the bus travels should be clearly identified on the schedule.

5.3 Prototype Design and Development

The two prototypes that were developed had incorporated in them the opinion of the focus groups, information from other public transportation agencies and the guidelines for printed displays. Both prototype schedules represent modifications, which are believed to optimize the ability to read and interpret the information presented in the schedule. The design modifications in the prototype schedules and the source of information that motivated it are tabulated in Table 5.4.

Table 5.4 Prototype Design Features Implemented and the Source of Information

Design Modification	Source*
Decreased the column length of the timetable	1
Realigned the time point locations, making it slanted instead of vertical orientation	1, 3
Resized the Font	1, 4
Shaded alternate columns / Zebra Pattern	1, 3
Represented the different zones in a bus route, which helps the passengers in deciding the fare	1
Distinction of AM /PM or Morning and Afternoon / Evening	2, 3
Configured the reference time points in the time table to the map	1, 2
Weekday and Weekend distinction / separation	2
Prioritized the display of general information	2

* 1. Literature Search
2. Focus Group
3. Other Public Transportation Agencies
4. American Public Transportation Association (APTA) standards

5.4 Time Based Laboratory Test

5.4.1 Paper Based Test

Questions were designed to capture the difference in performance with respect to the three different bus schedule formats. Some of the questions were grouped to analyze the effect of the design modifications. Certain questions in each questionnaire were designed to test a particular design feature. The lay out of the questions are presented in Table 5.5. Question numbers presented in the same row test the same design feature. The question groups are tabulated in Table 5.6 and the corresponding explanations are provided.

Table 5.5 Relation Between the Corresponding Questions in the Three Question Sheets

Question Sheet 1	Question Sheet 2	Question Sheet 3
1	4	3
2	2	9
3	10	6
4	8	10
5	9	8
6	1	4
7	5	7
8	6	1
9	3	5
10	7	2

Table 5.6 Design Features and the Corresponding Question Numbers

Design Feature	Question Number
Zebra Pattern	1, 5
Morning – Afternoon / Evening Breakup	7, 10
Morning - Afternoon Shift	9
Public Holidays	4
Weekend Schedules	8
Bus Transfer	3
Map	2
Zones	6

Zebra Pattern (Shading Alternate Columns): Answers for question number 1 and 5 fall in the same table of the timetable. The only difference being that for question number 1, the answer is in the top few rows, while the answer for question number 5 is in the last few rows of the table. This implies that if the subject needs to find the answer for question number 5, he / she will have to read all the way down the table. The difference between the times and error rate in finding the answer from the current schedule and the two prototypes would substantiate the effect of the zebra pattern. It is hypothesized that the shading of alternate columns could enhance the readability by avoiding any jumps between columns.

Morning – Afternoon / Evening Breakup: Question numbers 7 and 10 were designed to test the difference between reading from the straight long table and from the new prototypes where the morning and afternoon / evening times were tabulated separately. The answer to question number 7 is positioned in the morning session, which means on the morning table for the new prototypes and in the top few rows in the current schedule. The answer to question number 10 is in the afternoon / evening table in the newly developed prototypes and in the last few rows of the long table in the current schedule.

Morning - Afternoon Shift: In the newly developed prototypes, there were two lines of time in the morning table, which were actually after 12:00 noon, but had to be part of the morning table as they were the continuation of a bus which started before noon. One question was designed to capture any negative effects with this feature. The word "afternoon" was included in the question to test if the participants read a time from the afternoon table, even though the correct answer was in the morning table.

Public Holidays, Weekend Schedule and Bus Transfer: One question was designed separately for the public holiday, weekend schedule and bus transfer information.

Maps: Even though the maps were not modified in the newly developed prototypes, the participants were tested for the general readability and comprehension of the maps.

Zones: In the newly developed prototypes, the zones were marked on the bottom of every table and the maps. In the current schedule they are marked only on the maps. The zones are necessary to calculate the fare for travel between two locations. One question was exclusively designed to capture the effect of the new form of zone representation.

5.5 Analysis of Time Test Data

The experimental data was analyzed and validated based on the speed and accuracy of the participant in finding the answer. Since each participant was tested for all three schedules (existing and two prototypes), a within-subject experimental design was used for quantitative analysis. The order of distribution of prototypes along with the question sheets was counterbalanced in order to cancel any sequential effects. Analysis of variance (ANOVA) was used to compare the three designs on performance variables with respect to time. Chi-square analysis was used for the error table to substantiate the design modifications.

5.5.1 Time Analysis

The individual times recorded for the twenty-six participants were analyzed and the separate design features were tested for statistical significance. A cut off rate of sixty percent correct answers in at least one of the tests was kept as the baseline to avoid the noise in the data. Finally, data from twenty-four subjects was used for time analysis. Each

of the ten questions was analyzed using analysis of variance. Since the efficiency of a particular prototype in presenting the required information was our primary concern, the response for each question was modeled on the type of prototype. After using a general linear model of the analysis of variance, no statistical significance was observed for questions 1, 2, 3, 4, 5, 7, 8, 9 and 10. The features that were tested in these nine questions were zebra pattern, morning –afternoon / evening breakup, weekend schedules, public holiday schedules, map reading and comprehension and the transfer information of the buses. Question number six, which dealt with the different zone representations showed statistical significance. The result of the analysis of variance for that question has been shown in Table 5.6.

Table 5.7 Analysis of Variance for the Question on Zone Representation

Source	DF	Sum of Squares	Mean Square	F - Value	P - Value
Prototype	2	35380	17690	11.28	0.000 < 0.01
Error	46	72135	1568		

Interpretation of the ANOVA for Questions on Zone Representation: Question number 6, which was designed to capture the efficiency of the different zone representation formats shows statistical significance (see Table 5.7). The zones have been represented in the map as well as at the bottom of every table in the two new prototype schedules, while it has been shown only on the map in the current schedule. The zone representation is easily visible in the newly developed prototypes compared to the current schedule.

5.5.2 Analysis of Errors

The errors committed by the participants for the ten different questions were tabulated and a baseline of one-third, or 33% was kept as the cut off mark, to highlight the questions that generated high error rates. The errors committed on each prototype for a particular question is tabulated in Table 5.8 along with the overall error percentages.

Table 5.8 Error Rates and Overall Error Percentages for the Three Prototype Schedules

Question Number	Current Schedule	Directional Prototype	Weekday / Weekend Prototype	Total Errors	Overall Error Percentages (%)
1	4	6	6	16	22.2
2	12	12	18	42	58.3
3	2	4	2	8	11.1
4	5	2	6	13	18.1
5	3	7	2	12	16.7
6	8	5	5	18	25.0
7	5	5	7	17	23.6
8	4	2	2	8	11.1
9	8	18	16	42	58.3
10	4	2	4	10	13.9

*For the features being tested for the respective questions, refer to Table 5.6

Question number 2 and question number 9 have a very high error rate (58.33 % for both). Question number 2 was testing the readability of maps. This high error rate substantiates the fact that participants found it difficult to read and comprehend the maps. Question number 9 was designed to test effects arising from the inclusion of two lines of afternoon times in the morning table of the newly developed prototypes. The high error rate for this question substantiates the fact that most of the participants believed that there could not be any afternoon times in the morning tables in the newly developed prototypes. As shown in Table 5.7 the current schedule did not generate as many errors for question number 9 as opposed to the two newly developed prototypes.

5.5.3 Effects of Age and Educational Level on Performance

The effect of age on performance, with respect to the average time taken for a question and the average number of errors committed for thirty questions are shown in Figures 5.1 and 5.2 respectively.

Figure 5.1 Average Time in Seconds Taken by Participants in Different Age Categories.

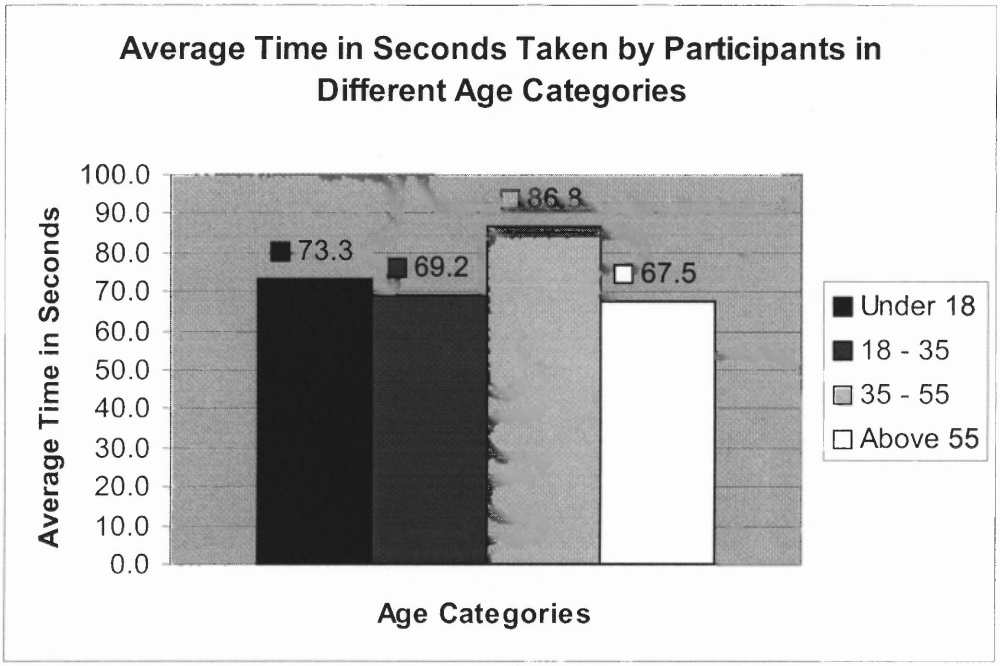
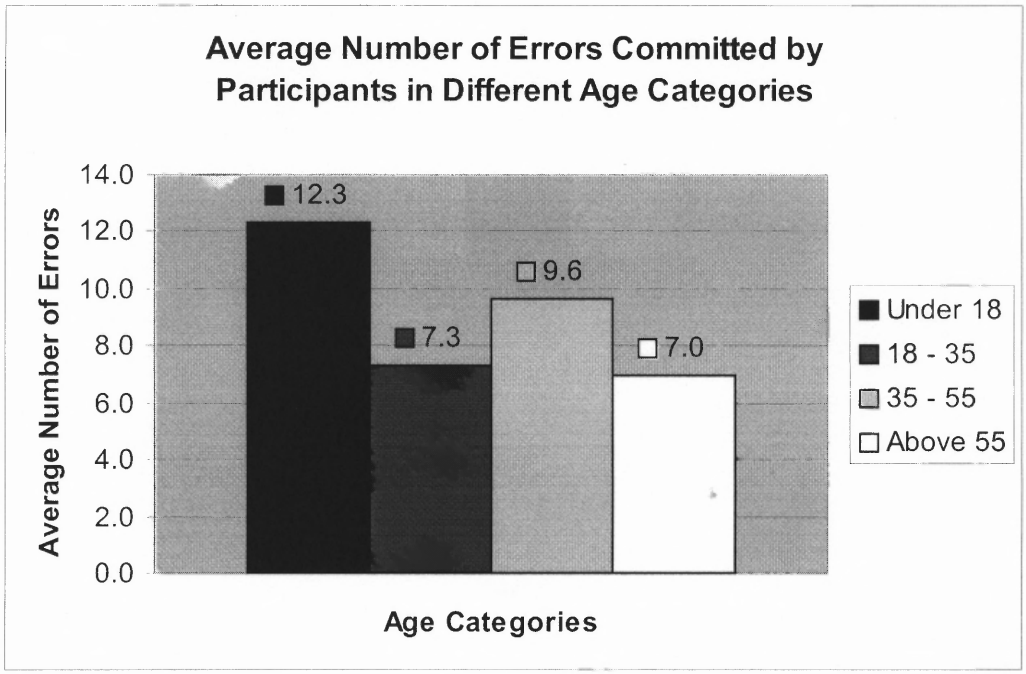


Figure 5.2 Average Number of Errors Committed by Participants in Different Age Categories.



