Affect of Different Factors on the Start-up Times of Pedestrians

Sewmini JAYATILAKE [a], Niroshana PREMACHANDRA [b], Vasantha WICKRAMASINGHE [c], Sunanda DISSANAYAKE [d]

[a,b,c] *Faculty of Engineering, University of Peradeniya, Sri Lanka*
[a] *E-mail: sewminiravihari@gmail.com*
[b] *E-mail: niroshanapremachandra@gmail.com*
[c] *E-mail: vskw@pdn.ac.lk*
[d] *Department of Civil Engineering, Kansas State University, USA*
[d] *E-mail: sunanda@ksu.edu*

Abstract: *Pedestrian start-up time at signalized crosswalks is an important factor to be considered in allocating green time for the pedestrian signal phase. That will be helpful in reducing dangerous pedestrian-vehicle conflicts. This research presents the start-up time of pedestrians and the effect of several factors to it. In this research start-up time was considered under two categories as Early start-up time and Delayed start-up time. The factors that considered are age, gender & group size of the pedestrians. At each selected location video surveying was done to collect data and then analysis was done mainly as Statistical analysis and Probability analysis. Statistical analysis was done to find the mean & standard deviation. Also the variation of start-up time with different factors was found by graphical interpretation. Probability analysis results give the probability that an individual will have for different start-up times.*

Keywords: Start-up time, Early start-up, Delayed start-up

1. INTRODUCTION

Signalized crosswalks have been implemented with the aim of controlling interactions between pedestrians and vehicles. The total time required for pedestrians to cross the road is the summation of the time required to traverse the crosswalk and the pedestrian start-up time. However most of the signal time calculations are not paying attention towards the start-up time. This may result in dangerous situations caused due to pedestrian vehicle interactions.
Pedestrian start-up time is the difference between the time at which the pedestrian stepped off the curb to cross the road and the time at which the pedestrian signal phase turns to green. If the pedestrian stepped off the curb during red phase, then the start-up time is negative and it is known as early start-up time. If the pedestrian stepped of the curb during green phase, then the start-up time is positive and it is known as delayed start-up time. However early or delayed start-up times can create dangerous impacts on pedestrians. In that context, it is essential to pay attention towards the start-up time when designing the signal phase in a signalized pedestrian crosswalk.

As the pedestrians' behavior varies with several factors, there start-up times also may vary from person to person. Therefore, factors like age, gender & group size were considered in this research and affect of these factors to the start-up times of pedestrians were found. Factors were noted down for each pedestrian during the data extraction and their variations were found during the analysis

1.1 Objectives

To find the start-up times of pedestrians at signalized crosswalks and to find the affect of age, gender and group size on the start-up times.

2. LITERATURE REVIEW

Many research papers have paid attention towards pedestrians and their safety. Some of them have focused on pedestrians at signalized crosswalks and green time allocations at the crosswalks. At there, most of them have considered only the time taken by the pedestrians to traverse the crosswalk. But there are few who paid their main attention towards start-up time of pedestrians, which is also an important factor to be considered in green time allocation. However, paying attention towards the start-up times of pedestrians at signalized crosswalks can improve the safety of pedestrians.

As existing data on walking speeds and start-up times have many shortcomings, Knoblauch *et al*. (1996) have carried out a series of field studied to quantify the walking speed and start up time of pedestrians of various ages under different conditions and data were collected on walking speeds and start up times relative to site and environmental factors. But the methodology developed by Alahajyaseen and Nakamura (2010), is based on modeling total pedestrian platoon crossing time which consist of discharge and crossing times. Jain *et al*. (2014), have carried out their research to examine the effect of pedestrian characteristics to the crossing speed and waiting time. The objective of Marisamynathan and Perumal (2013), was to develop a pedestrian delay model for signalized intersection crosswalks. However, Easa and Cheng (2013), have collected data to establish a correlation coefficient between start-up time and walking time of pedestrians and have presented a probabilistic method to compute minimum green time.

When collecting data, Golani and Damti (2007), have considered the behavior of group of pedestrians. Knoblauch *et al*. (1996), have considered several factors like weather, age, gender, curb height, number of travel lanes, street width etc. and data were categorized accordingly. And they haven't considered pedestrians under 13 years, pedestrians carrying children, pedestrians walking as a group and pedestrians in wheelchairs or crutches. Jain *et al*. (2014), have conducted their research considering the pedestrian characteristics of age, gender and whether they carry baggage or luggage. Lipovac *et al.* (2012), have considered gender, age and group size in their research where the research conducted by Galanis *et al*. (2012), have considered only age and gender. Categories compared by Gates *et al*. (2006), are age & disability, intersection traffic control condition, gender and group size. To have a fair conclusion, consideration on both gender and age is essential and addition of some more factors may improve the safety of pedestrians.

As the data collection method, most researches have used video surveying. Gates *et al.* (2006), have used video camera for data collection and 1947 pedestrian data were gathered at 11 intersections in Madison and Milwankee. Vujanic *et al.* (2014) also have used video tapping using a hidden digital camera and survey was carried out in Serbia for 7 days with 1 hour per day. Galanis *et al*. (2012), have used video tapping as the data collection method and data analysis was done by captiv L2100 (TEA) software. More than 1300 pedestrians were recorded in 12 signalized intersections in Greece. Golani and Damti (2007), have used video survey as the data collection method and survey was done at 7 crosswalks in Israel. A total of around 55 hours of video data have been gathered by them. In the research carried by Brosseau *et al*. (2013), 13 intersections with similar geometry and traffic condition were

selected in Canada and data collection was done manually for main analysis and complimentary video data was used for the validation. However, Jain *et al*. (2014), have paid attention to different data collection techniques like direct observation methods, video observation methods, time lapse photographs and pedestrian opinion surveys. Out of them video observation method was selected by them and video camera was fixed in an elevated position so as to obtain an overall view. According to Easa and Cheng (2013), survey was done at 14 intersections in Canada & China and data were recorded using the lap time recording in smart phone. In that method, there is a tendency for errors to occur and recorded data depends entirely on the observer. Knoblauch *et al*. (1996), have used a hand held digital electronic stopwatch to record data. Lap times have used in order to record the start of green time and also the pedestrians' start-up times. As the times are recorded at the site, only few pedestrians can be considered in this method. But to improve the accuracy of data, 5 field observers have been used. Their research has been carried out at 16 crosswalks in USA and data were collected during 8 hour period. In total they have considered 7123 pedestrians and out of them 750 were used in calculating start-up time. However, video tapping will be the most suitable method to collect data as the start-up time calculations can be done precisely after finishing data collection.

