CHAPTER 6

EVIDENCE THEORY

This chapter has described the Evidence Theory and its basic structure. The complete detail of the ET for various applications with examples is done here. Its application for EV and its algorithm described here. The observations of the Hardware and its average results are tabulated in this chapter.

THEORY:

6.1 INTRODUCTION:

Artificial Intelligence (AI) is a new emerging popular innovative area of research. It has resulted in wide area in issues relating to the management of certainty, uncertainty and evidential problems. It is essential to make decision for future concern in AI method which may be relatively based on past or present concern. This decision making process needs the certainty and uncertainty on any matter to creates the possibilities. These possibilities for particular concern may be created from the proper evidence. This technique is used in multiple criteria decision preparing at the time when evidence theory is used to collect the information about the possible relation between the criteria. Ronald R. Yager and all say that the problem in which the selection of the best alternative from a set of possibilities is based upon its satisfaction to a collection of multiple criteria is preserve.

The theory of belief functions referred to as evidence theory or Dempster-Shafer Theory (DST). DST is a usual frame work for reasoning with uncertainty or certainty and understood connections to other frameworks of probability theory. Glenn Shafer [160] says "The Dempster-Shafer theory owes its name to work by A P Dempster (1968) and Glenn Shafer (1976), but the kind of reasoning the theory uses can be found as far back as the seventeenth century. The theory came to the attention of AI researchers in early 1980s, when they were trying to adapt probability theory to expert systems. Dempster-Shafer degrees of belief resemble the certainty factors and this resemblance suggested that they might combine the rigor of probability theory with the flexibility of rule based systems. Subsequent work has made clear that the management of uncertainty inherently requires more structure than is available in simple rule-based systems." DST remains attractive because of its relative flexibility. Dempster introduced it in the context of statistical inference. The theory was later developed by Shafer into a usual framework for modeling epistemic uncertainty-a mathematical theory of evidence. The theory allows one to combine evidence from diverse sources and bring at a degree of belief that takes in to account all the available evidence. The term DST refers to the original conception of the theory by Dempster and Shafer. However, it is more common to use the term in wider sense of same usual approach, as adapted to specific kinds of situations.

DST is based on two ideas:

1. The idea of gaining degrees of belief for one question from subjective probabilities for a related question, and

2. Dempster's rule for combining these degrees of belief when they are based on independent items of evidence.

To get the clarity about the degrees of belief, subjective probabilities for particular questions and evidence there are some practical examples explained based on it, which can focus on the theme of the DST ideas.

6.2 OVERVIEW OF DST

To illustrate the idea of obtaining degrees of belief for one question from subjective probabilities for another, suppose there are subjective probabilities for the reliability of a man named Atul. The probability for his reliability is 0.9, and his friend Mitul's probability that Atul is unreliable is 0.1. Suppose Atul tells Mitul a limb fell on Mitul's car. This statement, which must true if Atul is reliable, is not necessarily false if he is unreliable. So his testimony alone justifies a 0.9 degree of belief that a limb fell on Mitul's car, but only a zero degree of belief that no limb fell on car. This zero does not mean that Mitul is sure that no limb fell on his car, as a zero probability would; it means that Atul's testimony gives Mitul no reason to believe that no limb fell on Mitul's car. The 0.9 and the zero together constitute a belief function. To illustrate Dempster's rule for combining degrees of belief, suppose there is also a 0.9 subjective probability for the reliability of Ketul, and suppose he too testifies, independently of Atul, that a limb fell on Mitul's car. The event that Atul is reliable is independent of the event that Ketul is reliable, and after multiplication of the probabilities of these events; the probability that both are reliable is 0.9*0.9=0.81, the probability that neither is reliable is 0.1*0.1=0.01, and the probability that at least one is reliable is 1-0.01=0.99. Since they both said that a limb fell in Mitul's car, at least one of them being reliable implies that a limb did fall on car, and hence Mitul may assign this event a degree of belief of 0.99. [162]

Implementing the D-S Theory in a specific problem normally involves solving two related problems:-

► The uncertainties must be sorted in the problem into a priori independent items of evidence.