The participants basically belonged to three different educational levels, which were, high school, college and advanced degree. The effect of the educational level on the performance of the participants with respect to average time per question and the average number of errors committed in thirty questions have been shown in Figure 5.3 and 5.4 respectively.

Figure 5.3 Average Time in Seconds Taken by Participants in Different Educational Levels.

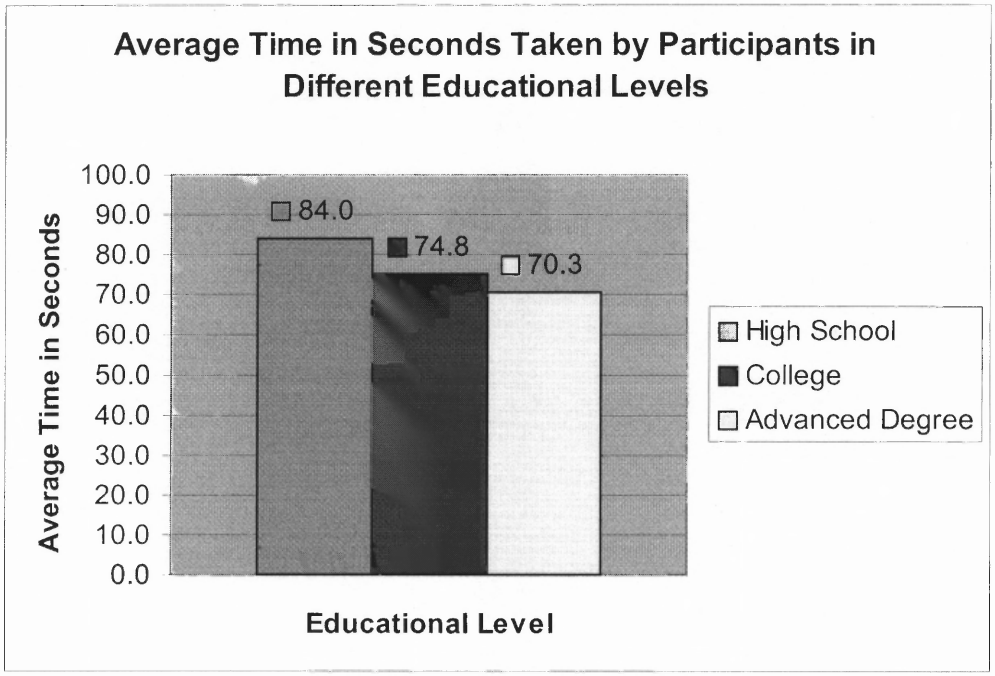
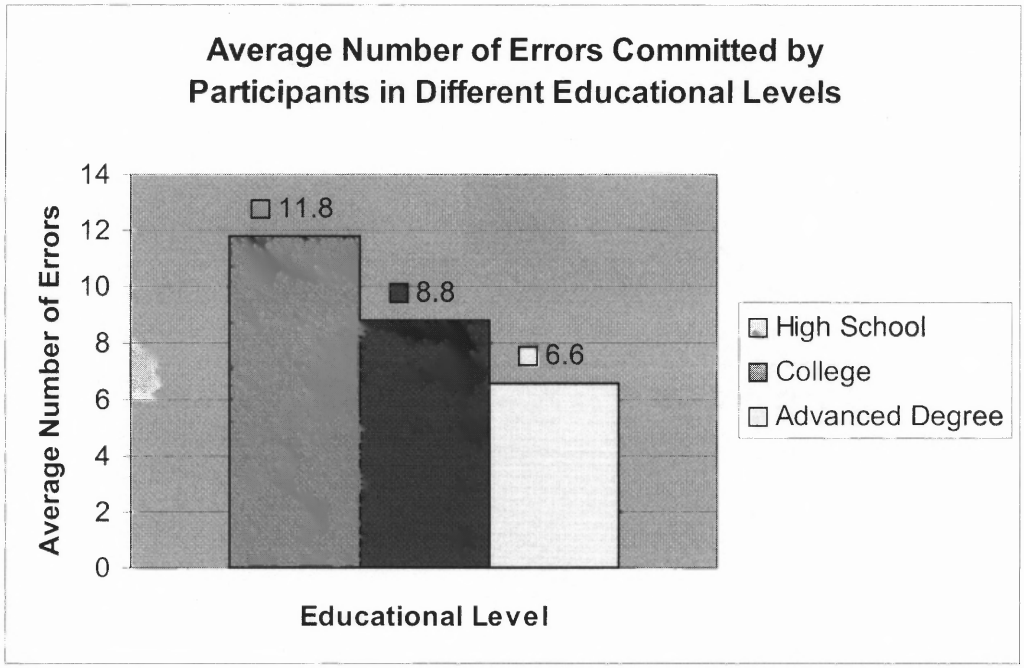


Figure 5.4 Average Number of Errors Committed by Participants in Different Educational Levels.



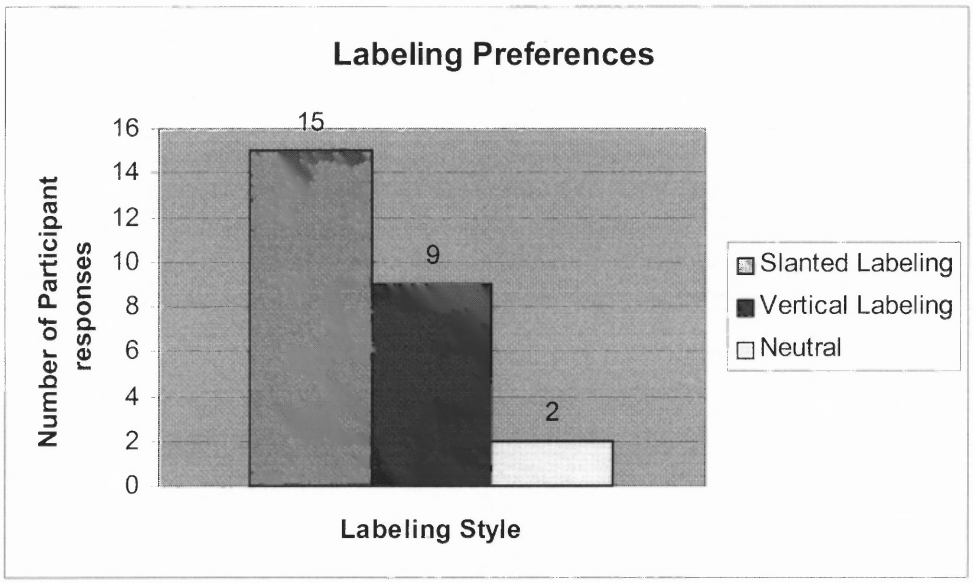
5.6 Analysis of Subjective Data

5.6.1 Analysis of Other Subjective Data

Seven questions were designed in the subjective questionnaire to capture the subjective preferences of the participants regarding the readability and general layout of the schedule formats. Questions differentiating the formats were asked and the participants had to pick one format over the other, or had the option of being neutral. The responses of the twenty-six participants were converted to a bar chart format and are discussed in the following sections.

Labeling Preference: Two styles of labeling were tested, one being the vertical labeling and the other being the slanted style of labeling. Vertical labeling is followed in the current schedule. The bar chart depicting the responses of the participants is shown in Figure 5.1.

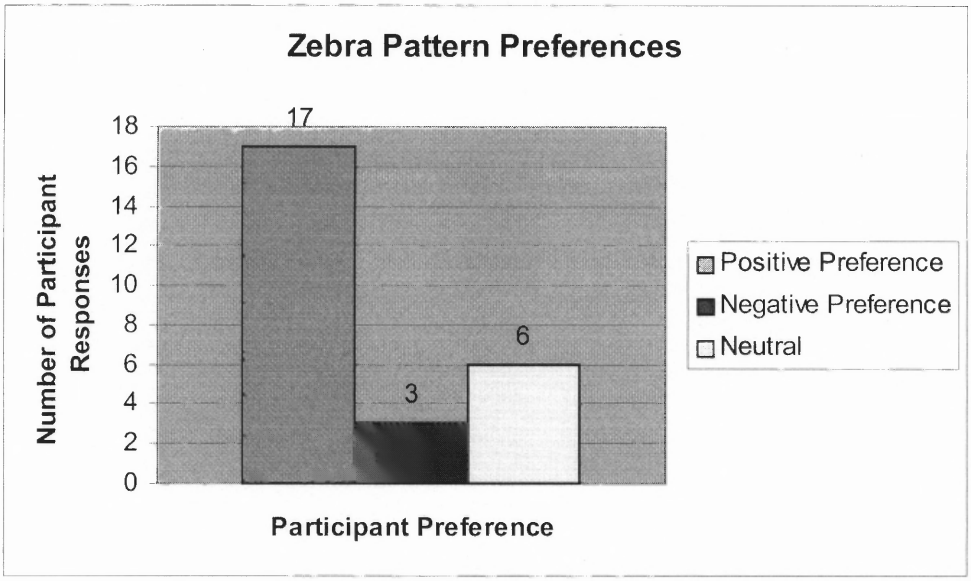
Figure 5.5 Labeling Preferences of Participants.