When considering the results, in the research carried by Vujanic *et al.* (2014), 17.5% pedestrians have started crossing during red phase and the highest number of offenders of both genders is under the age of 30 and majority is male. According to Easa and Cheng (2013), 95^{th} percentile value of start-up time is 3.9-5.7s while the 99^{th} percentile value is 5.3-7.6s. Results obtained by Galanis *et al*. (2012), shows that 17% of the pedestrians have crossed during the red phase. In the research done by Knoblauch *et al*. (1996), the highest start-up was given by female of age above 65years and the value is 2.57s. However according to Golani and Damti (2007), average start-up time is 2.7s and 15^{th} percentile value is 3.85s and it was used to include slow walkers.

If we consider the results of those research papers, we can see that there is a significant value for the start-up time of pedestrians. Therefore, use of start-up time in green time allocation in pedestrian's signal phase is essential in order to provide more safety for pedestrians. In that case consideration on several factors like age, gender, group size is also needed. In this paper, authors have aimed to find the start-up time of pedestrians and group them under above mentioned three factors and find the effect of those factors to the start-up time. The uniqueness in this study is categorizing the start-up time as early start-up time and delayed start-up time and minimizing the dangerous situations that may occur due to early start-up and allowing individuals with delayed start-up to cross the road safely.

3. METHODOLOGY

3.1 Site selection

In this main attention was given to signalized crosswalks with time indication as the research is concerning about the start-up time of pedestrians at signalized crosswalks. Having considerable pedestrian concentrations at those signalized crosswalks and availability of locations to capture video data were considered. After that permission required to carry out video survey at selected locations were obtained.

3.2 Data collection

As the data collection method, video surveying was done specially during peak hours. A stationary digital camera was used to record video data and it was focused on the pedestrians' signal light, the curb, pedestrians who are waiting to cross the road and the road section in front of the pedestrians.

3.3 Data extraction

The collected video data were extracted in order to analyze. For that the video part from the last 10 seconds of pedestrian red phase to first 10 seconds of pedestrian green phase was extracted first. Next extracted video part was converted in to images with an accuracy of 0.1s, using 'Video to JPG Converter'. Start-up times of pedestrians were calculated using the signal phase indicated in each image.

3.4 Finding the start-up times of pedestrians

To find the start-up times, pedestrians at the front line and who are waiting for the pedestrian's signal phase to turn into green, were selected. Start-up time is the time at which the pedestrians stepped off the curb to cross the road and it was calculated using extracted images. Also the age, gender and group size of each pedestrian was observed and recorded. Age and group size were categorized as follows.

Age groups:-
- (10-30) years
- (30-60) years
- Above 60 years

Group size:-
- Alone
- Group (2 or more pedestrians)

3.5 Analysis of start-up time

Analysis was mainly done as statistical analysis and probability analysis. Statistical analysis was done for the calculated start-up time which is the dependent variable. Therefore, calculated start-up times were represented graphically with respect to each factor. It was done for both early and delayed start-up times, using 'Easy fit' software. Then using the curves obtained, mean & standard deviation values were found.

Probability analysis was done for early start-up time and delayed start-up time separately. At there, start-up time values were divided into ranges and for each range, probabilities of pedestrians were found for each category under age, gender and group size with respect to the total of pedestrians. Then using those probability values, cumulative probability curves were plotted for each category separately. Using that, a matrix of probability values was created so that when the age, gender and the group size of an individual is known, we can predict the probability that person will have to each start-up time range provided.

4. RESULTS AND DISCUSSION

4.1 Data Collected

In order to carry out the analysis, gathered data were tabulated separately for early and delayed start-up time.

Table 4.1. Data for early start-up time

Start-up time (s)	No. of pedestrians							
	Total	Male	Female	Alone	Group	10 to 30	30 to 60	Above60
-5	0	0	0	0	0	0	0	0
-4.9	0	0	0	0	0	0	0	0
-4.8	1	0	1	1	0	1	0	0
-4.7	4	3	1	4	0	2	0	2
-4.6	1	1	0	1	0	0	1	0
-4.5	2	2	0	1	1	1	1	0
-4.4	4	3	1	4	0	1	3	0
-4.3	3	2	1	2	1	2	1	0
-4.2	2	2	0	2	0	0	2	0
-4.1	3	1	2	4	3	1	4	0
-4	3	2	1	2	1	1	2	0
-4.6	1	1	0	1	0	0	1	0
-4.5	2	2	0	1	1	1	1	0
-4.4	4	3	1	4	0	1	3	0
-3.9	0	0	0	0	0	0	0	0
-3.8	2	2	0	2	0	0	1	1
-3.7	1	0	1	1	0	0	1	0
-3.6	1	0	1	1	0	0	1	0
-3.5	5	4	1	5	0	0	4	1
-3.4	1	1	0	1	0	0	1	0
-3.3	1	0	1	1	0	0	1	0
-3.2	1	1	0	1	0	0	1	0
-3.1	8	3	5	8	0	2	5	1
-3	4	2	2	3	1	1	3	0
-2.9	8	5	3	8	0	0	6	2
-2.8	10	5	5	10	0	4	3	3
-2.7	7	4	3	6	1	1	6	0
-2.6	6	5	1	5	1	2	3	1
-2.5	7	5	2	5	2	2	4	1
-2.4	7	5	2	7	0	1	5	1
-2.3	6	3	3	6	0	2	3	1
-2.2	9	6	3	9	0	3	5	1
-2.1	6	6	0	6	0	0	3	3
-2	4	3	1	4	0	0	4	0
-1.9	13	6	7	13	0	5	4	4
-1.8	12	8	4	11	1	2	10	0
-1.7	11	8	3	10	1	2	8	1
-1.6	14	9	5	14	0	1	10	3
-1.5	21	16	5	21	0	4	14	3

Table 4.1. Continued

Start-up time (s)	No. of pedestrians							
	Total	Male	Female	Alone	Group	10 to 30	30 to 60	Above60
-1.4	13	7	6	12	1	6	7	0
-1.3	15	6	9	13	2	3	9	3
-1.2	16	12	4	16	0	3	12	1
-1.1	19	13	6	16	3	4	12	3
-1	19	8	11	16	3	5	10	4
-0.9	24	16	8	22	2	6	14	4
-0.8	26	19	7	24	2	11	13	2
-0.7	30	16	14	27	3	7	20	3
-0.6	23	12	11	18	5	7	16	0
-0.5	35	24	11	31	4	6	25	4
-0.4	40	26	14	38	2	11	24	5
-0.3	48	26	22	45	3	13	28	7
-0.2	47	25	22	44	3	10	32	5
-0.1	28	12	16	24	4	7	19	2