► Dumpster's rule must be carried out computationally.

Ɵ is that into independent items leads to a structure involving items of evidence that bear on diverse but related questions, and this structure can be used to make computations feasible. Suppose, for example Mina and Tina testify independency that they heard a burglar enter in a house. They might both have mistaken the noise of a dog for that of burglar, and because of this considered, then three independent items of evidence can be identified; Other evidence for or against the presence of dog, evidence for Mina's reliability and evidence for Tina's reliability. These items can be combined of evidence by Dumpster's rule and computations are facilitated by the structure that relates the diverse questions involved.

Shafer proved "The advantage of DST over previous techniques is its ability to mock-up the narrowing the premise set with the amassing of indication, a process that characterizes diagnostic reasoning in medicine and other expert reasoning in common. An expert uses evidence that, instead of demeanor on a single hypothesis in the original hypotheses set, often bears on a larger subset of this set."

6.3 METHODOLOGY BASED ON DST:

► Each fact has a degree of support between 0 and 1

0- no support for the fact

1-full support for the fact

► Differs from Bayesian approach in that

-belief in a fact and its negation need not sum to 1.

-Both values can be 0 (meaning no evidence for or against the fact)

► Set of possible conclusions: Θ= {$ϴ_1$, $ϴ_2$, ……, $ϴ_3$}

Where, Θ is the set of possible conclusion to be drawn

-Each ϴi is mutually exclusive: at most one has to be true.

- Θ is exhaustive: at least one ϴi has to be true [29, 30, 31]

6.3.1 FRAME OF DISPLACEMENT OR POWER SET

► Θ= {$ϴ_1$, $ϴ_2$, ……, $ϴ_3$}, Bayes was concerned with evidence that supported single conclusions e.g. Evidence for each outcome ϴi in P (ϴi/E). DST concerned with evidences which support subset of outcomes in {$ϴ_1$, $ϴ_2$, $ϴ_3$}. The frame of displacement of Θ is the set of all possible subset of Θ.

e.g. if: Θ = {1, 2, 3}, then the frame of displacement is:

(Ø, $ϴ_1$, $ϴ_2$, $ϴ_3$, {$ϴ_1$, $ϴ_2$}, {$ϴ_1$, $ϴ_3$}, {$ϴ_2$, $ϴ_3$}, {$ϴ_1$, $ϴ_2$, $ϴ_3$})

-Ø, the empty set, has a probability of 0, since one of the outcomes has to be true.

-Each of the other elements in the power set has probability between 0 and 1.

-The probability of {$ϴ_1$, $ϴ_2$, $ϴ_3$} is 1.0 since one has to be true.

6.3.2 MASS FUNCTION *m(A)*:

► A is member of the power set

○ It includes proportion of all the evidence that supports this element of power set

○ The mass function *m(A)* of a given member of the power set A, express the proportion of all relevant and available evidence that supports the claim that the actual state belongs to A but to no particular subset of A.

The value of *m(A)* pertains only to the set A and makes no additional claims about any subset of A, each of which has, by definition its own mass.

○ Each *m(A)* is between 0 and 1 and all *m(A)* sum to 1.

○ For interpretation of *m({A U B})*=0.3 means that there is evidence for {A U B} that cannot be divided among more specific beliefs for A or B.

[Refer Appendix A for more details.]