As it is evident from the bar graph, more than 50% of the participants preferred slanted labeling and two participants out of twenty-six were neutral and nine out of twenty-six voted for the vertical format. Therefore, the slanted labeling dominates the vertical format.

Zebra Pattern: In the newly developed prototypes, alternate columns were shaded and this format is named the zebra pattern. The current schedules do not have a zebra pattern. The bar chart showing the subjective preferences of the twenty-six subjects with respect to zebra pattern is shown in Figure5.6. They were given the option of responding positively, negatively or neutral to the zebra pattern.

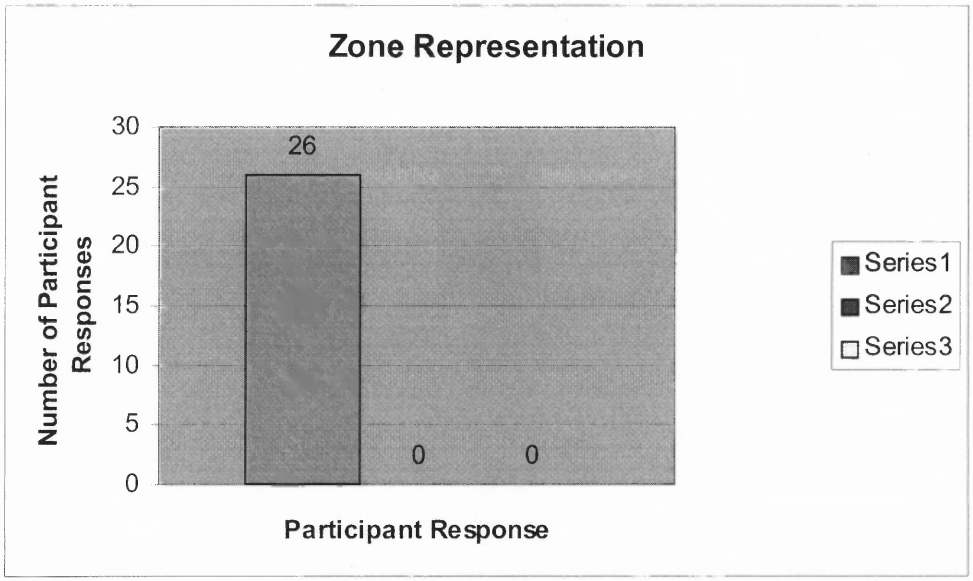
Figure 5.6 Zebra Pattern Preferences of Participants.



As it is evident from the bar graph, more than 50% of the participants voted for the zebra pattern and stated that the alternate shading of columns made the bus schedules more readable. Only three out of twenty-six subjects voted against the zebra pattern and six out of twenty-six remained neutral.

Zone Representation: Zones were incorporated at the bottom of every table in the newly developed prototypes in addition to being included in the map, as it is the practice in the current schedules. The participants were given the option of responding positively, negatively or being neutral to the representation of maps at the bottom of every table. Their response has been shown in Figure 5.7.

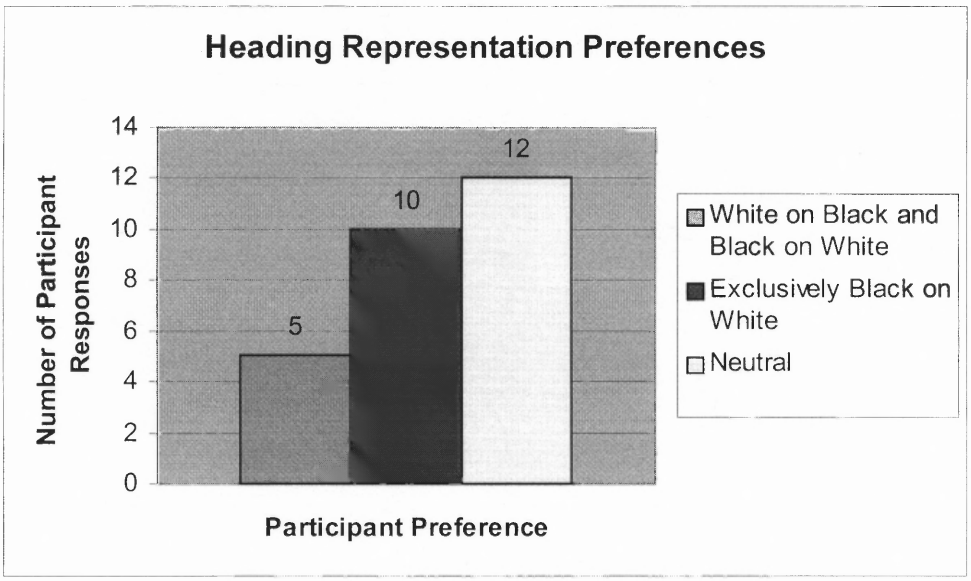
Figure 5.7 Zone Representation Preferences of Participants.



All participants voted for the zone to be represented at the bottom of every table. They stated that this mode of representation is very effective in calculating the fare.

Heading Representation: In the newly developed prototypes, the headings were represented differently with respect to the font and background color. In the current schedules, the headings have been laid out in black fonts on white background. In the newly developed prototypes, on one side of a schedule, the heading was laid out in black fonts on white background and on the other side, it was laid out in white fonts on black background. This was expected to catch the attention of the participants and help them in distinguishing the two sides when they used the timetable. In the subjective questionnaire, they were given the option of voting for either one of the representations or they could be neutral. The subjective responses are shown in Figure 5.8.

Figure 5.8 Heading Representation Preferences of Participants.

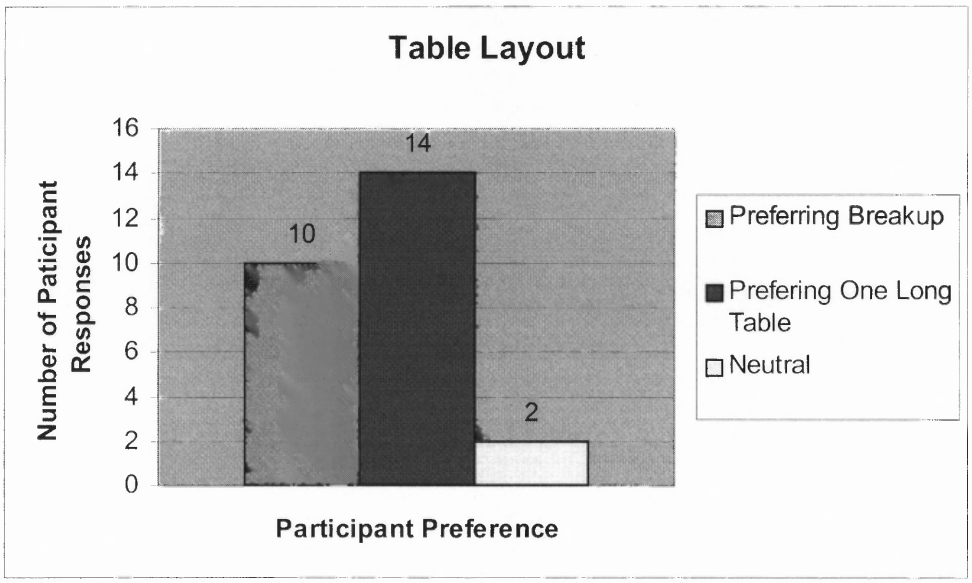


Twelve out of twenty-six participants chose to be neutral regarding this issue. They felt that this differentiation in representation neither affected their readability nor did it enhance their speed. Only five out of twenty-six subjects voted for the different representation, while ten out of twenty-six subjects voted for the black font on white background.

Table Layout: In the current bus schedule, the timetables are one straight table for weekends and weekdays, irrespective of their length. This in turn makes the participants to read all the way down the table for times, which are in the late evening or nights, especially in the weekday schedules. In the newly developed prototypes, these columns have been optimally divided into two (morning section and the afternoon / evening section). The Sunday schedules were kept as one table, since the frequency of buses is less and hence the overall length of the table is not too long. In the subjective questionnaire, the subjects were given the option of voting for the breakup, for no

breakup of the table or they could be neutral. The responses of the participants are shown in Figure 5.9.

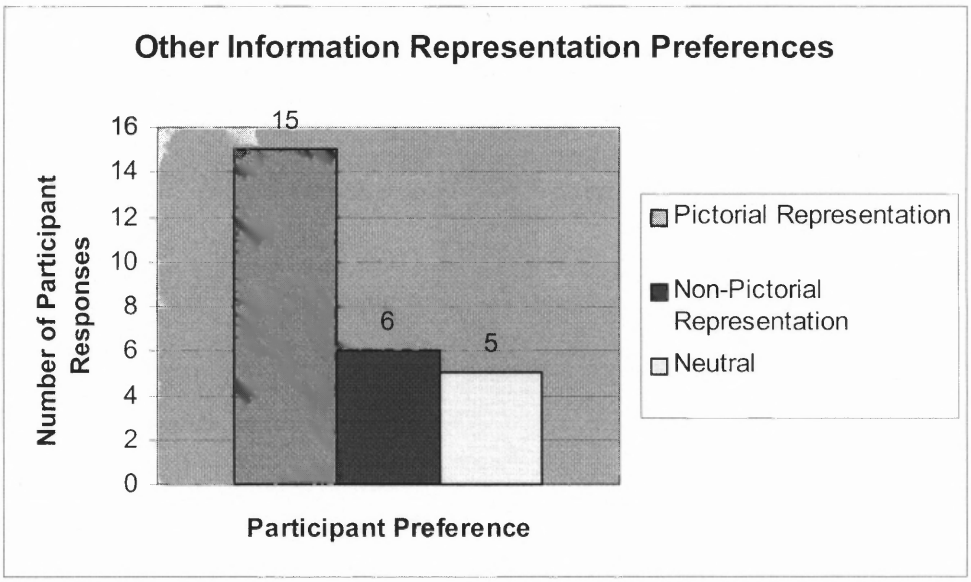
Figure 5.9 Table Layout Preferences of Participants.



More than 50% of the participants voted for the single table, without breakup. Ten out of twenty-six participants voted for the breakup of tables into morning and afternoon / evening and two remained neutral.

Other Information Representation: Some additional information like handicap facilities is listed in the current schedules exclusively in the form of text. In the newly developed prototypes, they were represented pictorially. This also saves some space. The participants were asked if they preferred the pictorial format of representation to the textual format. They also had the option of being neutral. Their responses are shown in Figure 5.10.