Table 4.2. Data for delayed start-up time

Start-up time (s)	No. of pedestrians							
	Total	Male	Female	Alone	Group	10 to 30	30 to 60	Above60
0	35	13	22	29	6	9	26	0
0.1	57	27	30	50	7	10	43	4
0.2	50	31	19	46	4	9	38	3
0.3	49	27	22	43	6	14	27	8
0.4	57	31	26	51	6	11	42	4
0.5	68	27	41	61	7	18	43	7
0.6	48	26	22	39	9	13	29	6
0.7	47	22	25	44	3	8	33	6
0.8	63	27	36	59	4	23	39	1
0.9	35	15	20	30	5	6	26	3
1	41	19	22	38	3	10	26	5
1.1	44	24	20	42	2	5	35	4
1.2	39	21	18	36	3	11	24	4
1.3	48	25	23	44	4	9	32	7
1.4	27	13	14	21	6	9	13	5
1.5	31	13	18	27	4	8	21	2
1.6	20	10	10	16	4	2	16	2
1.7	19	7	12	15	4	6	13	0
1.8	19	9	10	15	4	8	11	0
1.9	14	6	8	12	2	3	11	0
2	12	6	6	9	3	2	9	1
2.1	7	1	6	4	3	1	6	0
2.2	12	5	7	12	0	1	10	1
2.3	9	8	1	9	0	1	7	1
2.4	5	1	4	4	1	2	3	0
2.5	11	6	5	10	1	1	8	2
2.6	4	3	1	2	2	0	4	0
2.7	3	3	0	3	0	0	3	0
2.8	4	1	3	3	1	1	2	1
2.9	2	0	2	1	1	1	1	0
3	2	1	1	2	0	0	0	2
3.1	2	1	1	1	1	0	2	0

Table 4.2. Continued

Start-up time (s)	No. of pedestrians							
	Total	Male	Female	Alone	Group	10 to 30	30 to 60	Above60
3.2	2	1	1	2	0	0	2	0
3.3	0	0	0	0	0	0	0	0
3.4	0	0	0	0	0	0	0	0
3.5	0	0	0	0	0	0	0	0

4.2 Statistical Analysis

In this, probability density curves were plotted using “Easy fit” software for early and delayed start-up time. Also curves were plotted separately considering the factors age, gender and group size. When the start-up time values obtained are fed to the Easy fit software, it will run for all the types of probability density functions and will automatically give out the best fit curve. The mean and standard deviation values of that distribution are also given. Probability density plot for early start-up time of total pedestrians is shown in Figure 4.1. Similarly, probability density distributions were plotted for early and delayed start-up times considering each factor separately.

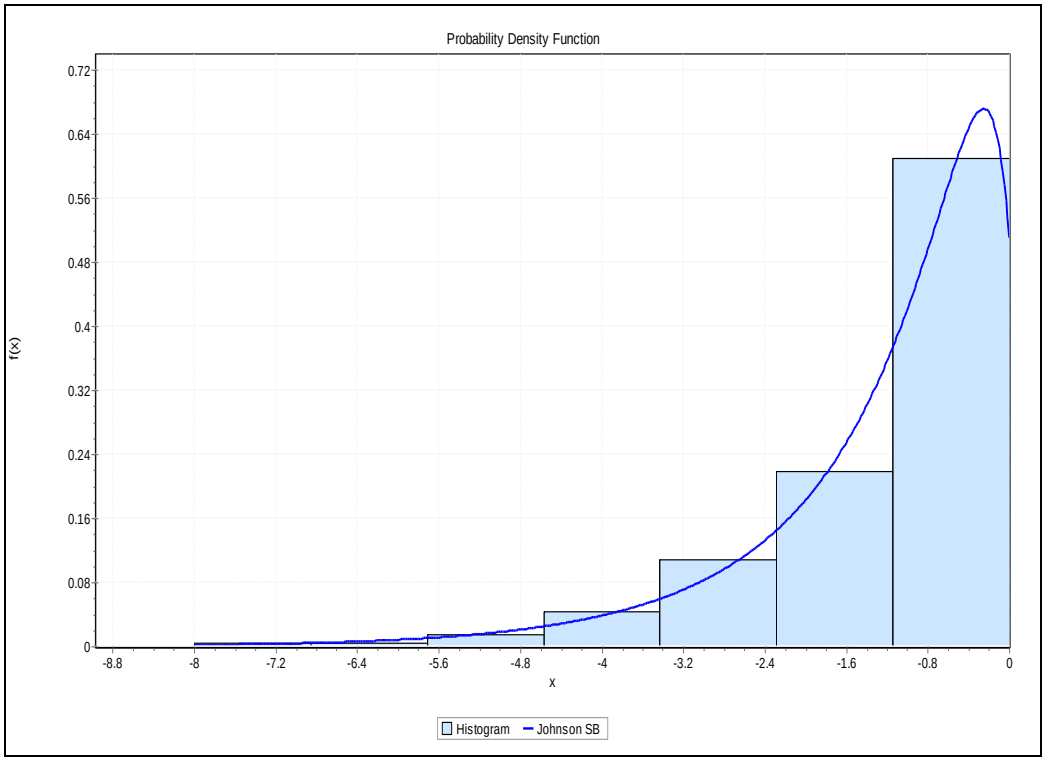

Figure 4.1. Probability density distribution for early start-up time data of total pedestrians

Table 4.3. Mean and Standard deviation for start-up time values

	Total start-up time (s)		Early start-up time (s)		Delayed start-up time (s)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Total	0.05	1.43	-1.23	1.21	0.93	0.69
Male	-0.08	1.45	-1.27	1.17	0.92	0.67
Female	0.20	1.40	-1.16	1.28	0.94	0.70
Alone	0.02	1.44	-1.24	1.22	0.92	0.68
Group	0.33	1.37	-1.06	1.16	1.02	0.75
10-30	-0.02	1.43	-1.23	1.27	0.89	0.61
30-60	0.12	1.38	-1.17	1.13	0.94	0.71
Above60	-0.23	1.66	-1.52	1.43	0.97	0.68

4.3 Probability Analysis

To carry out the probability analysis, start-up times were divided into ranges so that total number of pedestrians in each range is greater than 30. Then in each range, total number of pedestrians under each category was calculated. Next the probability values of each range were calculated under each category and using them, probability plots were obtained for each range. This was done separately for early and delayed start-up time.

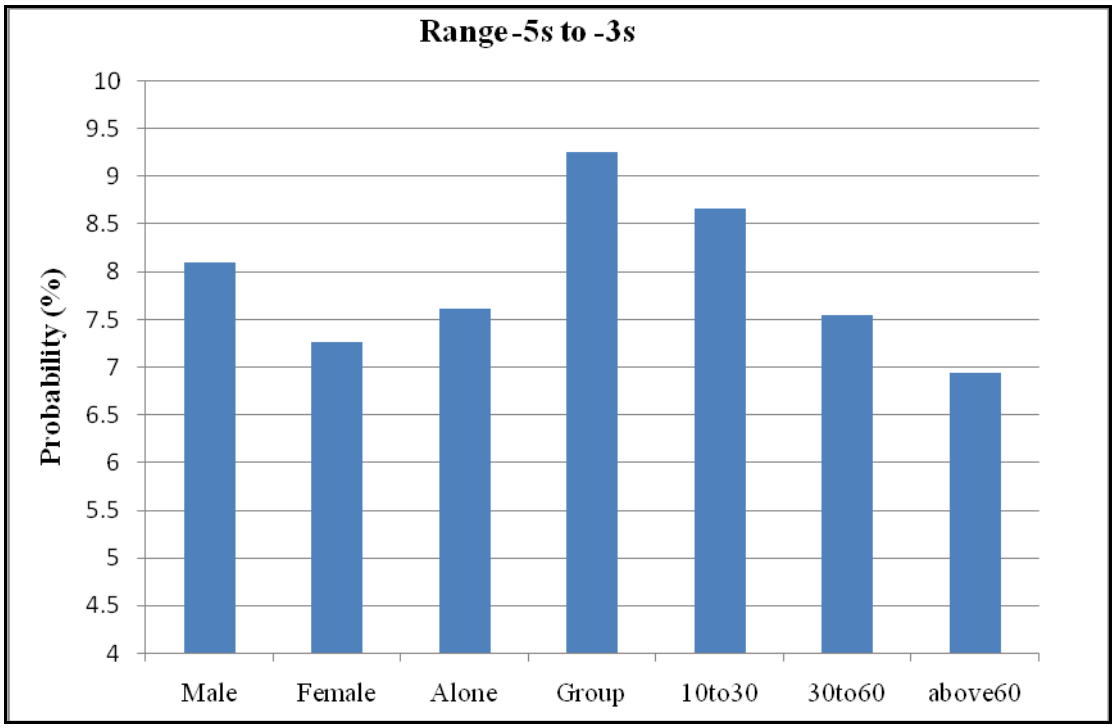

Figure 4.2. Probability plot for start-up time range -5s to -3s

It shows the probability that each category has to have a start-up time within the range -5s to -3s. Similarly, using all the plots obtained for each range, probability values that each category will have to have a start-up time within that specific range can be found.

Next each category indicated along the x axis of the above curves was considered separately and cumulative probability values were taken by summing up the probabilities obtained under each range. Then cumulative probability curves were obtained separately for early and delayed start-up times. (All the cumulative probability curves are given under the Appendix A)

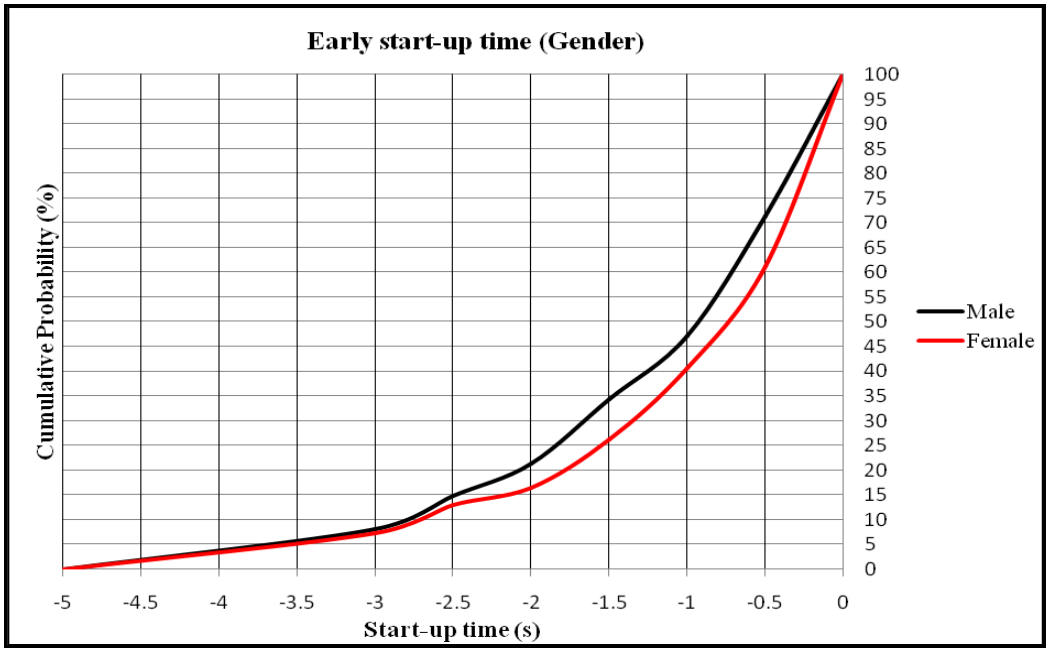

Figure 4.3. Cumulative probability curves for male and female with early start-up time