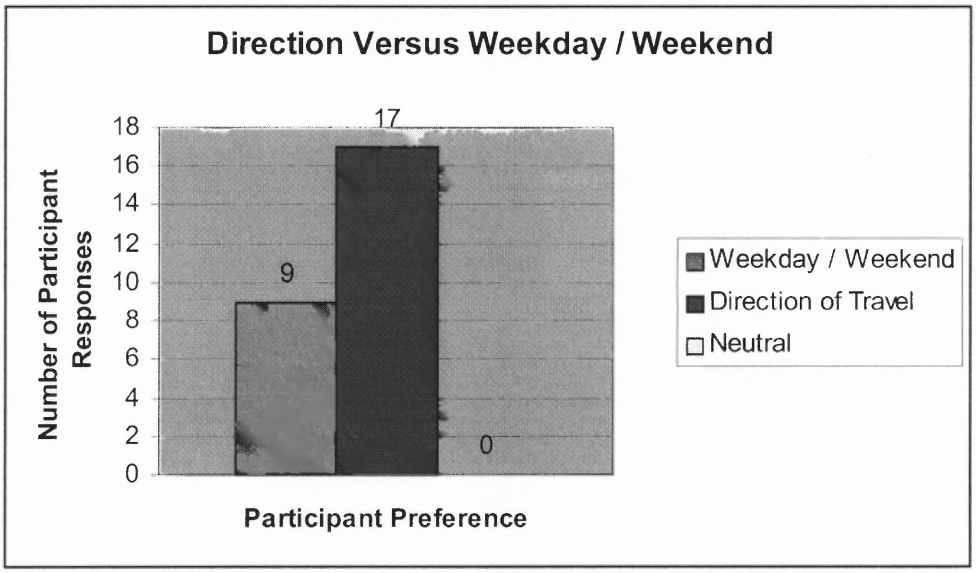
Figure 5.10 Other Information Representation Preferences of Participants.



More than 50% of the participants stated that they preferred the pictorial format of representation. Five out of twenty-six were neutral and six out of twenty-six preferred the textual format of representation.

Direction Versus Day of Travel: This particular question was asked only to distinguish between the two prototypes, with respect to their general layout. In the directional prototype, direction of travel was given primary importance, and hence the schedule exclusively had one destination on one side of the schedule, irrespective of the day of the week. Weekday and weekend schedules for the same direction were presented on the same side of the schedule. In the weekday / weekend schedule, the day of the week was given primary importance and hence, this schedule exclusively had weekends on one side of the schedule and weekdays on the other, irrespective of the direction of travel. The subjects were given the option of voting either for the two modes of representations, or they could choose to be neutral. Their responses are shown in Table 5.11.

Figure 5.11 Direction Versus Weekday / Weekend Preferences of Participants.



More than 50% of the participants chose the direction of travel over the weekday / weekend type of representation. None of the twenty-six subjects chose to be neutral. Nine out of twenty-six chose the weekday / weekend mode of representation.

5.6.2 Ranking Data Analysis

The subjective response of the participants was tabulated and analyzed. The data from twenty-six subjects were considered for the subjective analysis. The first part of the subjective questionnaire was to rank the schedules with respect to the participant's preference for a particular prototype, with rank 1 being the best and rank 3 being the least liked schedule format. A chi-square test was used on the general ranking data. The general ranking of the schedules by the participants are shown in Table 5.9.

Table 5.9 General Ranking of the Three Bus Schedule Formats

	Rank 1	Rank 2	Rank 3
Current Schedule	5	6	15
Directional Schedule	13	10	3
Weekday / Weekend Schedule	8	10	8

Chi-Square Test for Ranking: Chi-Square test was performed on the general ranking table for the three different bus schedule prototypes in order to recognize if subjects responded differently for the three different prototypes. The chi-square table is shown in Table 5.10. The formula and value of the expected value has been given below the table.

Table 5.10 Chi-Square Test for the Ranking of the Three Prototypes

	Rank 1	Rank 2	Rank 3	Row Total
Current Schedule	5	6	15	26
Directional Schedule	13	10	3	26
Weekday / Weekend Schedule	8	10	8	26
Column Total	26	26	26	78 (Grand Total)

Expected value for each cell = (Sum of Row X Sum of Columns) / Grand Total
= (26 x 26) / 78 = 8.67

ChiSq = 1.551 + 0.821 + 4.628
+2.167 + 0.205 + 3.705
+0.051 + 0.205 + 0.051 = 13.385
df = 4

The chi-square value of 13.385 is greater than 9.49, the value for a 95% confidence interval four degrees of freedom. This result shows that there is significant difference in the ranking of the prototype schedules. To attain more clarity about the ranking preferences, the prototypes and ranks were tested exclusively using chi-square test.

Interpretation of the Exclusive Chi-Square Tests: The chi-square test for the current schedule shows statistical significance. The results suggest that subjects ranked the current schedule more as rank three as compared to rank two or rank one. Exclusive chi-square test for directional schedule shows statistical significance too. The results suggest that subjects ranked the directional schedule more as rank one and rank two as compared to rank three. The exclusive chi-square test for the weekday / weekend schedule did not show any statistical significance.

CHAPTER 6

DISCUSSION AND FUTURE SCOPE

One of the difficulties human factors practitioners face is to redesign a system that already exists within an operational environment. It is difficult because users may have become intimately familiar with one form of representation or operation and / or regulations and techniques might have been developed that involve the particular characteristics associated with the operation or handling of the product or system (Molesworth and Wiggins, 2004). Standardization is an important principle that underscores design (Wiener, 1993) and it was necessary to maintain consistency with the regulations of the public transportation agency in the State of New Jersey.

An exclusive human factors approach was adopted for this research, starting from the initial study of the schedule to the testing method and analysis. A literature review was conducted on topics related to learning, attention, cognition, information processing and performance testing. There were several constraints in the research platform. The public transportation agency in the State of New Jersey prints millions of copies of schedules a year. Therefore, several aspects had to be taken in to consideration before suggesting the modifications for prototype development and testing. Usage of color to highlight certain information is a very effective tool and this technique is being used by several public transportation agencies in the United States. Major and Shellswell (1976) found that, compared with using a single color, the application of a combination of colors was more effective in facilitating the identity of specific features on a chart. It also has been proved that the primary colors (red, blue and yellow) provide the greatest degree of

discrimination. In addition, information is acquired more rapidly when there is a great difference between the brightness of the colors utilized in the display (Nelson, 1994). In this context, shading was the only permissible modification that could be done within the financial constraints of the agency.

The space available for the schedule format was also limited. The paper size could not be increased beyond a certain limit due the printing facilities used by the agency. Further increase in paper size would lead to a change in the whole printing set up. Meanwhile, the minimum information required to be on the bus schedule could not be compromised either. There is a lot of information on the bus schedule, which makes it look busy. This in turn left very little space for further modifications to be integrated, which otherwise could have further enhanced the readability of the bus schedules to a credible limit. The font size could not be improved while developing the prototypes due to this concern. Increasing the font size could really improve the readability of any printed display, especially a busy timetable like the one in the State of New Jersey.

All the design features included in the directional schedule and weekday / weekend schedule were believed to serve certain purposes. The slanted labeling was introduced because as per the literature review findings, the time and the location should not be laid out on the same axis. Due to the lack of space, the layout of the locations was rotated to the right at an angle with to the horizontal axis. The zebra pattern was introduced to avoid skipping between columns when the user has to read way down the table and also to give a reference line when users read the times.

The heading distinction and highlighting with respect to font colors and backgrounds were introduced in order to attract the attention of users when they read the headings on two different sides, which would help them in coding, storing and retrieving information from short-term memory. The columns were divided into morning, afternoon / evening to decrease for users the reading length in the downward direction. The time of the day could also help users to revert to the required table faster. The zones were represented at the bottom of every table along with the representation on the map for the newly developed prototypes to instantly grab the attention of users.

From the analysis of the results of the time-based test, the only feature that showed statistical significance was the zone representation. The other factors which were incorporated in to the newly developed prototypes failed to show any statistical significance. Apart from the views of the focus groups and the information from other transit agencies, the literature surveyed also supported certain design features, which were introduced into the schedule layout. In spite this, no statistical significance was observed on the performance, with respect to speed.

With respect to error, question number 2 and question number 9 showed high error rates. Question number 2 deals with the readability of the maps. Amongst the three different question sheets, there were questions on the map, which required the participants to read from right to left, even though the universal direction of reading is from left to right. This is one of the reasons for a high error rate. Another reason that led to the high error rate for the map question, was due to the number of times the participant had to flip the schedule to view the map and the timetable concurrently. Due to the space constraint the map could not be printed on both sides of the bus schedule. Since the

distribution of the question sheets and the schedules were counterbalanced, the pairing of a particular schedule with a particular question type could not be controlled.

The bus stops at locations between the time points provided on the schedule. Question number 2 had the participant positioned at an intersection and requested the participant to trace back to the previous time point with respect to the direction of travel of the bus. This action along with the flipping of the schedule, where the participant has to store and retrieve information from his / her short term memory is demanding on the human cognitive capacity and this could in turn be the reason for a high error rate.

Question number 9, was designed to capture any negative effects associated with the inclusion of two rows of afternoon times in the morning table of the newly developed prototypes. These two rows could not be avoided since the originating times of these buses were in the morning. The question had the word "afternoon" in it, to test how participants comprehend the information. As it is evident from the results, the majority of participants overlooked the morning table, believing that the answer was in the afternoon table. This result suggests that there has to be a mode of representation in the newly developed prototype schedules, which could direct the user to the afternoon times present in the morning table.

The effect of age and educational level on the performance indicated some interesting facts. Participants with high school level of education had the highest error rate followed by participants with college level of education. Participants with an advanced level of education did the best, with the least number of average errors. The results look significant from the bar chart, as the difference between the average number of errors of the high school level participants is almost double that of the participants

with an advanced degree of education. With respect to time, there is no striking difference amongst the participants in different educational levels. If a between-subject design is performed with a big sample size, the performance of the participants with respect to educational level could show statistical significance.

The effect of age on performance has been plotted and the results do not show striking distinction between the specific age categories. Error wise, the high school students committed more errors compared to other groups. With respect to time, there is not a mentionable difference in performance. From the results of the effect of age and educational level on performance, it is suggested that there could be a minimum cognitive capability, which could be marked as the baseline for proficiently reading bus schedules.

The analysis of the subjective data provided certain noteworthy results. With respect to the design features that they felt could enhance the readability of the timetables, most of the features preferred, were the ones incorporated in the newly developed prototypes. In other words, the majority of the participants preferred the newly developed prototypes' mode of representing information. The straight, long table was the only feature favored from the current schedule. Majority of the participants voted for the straight, long table over the divided table. Regarding the heading representation, there is no significant preference that can be deduced from the collected data, with the greater number of participants preferring to remain neutral.

All the twenty-six participants preferred the zone representation incorporated in the newly developed prototypes. This coincides with the results obtained from the analysis of the time data. All the other information preferred by the participants, like the zebra pattern, slanted labeling, and pictorial mode of representing information are part of

the newly developed prototypes. The directional prototype schedule was preferred over the weekday / weekend schedule by the majority of participants. Accruing all the information from the subjective data analysis, the optimal prototype would be the one similar to the directional prototype, except for the distinction of the morning and afternoon tables. The table could be laid out as undifferentiated, but with all the new design features from the new prototypes incorporated in it.

There are certain limitations to the experimental design. Increasing the sample size to a large number is a probable solution to bring out the differences between the different prototypes. Instead of within-subject design, between-subject design may be considered. In within-subject design, there is a learning curve, which could in turn distort the data, with respect to performance. Instead, if three different groups could be assigned for the three different prototype schedules, their performance results could be compared without confounding with learning effects. This in turn means a very large sample size and numerous tests. This was beyond the capacity of this research project.

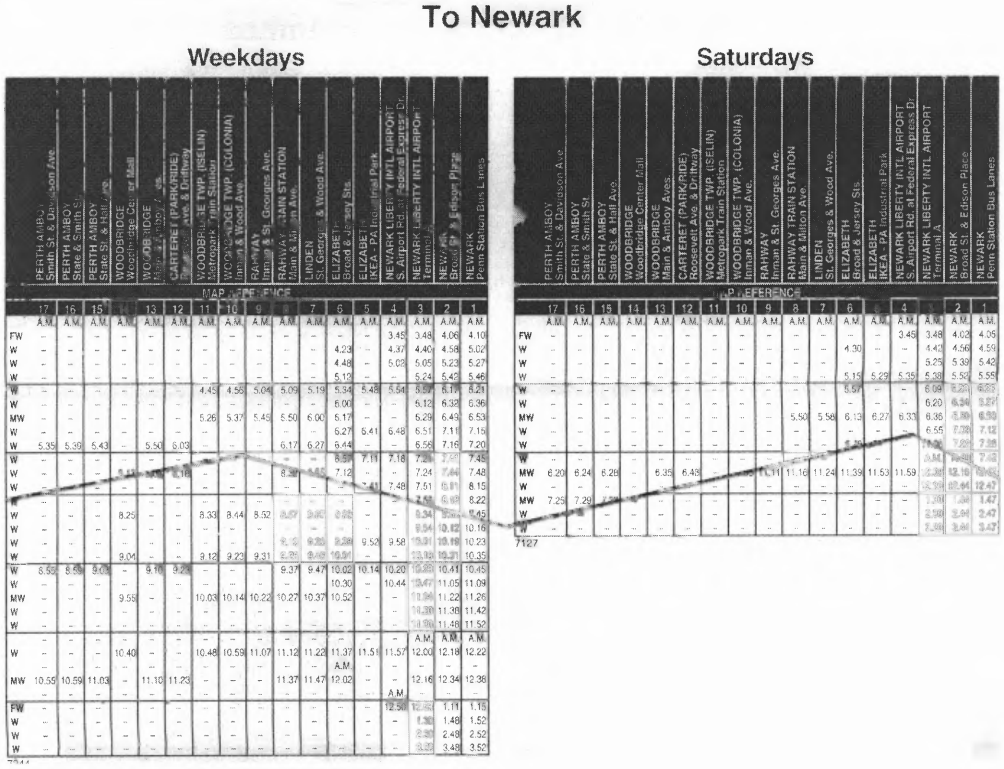
Regarding further resolution on the subject, since the reading and comprehension of bus timetables is a complex cognitive task, specific design parameters have to be singled out and tested separately with respect to performance (speed and accuracy). The extent of combining the different design parameters to the maximum limit of efficiency could also be studied. After a specific limit, the combination ratio of design parameters might have to be altered to avoid a decrease in performance. Decrease in performance could be due to the presence of other features.

The shortfall of this mode of testing is that the testing scenario would not be real. It would take away the reality that goes into testing bus schedules as a whole for their readability. Although it might be argued that an optimal design is one that is "transparent" (Norman, 1988), this is very difficult to achieve in practice.

Appendix A

Reduced Images of the Prototype Schedules

Figure A-1 Current Bus Schedule – Side 1.



To Newark

Weekdays

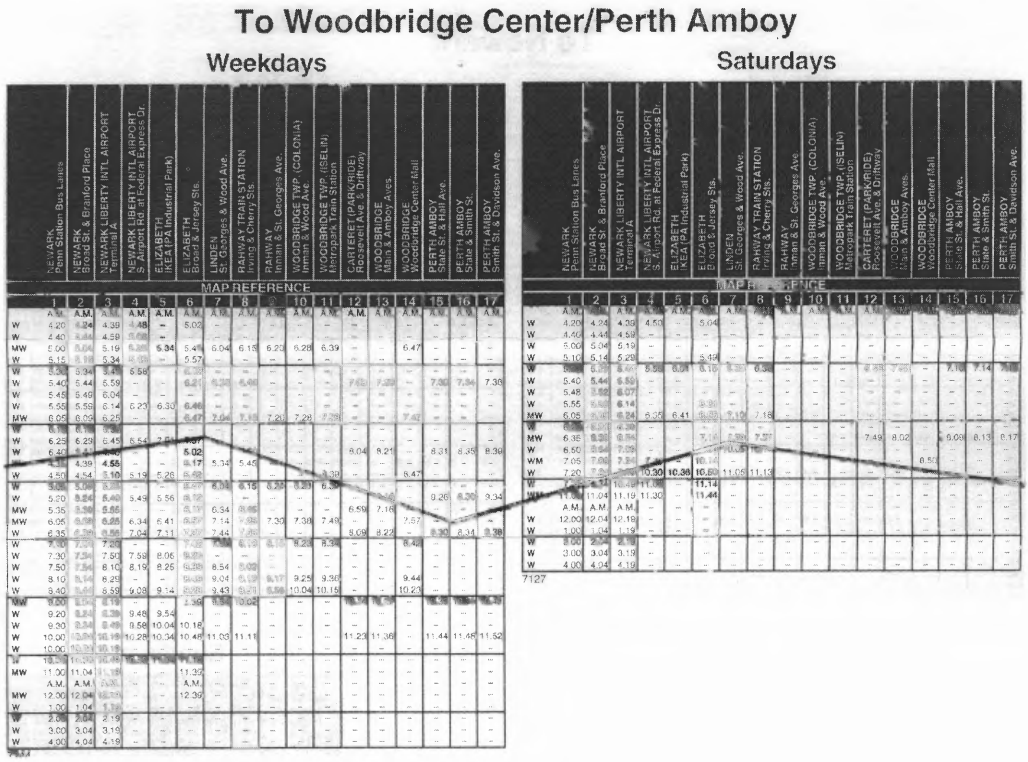
	PERTH AMBOY Smith St. & Davidson Ave.	PERTH AMBOY State & Smith St.	PERTH AMBOY State St. & Hamilton Ave.	WOODBRIDGE Woodbridge Center Mall	WOODBRIDGE Rahway Ave. / Main St.	CARTERET (PARK/RIDE) Roosevelt Ave. & Driftway	WOODBRIDGE TWP. (ISELIN) Metropark Train Station	WOODBRIDGE TWP. (COLONIA) Inman & Wood Ave.	RAHWAY TRAIN STATION Irving & St. Georges Ave.	RAHWAY Main & Milton Ave.	LINDEN St. Georges & Wood Ave.	ELIZABETH Broad & Jersey Sts.	ELIZABETH IKEA (PA Industrial Park)	NEWARK LIBERTY INTL AIRPORT S. Airport Rd. at Federal Express Dr.	NEWARK LIBERTY INTL AIRPORT Terminal A	NEWARK Broad St. & Edison Place	NEWARK Penn Station Bus Lanes
MAP REFERENCE	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.
FW	–	–	–	–	–	–	–	–	–	–	–	–	–	3.45	3.48	4.06	4.10
W	–	–	–	–	–	–	–	–	–	–	–	4.23	–	4.37	4.40	4.58	5.02
W	–	–	–	–	–	–	–	–	–	–	–	4.48	–	5.03	5.05	5.23	5.27
W	–	–	–	–	–	–	–	–	–	–	–	5.13	–	–	5.24	5.45	5.46
W	–	–	–	–	–	–	4.45	4.55	5.04	5.09	5.19	5.34	5.48	5.54	5.57	6.17	6.21
W	–	–	–	–	–	–	–	–	–	–	–	6.00	–	–	6.12	6.33	6.36
MW	–	–	–	–	–	–	5.26	5.37	5.49	5.50	6.00	6.17	–	–	6.29	6.49	6.53
W	–	–	–	–	–	–	–	–	–	–	–	6.27	6.41	6.48	6.51	7.11	7.15
W	5.35	5.39	5.43	–	5.50	6.03	–	–	–	6.17	6.27	6.44	–	–	6.56	7.16	7.20
W	–	–	–	–	–	–	–	–	–	–	–	6.59	7.11	7.18	7.21	7.41	7.45
W	–	–	–	5.53	6.03	6.16	–	–	–	6.39	6.49	7.12	–	–	7.24	7.44	7.48
W	–	–	–	–	–	–	–	–	–	–	–	–	7.41	7.48	7.51	8.11	8.15
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7.53	8.13	8.22
W	–	–	–	8.25	–	–	8.33	8.44	8.52	8.57	9.07	9.22	–	–	9.34	9.54	9.45
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9.54	10.12	10.16
W	–	–	–	–	–	–	–	–	–	9.12	9.22	9.28	9.50	9.58	9.31	10.19	10.23
W	–	–	–	9.04	–	–	9.12	9.23	9.31	9.26	9.46	10.01	–	–	10.13	10.31	10.35
W	5.55	5.59	6.03	–	6.10	6.23	–	–	–	9.37	9.47	10.02	10.14	10.20	10.23	10.41	10.45
W	–	–	–	–	–	–	–	–	–	–	–	10.30	–	10.44	10.47	11.05	11.09
MW	–	–	–	9.55	–	–	10.03	10.14	10.22	10.27	10.37	10.52	–	–	11.04	11.22	11.26
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.38	11.38	11.42
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11.50	11.48	11.52
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	A.M.	A.M.	A.M.
W	–	–	–	10.40	–	–	10.48	10.59	11.07	11.12	11.22	11.37	11.51	11.57	12.00	12.18	12.22
	–	–	–	–	–	–	–	–	–	–	–	A.M.	–	–	–	–	–
MW	10.55	10.59	11.03	–	11.10	11.23	–	–	–	11.37	11.47	12.02	–	–	12.16	12.34	12.38
	–	–	–	–	–	–	–	–	–	–	–	–	–	A.M.	–	–	–
FW	–	–	–	–	–	–	–	–	–	–	–	–	–	12.50	12.53	1.11	1.15
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.30	1.48	1.52
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.30	2.48	2.52
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3.30	3.48	3.52