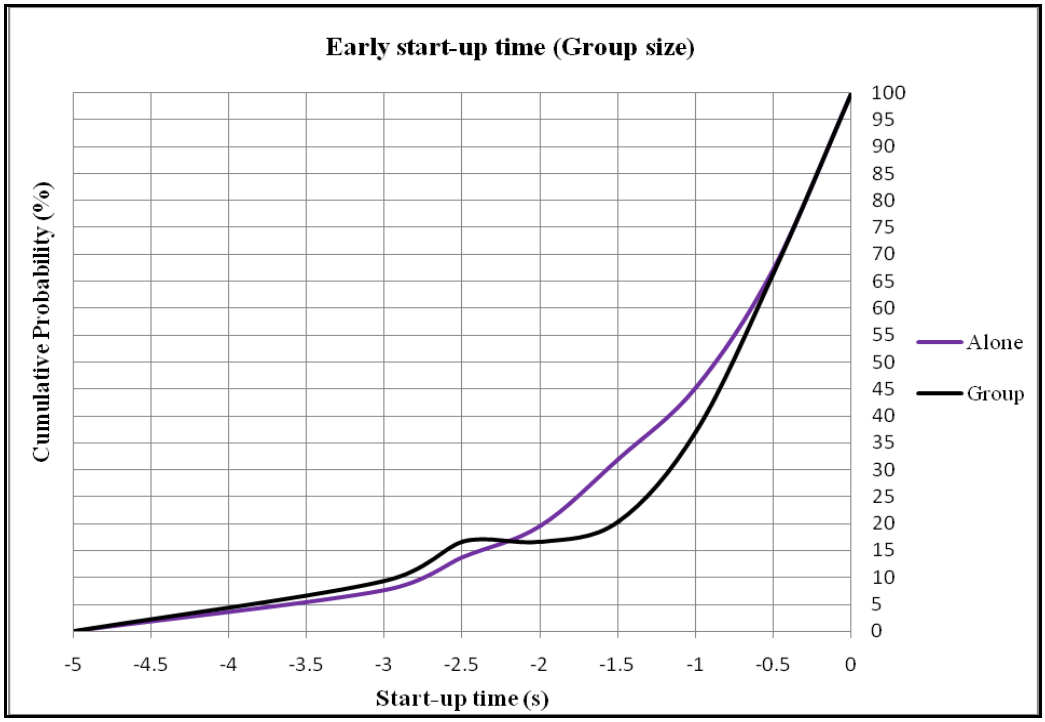

Figure 4.4. Cumulative probability curves for early start-up time of pedestrians considering the group size

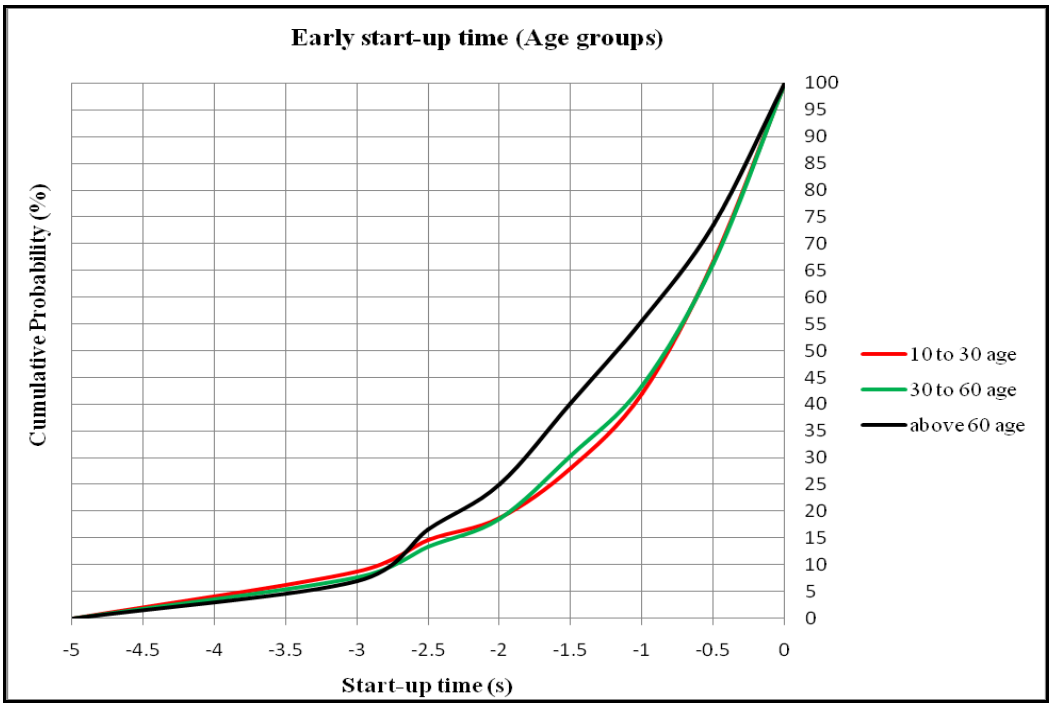

Figure 4.5. Cumulative probability curves for early start-up time of pedestrians under different age groups

When considering the Figure 4.3, we can see that a higher cumulative probability value is there for males than females for early start-up time. In Figure 4.4, when the group sizes are compared, a higher probability out of the pedestrians who are with a group has started to cross the road between the range of -5s to -2.2s, than that of the pedestrians who are alone. But it is in the other way when the start-up time is between -2.2s to 0s. When comparing the age groups, pedestrians within 10-30 age group and 30-60 age group shows a similar behavior. But out of the pedestrians above 60 years of age, a smaller fraction starts to cross when the start-up time is between -5s to -2.7s. But the fraction of them starting to cross the road between -2.7s to 0s is higher than the probabilities of other two age groups. So this gives the behavior for early start-up time of pedestrians.

Similarly, cumulative probability curves were obtained for delayed start-up. Finally, a matrix of probability values was constructed as shown in table 4.4. When an individual pedestrian with known age, gender and group size is going to cross the, we can predict the probability that individual will have for different start-up time ranges.

Table 4.4. Probability matrix

Start-up time range	Total	Male	Female	Alone	Group	10 to 30	30 to 60	Above 60
-4.1 to -5	1.58	1.10	0.48	1.3	0.27	0.69	0.75	0.14
-3.1 to -4	1.58	0.89	0.69	1.51	0.07	0.21	1.17	0.21
-2.1 to -3	4.8	3.16	1.65	4.46	0.34	1.1	2.81	0.89
-1.1 to -2	9.47	6.04	3.43	8.92	0.55	2.06	6.18	1.24
0 to -1	24.37	13.52	10.84	21.83	2.54	6.31	15.58	2.47
0.1 to 1	35.35	17.30	18.05	31.64	3.71	8.37	23.75	3.23
1.1 to 2	18.74	9.20	9.54	16.27	2.47	4.32	12.70	1.72
2.1 to 3	4.05	1.99	2.06	3.43	0.62	0.55	3.02	0.48
3.1 to 4	0.27	0.14	0.14	0.21	0.07	0	0.27	0

4.1 Discussion

From table 4.1 and 4.2, we can see that start-up times of pedestrians are varying within a range of around -5s to 3.5s. That means pedestrians are having both early start-up as well as delayed start-up. When we compare the start-up times of male and female, male pedestrians are having early start-up times than female pedestrians. Also when the group size is considered, pedestrians who are alone are having early start-up time values when compared with the pedestrians who are crossing with a group (that is 2 or more pedestrians). Start-up times vary within different age groups. However, in most instances, pedestrians within the age limit of 10-30 years showed early start-up and while pedestrians of age greater than 60 showed delayed start-up. Different start-up times and different mean values obtained under all these factors, age, gender and group size, shows how these factors effect in start-up times.

The probability analysis has given the probabilities that a set of pedestrians waiting to cross the road will have for different start-up times. The probability matrices given in table 4.4 give the probability that an individual will have for different start-up time ranges, when their age, gender and group are considered separately.

So our primary objectives have been achieved by carrying out statistical analysis and probability analysis.

5. CONCLUSION

When considering the results of this research, it shows the importance of start-up time. But in many instances, designing of pedestrian signal times do not pay much attention towards pedestrians' start-up time and designing is carried out mainly focusing on crossing time of pedestrians. But that can lead to pedestrian-vehicle interactions and can cause severe impacts on pedestrians. Those situations can be eliminated by paying attention towards the start-up time. In that case also separating the start-up time into two as early start-up time and delayed start-up time and considering both in green time allocation in pedestrian signal timing improves the safety of pedestrians. Also the start-up time is effected by several other factors of pedestrians. In this paper, major factors like age, gender and group size are considered. Categorizing the start-up times of those factors separately and giving consideration on those factors ensure the safety of each individual pedestrian. However, start-up times are important to be considered in pedestrian signal phase designing as it is advantageous in improving the safety of pedestrians.

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APPENDIX

Appendix A – Cumulative Probability Graphs

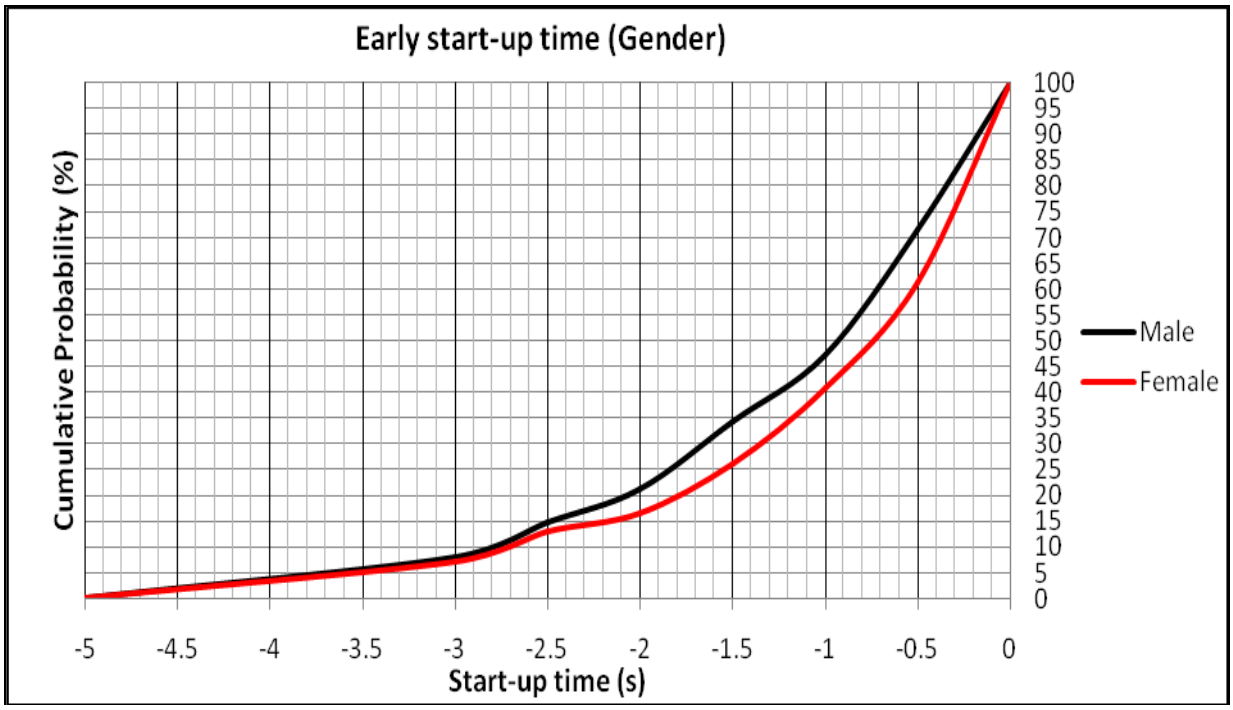

Figure A.1. Cumulative probability curves for early start-up time of male and female

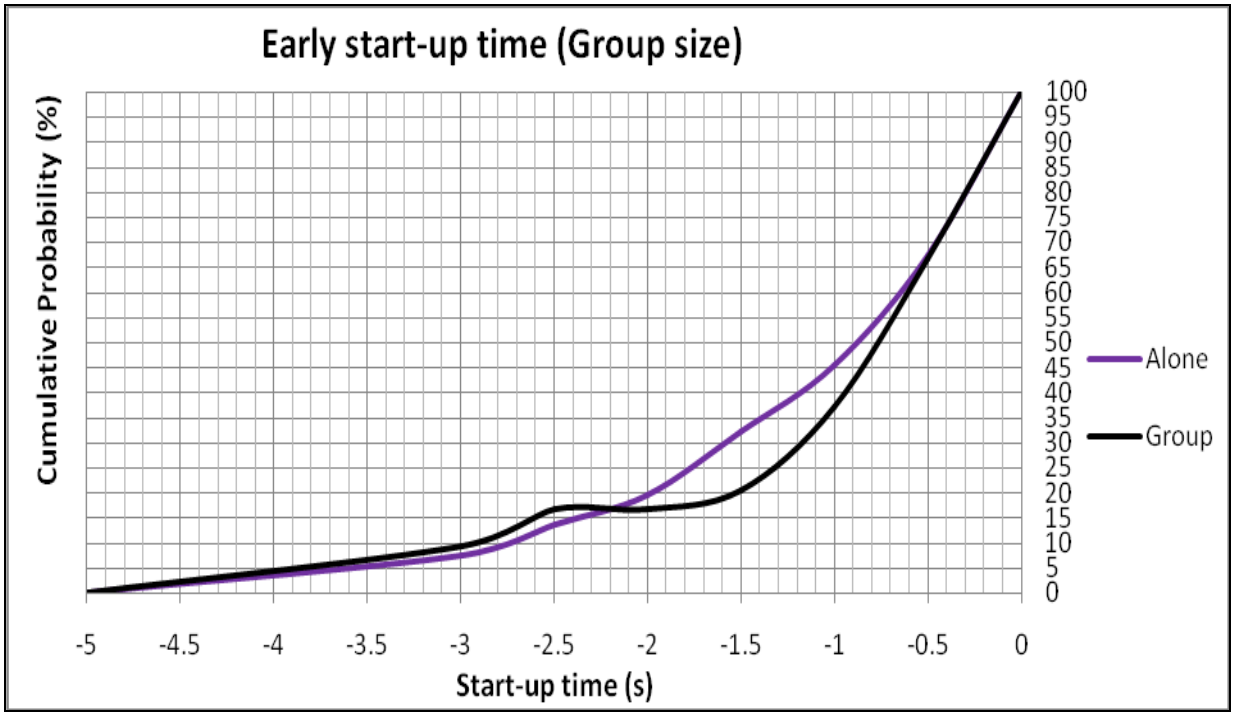

Figure A.2. Cumulative probability curves considering group size for early start-up time