Saturdays

	PERTH AMBOY Smith St. & Davidson Ave.	PERTH AMBOY State & Smith St.	PERTH AMBOY State St. & Hamilton Ave.	WOODBRIDGE Woodbridge Center Mall	WOODBRIDGE Main & Amboy Aves.	CARTERET (PARK/RIDE) Roosevelt Ave. & Driftway	WOODBRIDGE TWP. (ISELIN) Metropark Train Station	WOODBRIDGE TWP. (COLONIA) Inman & Wood Ave.	RAHWAY Inman & St. Georges Ave.	RAHWAY TRAIN STATION Main & Milton Ave.	LINDEN St. Georges & Wood Ave.	ELIZABETH Broad & Jersey Sts.	ELIZABETH IKEA (PA Industrial Park)	NEWARK LIBERTY INTL AIRPORT S. Airport Rd. at Federal Express Dr.	NEWARK LIBERTY INTL AIRPORT Terminal A	NEWARK Broad St. & Edison Place	NEWARK Penn Station Bus Lanes
MAP REFERENCE	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.
FW	–	–	–	–	–	–	–	–	–	–	–	–	–	3.45	3.48	4.02	4.05
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4.30	4.46	4.50
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5.29	5.33
W	–	–	–	–	–	–	–	–	–	–	–	5.15	5.29	5.35	5.38	5.52	5.55
W	–	–	–	–	–	–	–	–	–	–	–	5.57	–	–	–	6.09	6.13
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6.20	6.24
MW	–	–	–	–	–	–	–	–	–	5.50	5.58	6.13	6.27	6.33	6.36	6.49	6.53
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6.55	7.08
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7.20	7.23
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	A.M.	7.43
MW	6.20	6.24	6.28	–	6.35	6.43	–	–	7.11	7.16	7.24	7.39	7.53	7.59	8.02	8.18	8.22
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.39	8.44	8.47
MW	7.25	7.29	7.33	–	–	–	–	–	–	–	–	–	–	–	–	9.08	9.12
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9.38	9.44	9.47
W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9.38	9.44	9.47

7127

Figure A-2 Current Bus Schedule – Side 2.



To Woodbridge Center/Perth Amboy

Weekdays

	NEWARK Penn Station Bus Lanes	NEWARK Broad St. & Bradford Place	NEWARK LIBERTY INTL AIRPORT Terminal A	NEWARK LIBERTY INTL AIRPORT S. Airport Rd. at Federal Express Dr.	ELIZABETH IKEA (PA Industrial Park)	ELIZABETH Broad & Jersey Sts.	LINDEN St. Georges & Wood Ave.	RAHWAY TRAIN STATION Irving & Cherry Sts.	RAHWAY Inman & St. Georges Ave.	WOODBRIDGE TWP. (COLONIA) Inman & Wood Ave.	WOODBRIDGE TWP. (ISELIN) Metropark Train Station	CARTERET (PARK/RIDE) Roosevelt Ave. & Driftway	WOODBRIDGE Main & Amboy Aves.	WOODBRIDGE Woodbridge Center Mall	PERTH AMBOY State & Smith St.	PERTH AMBOY State St. & Hamilton Ave.	PERTH AMBOY Smith St. & Davidson Ave.
MAP REFERENCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.
W	4.20	4.24	4.38	4.48	–	5.02	–	–	–	–	–	–	–	–	–	–	–
W	4.40	4.44	4.58	5.08	–	–	–	–	–	–	–	–	–	–	–	–	–
MW	5.00	5.04	5.19	5.28	5.34	5.47	5.04	6.15	6.23	6.28	6.39	–	–	6.47	–	–	–
W	5.15	5.19	5.34	5.43	–	5.57	–	–	–	–	–	–	–	–	–	–	–
W	5.30	5.34	5.49	5.58	–	6.12	–	–	–	–	–	–	–	–	–	–	–
W	5.40	5.44	5.59	–	–	6.21	5.38	5.48	–	–	–	7.02	7.22	–	7.30	7.34	7.38
W	5.45	5.49	6.04	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	5.55	5.59	6.14	6.23	6.30	6.46	–	–	–	–	–	–	–	–	–	–	–
MW	6.05	6.09	6.25	–	–	6.47	7.04	7.15	7.20	7.28	7.28	–	–	7.42	–	–	–
W	6.15	6.19	6.34	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	6.25	6.29	6.45	6.54	7.01	7.17	–	–	–	–	–	–	–	–	–	–	–
W	6.40	6.44	6.59	–	–	5.02	–	–	–	–	–	8.04	8.21	–	8.31	8.35	8.39
	6.35	6.39	4.55	–	–	6.17	5.14	5.45	–	–	–	–	–	–	–	–	–
W	4.50	4.54	5.10	5.19	5.26	5.42	–	–	–	5.38	–	–	–	5.47	–	–	–
W	5.05	5.09	5.25	–	–	5.27	6.04	6.15	6.23	6.28	6.39	–	–	–	–	–	–
W	5.20	5.24	5.40	5.49	5.56	6.12	–	–	–	–	–	–	–	–	9.26	9.30	9.34
MW	5.35	5.39	5.55	–	–	6.17	6.34	6.45	–	–	–	6.59	7.16	–	–	–	–
MW	6.05	6.09	6.25	6.34	6.41	6.57	7.14	7.25	7.30	7.38	7.48	–	7.57	–	–	–	–
W	6.35	6.39	6.55	7.04	7.11	7.27	7.44	7.55	–	–	–	8.09	8.22	–	8.30	8.34	8.38
W	7.00	7.04	7.20	–	–	7.22	7.34	6.19	6.15	6.28	6.38	–	–	6.42	–	–	–
W	7.30	7.34	7.50	7.58	8.06	8.22	–	–	–	–	–	–	–	–	–	–	–
W	7.50	7.54	8.10	8.19	8.25	8.38	8.54	9.03	–	–	–	–	–	–	–	–	–
W	8.10	8.14	8.25	–	–	9.03	9.04	9.13	9.17	9.25	9.36	–	–	9.44	–	–	–
W	8.40	8.44	8.59	9.08	9.14	9.28	9.43	9.51	9.55	10.04	10.15	–	–	10.23	–	–	–
MW	9.00	9.04	9.19	–	–	9.36	9.52	10.02	–	–	–	–	–	–	–	–	–
W	9.20	9.24	9.39	9.48	9.54	–	–	–	–	–	–	–	–	–	–	–	–
W	9.30	9.34	9.49	9.58	10.04	10.18	–	–	–	–	–	–	–	–	–	–	–
W	10.00	10.04	10.19	10.28	10.34	10.48	11.03	11.11	–	–	–	11.23	11.36	–	11.44	11.48	11.52
W	10.00	10.04	10.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	10.30	10.34	10.49	10.58	11.04	11.18	–	–	–	–	–	–	–	–	–	–	–
MW	11.00	11.04	11.19	–	–	11.32	–	–	–	–	–	–	–	–	–	–	–
	A.M.	A.M.	A.M.	–	–	A.M.	–	–	–	–	–	–	–	–	–	–	–
MW	12.00	12.04	12.19	–	–	12.32	–	–	–	–	–	–	–	–	–	–	–
W	1.00	1.04	1.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	2.00	2.04	2.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	3.00	3.04	3.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	4.00	4.04	4.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Saturdays

	NEWARK Penn Station Bus Lanes	NEWARK Broad St. & Bradford Place	NEWARK LIBERTY INTL AIRPORT Terminal A	NEWARK LIBERTY INTL AIRPORT S. Airport Rd. at Federal Express Dr.	ELIZABETH IKEA (PA Industrial Park)	ELIZABETH Broad & Jersey Sts.	LINDEN St. Georges & Wood Ave.	RAHWAY TRAIN STATION Irving & Cherry Sts.	RAHWAY Inman & St. Georges Ave.	WOODBRIDGE TWP. (COLONIA) Inman & Wood Ave.	WOODBRIDGE TWP. (ISELIN) Metropark Train Station	CARTERET (PARK/RIDE) Roosevelt Ave. & Driftway	WOODBRIDGE Main & Amboy Aves.	WOODBRIDGE Woodbridge Center Mall	PERTH AMBOY State & Smith St.	PERTH AMBOY State St. & Hamilton Ave.	PERTH AMBOY Smith St. & Davidson Ave.
MAP REFERENCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.
W	4.20	4.24	4.38	4.50	–	5.04	–	–	–	–	–	–	–	–	–	–	–
W	4.40	4.44	4.59	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	5.00	5.04	5.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	5.10	5.14	5.29	–	–	5.49	–	–	–	–	–	–	–	–	–	–	–
W	5.30	5.34	5.49	5.58	6.04	6.16	5.38	5.38	–	–	–	–	–	7.00	–	7.16	7.14
W	5.40	5.44	5.59	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	5.48	5.52	6.07	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	5.55	5.59	6.14	–	–	–	5.38	–	–	–	–	–	–	–	–	–	–
MW	6.05	6.09	6.24	6.35	6.41	6.53	6.10	7.18	–	–	–	–	–	–	–	–	–
W	6.35	6.39	6.54	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MW	6.35	6.39	6.54	–	–	7.16	7.28	7.37	–	–	–	–	–	7.49	8.02	–	9.08	8.13	8.17
W	6.50	6.54	7.09	–	–	–	6.10	–	–	–	–	–	–	–	–	–	–
WM	7.05	7.09	7.24	–	–	10.14	–	–	–	–	–	–	–	–	–	8.50	–	–	–
W	7.20	7.24	7.39	10.30	10.38	10.50	11.05	11.13	–	–	–	–	–	–	–	–	–	–
W	7.40	7.44	7.59	11.38	–	11.14	–	–	–	–	–	–	–	–	–	–	–	–
W	11.00	11.04	11.19	11.30	–	11.44	–	–	–	–	–	–	–	–	–	–	–	–
	A.M.	A.M.	A.M.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	12.00	12.04	12.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	1.00	1.04	1.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	2.00	2.04	2.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	3.00	3.04	3.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W	4.00	4.04	4.19	–	–	–	–	–	–	–	–	–	–	–	–	–	–

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Figure A-3 Weekday / Weekend Prototype Schedule – Side 1.