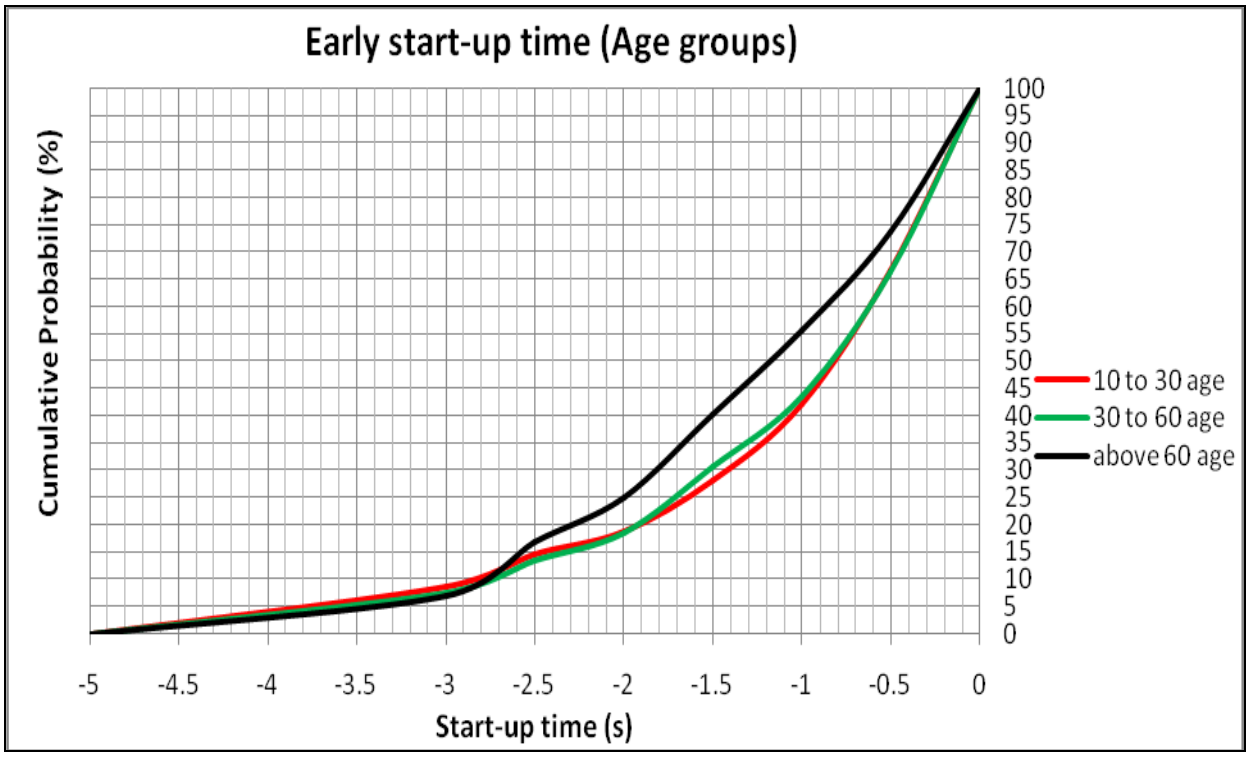

Figure A.3. Cumulative probability curves considering age groups for early start-up time

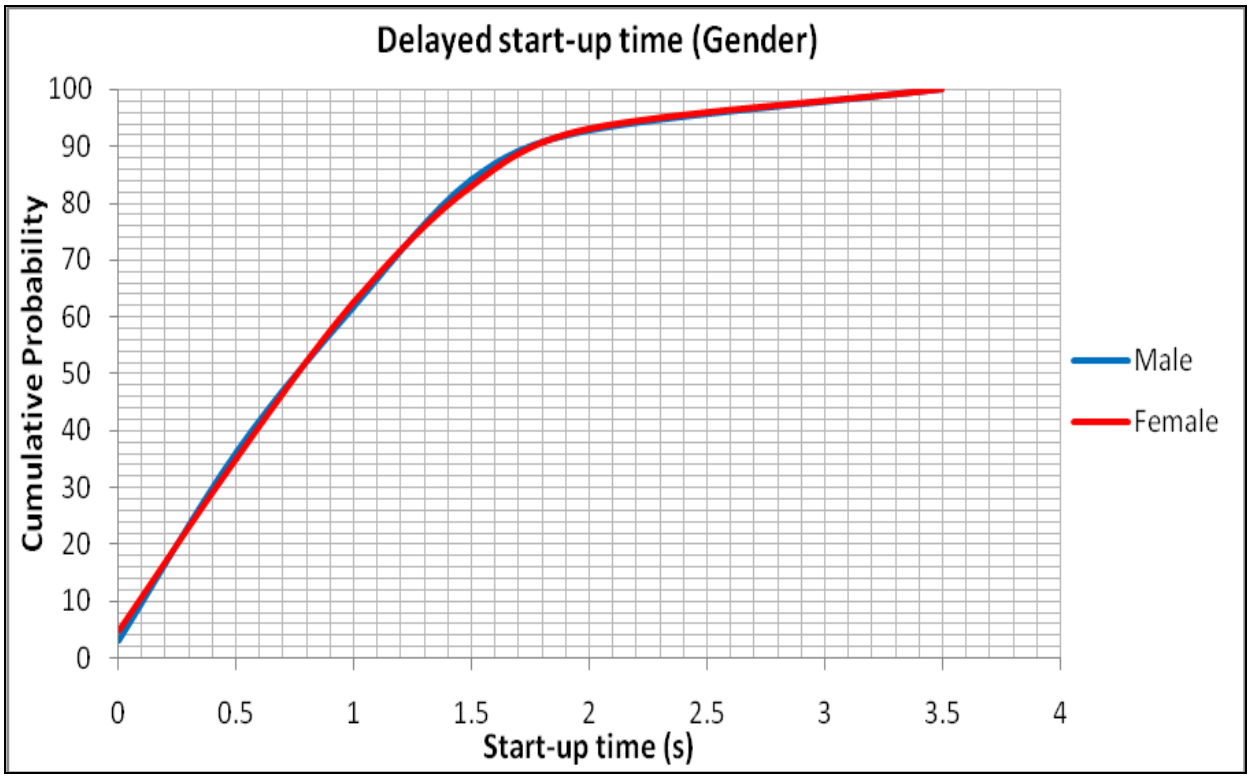

Figure A.4. Cumulative probability curves for delayed start-up time of male and female

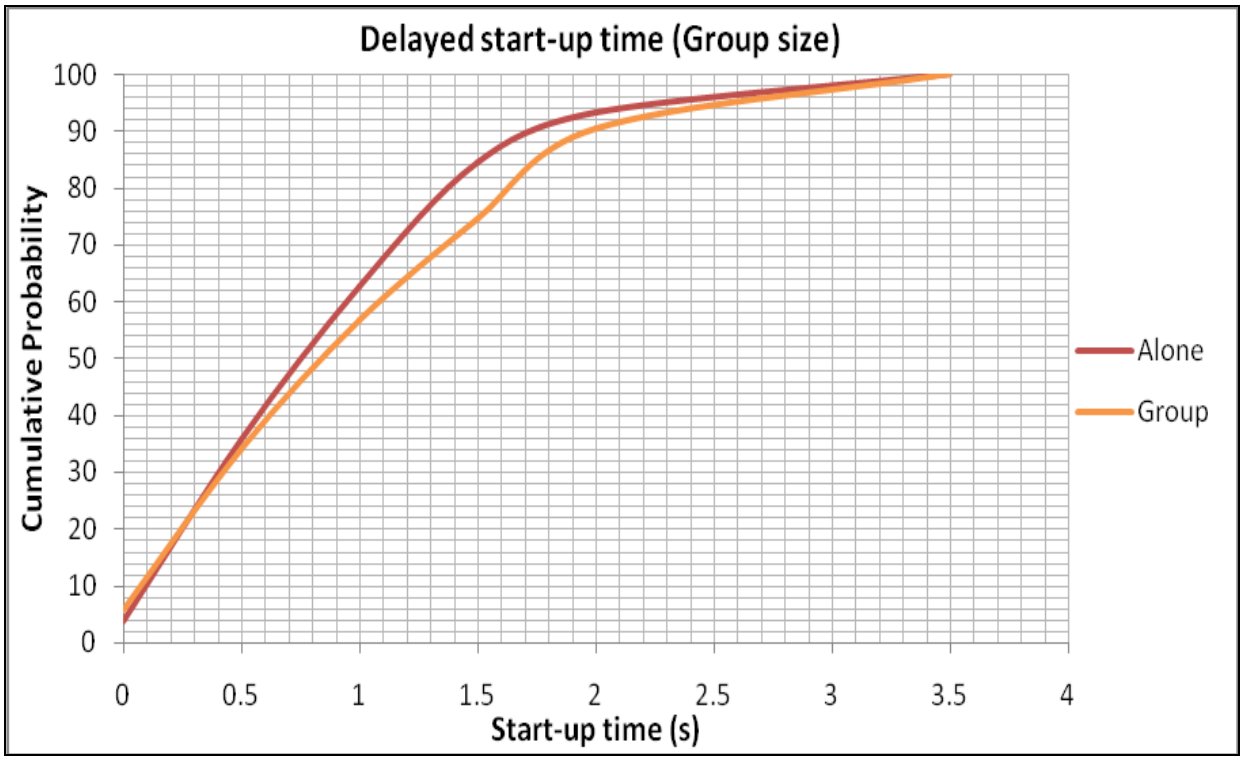

Figure A.5. Cumulative probability curves considering group size for delayed start-up time

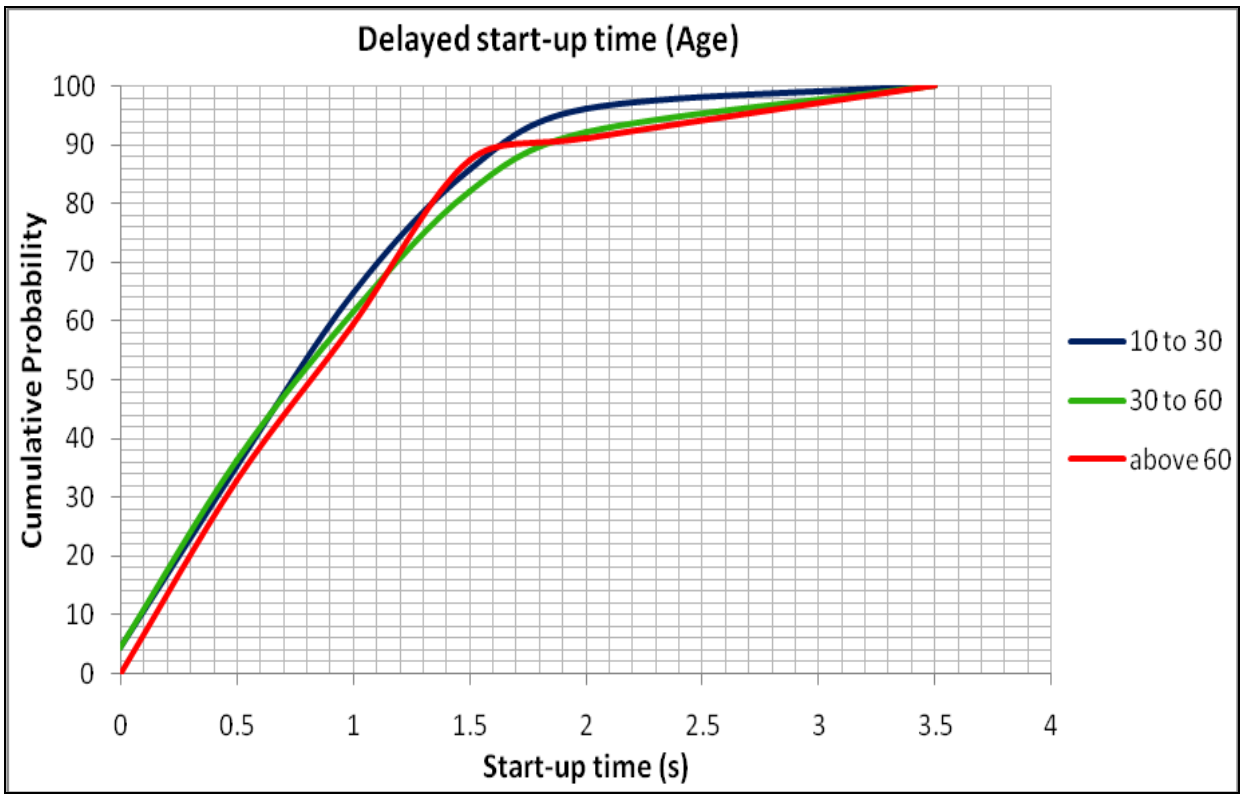

Figure A.6. Cumulative probability curves considering age groups for early start-up time