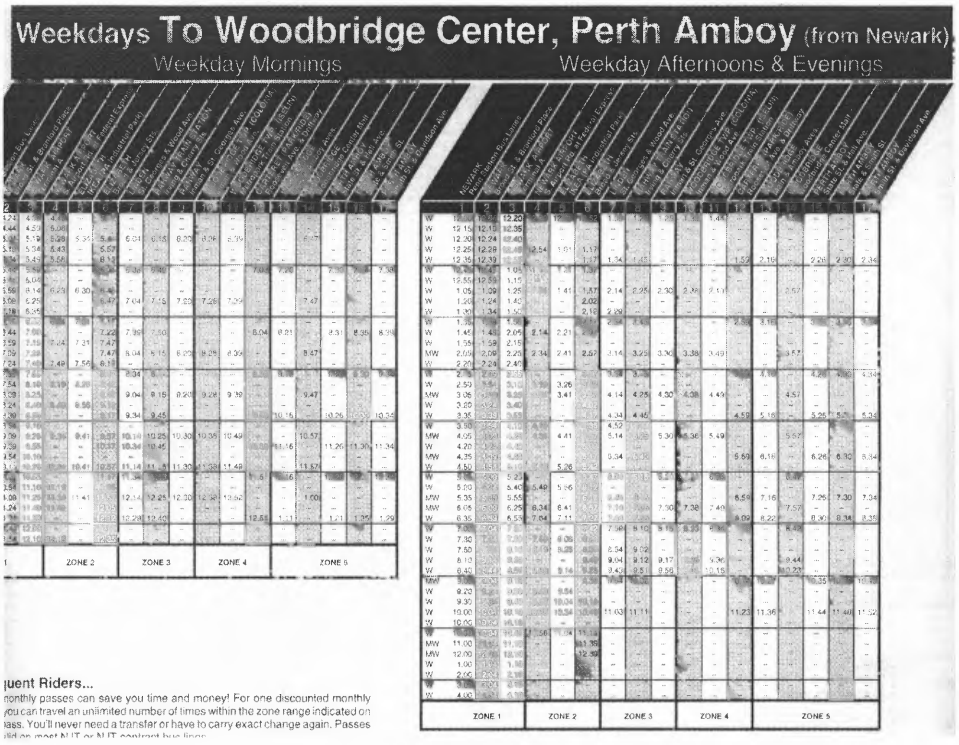


Figure A-4 Weekday / Weekend Prototype Schedule – Side 2.

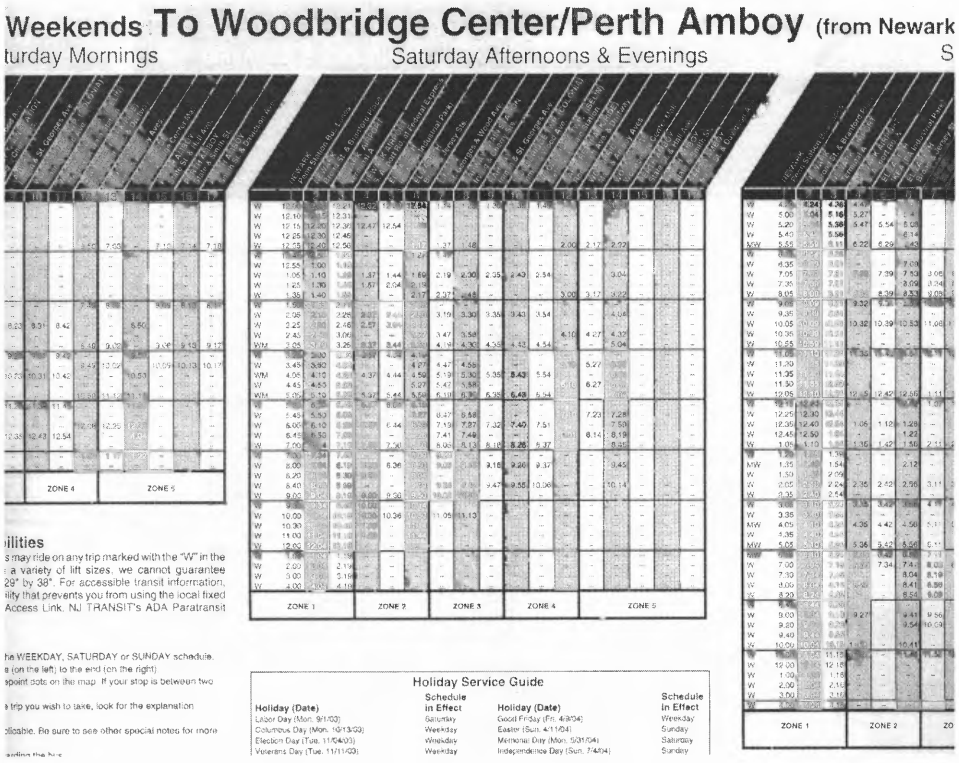
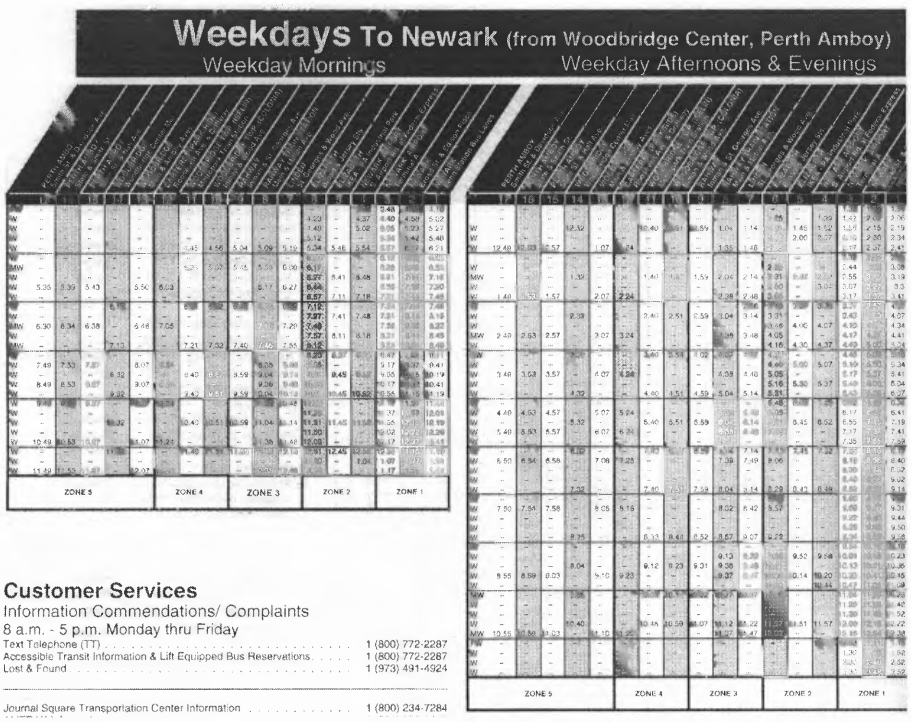
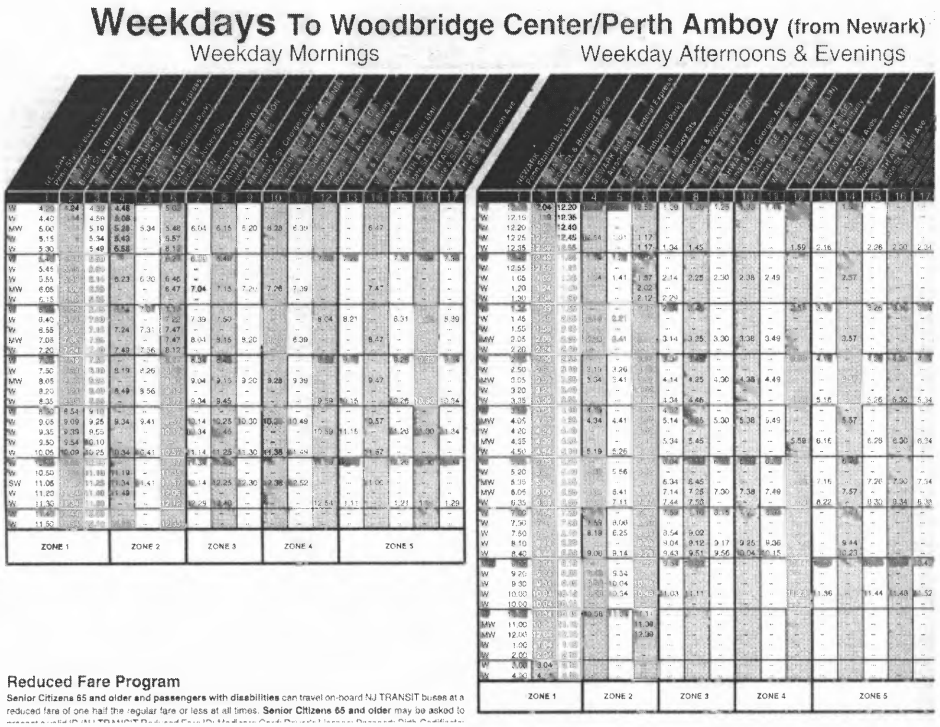


Figure A-5 Directional Prototype Schedule - Side 1.



FigureA-6 Directional Prototype Schedule - Side 2.



Appendix B

Thirty Questions Used for the Time Based Laboratory Experiment

QUESTION SHEET 1

1. On a Friday you are at Broad Street & Branford Place in NEWARK. The time is 5:30 am. What time does the next bus to State Street and Hall Avenue in PERTH AMBOY leave?

2. On a Wednesday, you are at the intersection of Chestnut Ave & Rahway Ave in ELIZABETH Township. The time is 11:45 am. What time will the next bus to Woodbridge Center Mall arrive (Considering that the bus would stop at the intersection of Chestnut Ave & Rahway Ave)?
   # Hint: Use the map & Select the earlier / previous time point along the particular desired direction of bus route for this question.

3. On a Friday you are at Terminal 'A' of the NEWARK AIRPORT. If you board a bus from there towards WOODBRIDGE/PERTH AMBOY, at which stop would you get off to transfer to bus number 810?

4. On Thanksgiving Day, a holiday, you are at IKEA -PA Industrial Park in ELIZABETH. Your final destination is Inman and Wood Ave in WOODBRIDGE and you have to reach there before 5:30 pm. What is the last bus you could take to reach Inman and Wood Ave in WOODBRIDGE TWP. (ISELIN) before 5:30 pm?

5. *On a Tuesday you are at Penn Station Bus Lanes in NEWARK. The time is 11:00 am. If you board the next bus going to Woodbridge Center Mall, what time would you arrive at your destination?*

6. If the fare is $1.10 within one zone (2 zones is $2.20 and so on), and you want to take a bus from S. Airport Road at Federal Express Drive in NEWARK AIRPORT to Inman and St. Georges Ave in RAHWAY, how much would you pay?

7. On a Wednesday, you are at Woodbridge Center Mall. If you want to take the last bus from there that drops you at Terminal 'A' of the NEWARK AIRPORT before 11:00 am, what time would you board the bus?

8. On a Sunday, you are at Penn Station Bus Lanes in NEWARK. The time is 10:30 pm. What time does the next bus to Irving and Cherry Streets (RAHWAY TRAIN STATION) leave?

9. On a Wednesday Afternoon you are at S. Airport Road at Federal Express Drive in NEWARK AIRPORT. The time is 1:00 pm. What time does the next bus to Penn Station Bus Lanes in NEWARK leave?

10. On a Monday, you are at Metropark Train Station in WOODBRIDGE TWP. (ISELIN). What would be the latest time you could board a bus from there, so that you reach Penn Station Bus Lanes in NEWARK before 11:30 pm?

QUESTION SHEET 2

1. If the fare is $1:10 within one zone (2 zones is $2.20 and so on), and you want to take a bus from Penn Station Bus Lanes in NEWARK to St. George Ave and Wood Ave in LINDEN, how much would you pay?

2. On a Wednesday, you are at the intersection of Milton Ave & Jacques Ave in RAHWAY Township. The time is 9:00 am. What time will the next bus to Penn Station Bus Lanes (Considering that the bus would stop at the intersection of Milton Ave & Jacques Ave) arrive?
   # *Hint:* Use the map & Select the earlier / previous time point along the particular desired direction of bus route for this question.

3. On a Saturday afternoon you are at Terminal 'A' of NEWARK AIRPORT. The time is 12:00 pm. If you take the next bus to Broad and Jersey Streets in ELIZABETH, what time will you arrive at your destination (Broad and Jersey Streets in ELIZABETH)?

4. On a Monday you are at Penn Station Bus Lanes in NEWARK. The time is 6:15 am. What time does the next bus to Main and Amboy Avenues in WOODBRIDGE leave?

5. On a Friday you are at State St and Hall Ave in PERTH AMBOY. If you want to take the last bus from there that drops you at Penn Station Bus Lanes in NEWARK before 11:00 am, what time would you board the bus?

6. On a Saturday you are at Woodbridge Center Mall. The time is 6:45 pm. What time does the next bus to IKEA -PA Industrial Park in ELIZABETH leave?

7. (Q8) On a Tuesday, you are at Smith Street and Davidson Ave in PERTH AMBOY. What would be the latest time you could board a bus from there, so that you reach Terminal 'A' of the NEWARK AIRPORT before 10:30 pm?

8. On Columbus Day, a holiday, you are at IKEA -PA Industrial Park in ELIZABETH. Your final destination is Main & Amboy Aves in WOODBRIDGE and you have to reach your destination before 9:00 pm. What is the last bus you could take to reach Main & Amboy Aves in WOODBRIDGE before 9:00 pm?

9. On a Thursday you are at Broad Street& Branford place in NEWARK. The time is 11:30 am. If you board the next bus going to Smith Street and Davidson Avenue in PERTH AMBOY, what time would you arrive at your destination?

10. On a Tuesday, you are at S. Airport Road at Federal Express Drive in NEWARK AIRPORT. If you board a bus from there towards WOODBRIDGE/PERTH AMBOY, which stop would you get off to transfer to bus number 112?

QUESTION SHEET 3

1. On a Sunday, you are at Penn Station Bus Lanes in NEWARK. The time is 7:00 am. What time does the next bus to Irving and Cherry Streets (RAHWAY TRAIN STATION) leave?

2. On a Friday, you are at IKEA -PA Industrial Park in ELIZABETH. What would be the latest time you could board a bus from there, so that you reach Main and Amboy Aves in WOODBRIDGE before 8:30 pm?

3. On a Thursday you are at Broad St & Jersey Street in ELIZABETH. The time is 6:30 am. What time does the next bus to Woodbridge Center Mall leave?

4. If the fare is $1:10 within one zone (2 zones is $2.20 and so on), and you want to take a bus from State & Smith Aves in PERTH AMBOY to Roosevelt Ave and Driftway in CARTERET (PARK/RIDE), how much would you pay?

5. On a Thursday afternoon you are at Broad and Jersey Streets in ELIZABETH. The time is 1:00 pm. What time does the next bus to Penn Station Bus Lanes in NEWARK leave?

6. On a Tuesday, you are at Broad and Jersey Streets in ELIZABETH. If you board a bus from there towards WOODBRIDGE/PERTH AMBOY, which stop would you get off to transfer to bus number 804?

7. On a Monday, you are at State St & Hall Ave in PERTH AMBOY. If you want to take the last bus from there that drops you at Broad Street and Edison Place in NEWARK before 10:00 am, what time would you board the bus?

8. On a Wednesday, you are at State St & Hall Ave in PERTH AMBOY. The time is 10:30 am. If you board the next bus going to Terminal 'A' of the NEWARK AIRPORT, what time would you arrive at your destination?

9. On a Friday, you are at the intersection of Main Ave & West Ave in PERTH AMBOY Township. The time is 5:45 am. What time will the next bus to Terminal 'A' of the NEWARK AIRPORT arrive (Considering that the bus would stop at the intersection of Main Ave & West Ave)?
   # Hint: Use the map & Select the earlier / previous time point along the particular desired direction of bus route for this question.

10. On President's Day, a holiday, you are at Penn Station Bus Lanes in NEWARK. Your final destination is Metropark train station in WOODBRIDGE TWP. (ISELIN) and you have to reach your destination before 8:00 pm. What is the last bus you could take to reach Metropark train station in WOODBRIDGE TWP. (ISELIN) before 8:00 pm?

REFERENCES

Bartram, D., Crawshaw, M., & Sprent, N. (1983). Structuring timetable information. *Ergonomics,* 26, pp. 505-516.

Bartram, D., Crawshaw, M., & Sprent, N. (1980). Intelligibility of timetables. *Human Factors in Transportation Research,* Vol.1, pp. 319-327.

Bellamy, L. J., & Courtney, A. J. (1981). Development of a search task for the measurement of peripheral visual acuity. *Ergonomics,* 24, pp. 497-510.

Booher, H. (1975). Relative comprehensibility of pictorial information and printed words in proceduralized instructions. *Human Factors*, 17,pp. 266-277.

Carswell, C. and Wickens, C. (1990). The perceptual interaction of graphical attributes: Configurality, stimulus homogeneity, and object integration. *Perception and psychophysics*, 47,pp 157-168.

Day & Ruth, S. (1989). Alternative representations. The psychology of learning and motivation: Advances in research and theory, Vol. 22, pp. 261-305.

Dueker, K.J., & Vorvick, J. (1998). Transit time internet access. *Transportation Research Record,* 1618, pp. 180-185. Washington, DC: USA.

Fisher, D., & Tan, K. (1989). Visual Displays: The highlighting paradox. *Human Factors*, 31, pp. 17-30.

Fisk, A., Kobylak, R., and Serbo, M. (1986). Relative value of pictures and text in conveying information: Performance and memory evaluations. *Proceedings of the Human Factors Society 30th Annual Meeting.* Santa Monica, CA: Human Factors Society, pp. 1269-1272.

Fox, K., & Wright, P. (1972). Explicit and implicit tabulation formats. *Ergonomics,* 15, pp. 175-188.

Fox, K., & Wright, P. (1970). Presenting information in tables. *Applied Ergonomics,* 1, pp. 234-242.

Goettl, B. P., Kramer, A. F., & Wickens, C. D. (1986). Display format and perception of numeric data. *Proceedings of the Human Factors Society- 30th Annual Meeting,* pp. 450-454. Santa Monica, CA: Human Factors Society.

Johnston, D. M, (1965). Search performance as a function of visual acuity. Human Factors, 1, pp. 527-535.

Major, M. A., & Shellswell, R. E. (1976). Towards objectivity in the use of color. *The Cartographic Journal, 13,* 72 – 84.

McCormick, E., & Sanders, M. (1993). Human factors in engineering and design, 7th ed., New York: McGraw-Hill.

Molesworth, B. R. C., & Wiggins, M. W. (2004). Redesigning an en – route aeronautical chart. *Ergonomics in Design*, Vol 12, No. 1, Winter 2004, pp. 18 – 23.

Nelson, E. S. (1994). Color detection on bivariate chloropleth maps: The visual search process. Cartographia, 31, 33 – 43.

Nimmo-Smith, M., & Wilkins, A. (1987). The clarity and comfort of printed text. *Ergonomics*, 30, pp. 1705-1720.

Norman, D. A. (1988). The design of everyday things. New York: Doubleday.

Philips, R. (1979). Why is lower case better? *Applied Ergonomics*, 10, pp. 211-214.

Rayner, K. (1978). Eye movements in reading and information processing. *Psychological Bulletin*, 85, pp. 618-660.

Schneiderman, B. (1998). Designing the User Interface, strategies for effective Human-Computer Interaction, 3rd ed., Addison-Wesley Longman, Inc.

Smith, S. L. (1979). Letter size and legibility. *Human Factors*, 21, pp. 661-670.

Sparrow, J. (1989). Graphical displays in information systems: Some data properties influencing the effectiveness of alternative forms. *Behaviour and Information Technology,* 8, pp. 43-56.

Swanstson, M. T., & Walley, C. E. (1984). Factors affecting the speed of acquisition of tabulated information from visual displays. *Ergonomics,* 27, pp. 321-330.

Tinker, M. A. (1960). Legibility of Mathematical tables. *Journal of Applied Psychology,* 44, pp. 83-87.

Tinker, M. A. (1954). Readability of Mathematical tables. *Journal of Applied Psychology,* 38, pp. 436-442.

Tufte, E. (1983). The visual display of quantitative design. Cheshire, CT: Graphic press.

Tullis, S. (1983). The formatting of alphanumeric: A review and analysis. *Human factors*, 25, pp. 657-682.

Wickens, C. D, & Hollands, J. D. (2000). Engineering Psychology and Human Performance 3rd, Upper Saddle River, New Jersey: Princeton Hall.

Wickens, C. D, Lee, J. D., Liu, Y., & Becker, S. E. G. (2004). An Introduction to Human Factors Engineering, 2nd ed., New Jersey: Upper Saddle River.

Wiener, E. L (1993). *Intervention Strategies for the management of human error* (Report No. 4547). Moffett Field, CA: National Aeronautics and Space Administration.

Wright, P. (1968). Using tabulated information. *Ergonomics,* 11, pp. 331-343.

Wright, P. (1977). Decision making as a factor in the ease of using numerical tables. Ergonomics, 20, pp. 91-96.