6.4 DEMPSTER'S RULE OF COMBINATION:

Dempster's Rule is "The best for combining the operators of the various independent sets of probability mass assignments in the specifically decided conditions. This rule concludes a common shared belief between multiple sources and neglects all the intersection of believes through a normalization factor. Use of that rule in other situations than that of combining belief constrains has come under serious criticism, such as in case of fusing separate beliefs estimates from several sources that are to be integrated in a collective manner, and not as constrains.[30] Cumulative fusion means that all probability masses from the diverse sources are reflected in the derived belief, so no probability mass is ignored specifically, the combination (called the joint mass) is calculated from the two sets of masses m_1 and m_2 in the following manner:

$$m_{1,2}(\emptyset) = 0$$

$$m_{1,2}(A) = (m_1 + m_2)(A) = 1/(1-K) + \sum_{B\cap C=A\neq\emptyset}^{\infty}[m_1(B)m_2(C)]$$

Where $K = \sum_{B\cap C=A\neq\emptyset}^{\infty}[m_1(B)m_2(C)]$

Where *K* is a measure of amount of conflict between the two mass sets."

6.5 BAYESIAN THEORY AS A SPECIAL CASE:

As in DST, a Bayesian belief function 2X [0, 1] has the properties bel(Ø) = 0 and

bel(X) = 1.

If then bel ( ) = bel (A) + bel (B)

Equivalently each of the following conditions defines the Bayesian special case of the DST.

► bel (A) + bel (A*) = 1, for all

For finite X, all focal elements of the belief function are singletons.

To understand practical use of DST, hereby the example, it can be understood easily:-

6.5.1 EXAMPLE 1 [166]

4 cells (B, J, S and K) of diverse ratings are situated in a room when the lights go out. When the lights come on, cell K is diffused Assume one is with the ratings which is used to improve the battery life.

ϴ= {B, J, S}

P (ϴ) = (Ø, {B}, {J}, {S}, {B, J}, {B, S}, {J, S}, {B, J, S})

Mass function m(A):

After reviewing the scene, observer assign mass probabilities to various elements of the power set:

Table 6. 1 Event and Mass Understanding

EVENT	MASS
No any cell	0.0
One of the 3 is used	0.1
either S or J is used	0.3
either B or S is used	0.1
either B or J is used	0.1
S is used	0.1
J is used	0.2
B is used	0.1

Belief in A

Bel(A) = m(q1) + m(q2) + m(q3) + m({q1, q2}) + m({q2, q3}) + m({q1, q3}) + m({q1, q2, q3})

Given the mass assignments as assigned by the observer:

bel({B}) = m({B}) = 0.1

bel({B,J}) = m({B})+m({J})+m({B,J}) =0.1+0.2+0.1=0.4

Result:

Table 6. 2 Mass and Belief Calculation

A	{B}	{J}	{S}	{B,J}	{B,S}	{J,S}	{B,J,S}
m(A)	0.1	0.2	0.1	0.1	0.1	0.3	0.1
bel(A)	0.1	0.2	0.1	0.4	0.3	0.6	1.0

Plausibility of A: pl(A)

pl({B,J}) = m(B) + m(J) + m(B,J) + m(B,S) + m(J,S) + m(B,J,S) = 0.9

Disbelief (or Doubt) in A: dis (A)

The disbelief in A is simply bel (¬A).

It is calculated by summing all masses of elements which do not intersect with A.

The plausibility of A is thus 1-dis (A):

pl (A) = 1- dis (A)

All results:

Table 6. 3 Results for diverse blocks.

A	{B}	{J}	{S}	{B,J}	{B,S}	{J,S}	{B,J,S}
m(A)	0.1	0.2	0.1	0.1	0.1	0.3	0.1
bel(A)	0.1	0.2	0.1	0.4	0.3	0.6	1.0
dis(A)	0.6	0.3	0.4	0.1	0.2	0.1	0
pl(A)	0.4	0.7	0.6	0.9	0.8	0.9	1.0

Belief interval of A:

The belief interval of {B, S} is: [0.1 0.8]

Battery life improvement in EVs by Dempster Shafer theory includes an interesting aspect. It involves the number of uncertainty and possibilities through which the direction of charge can be assumed and we get the idea about the flow of current. The direction of current can be assumed that how much current is going to the charging capacitor or cell and how much power is consumed, and wasted by a loss. The process wants evidence because our assumption is empirical.[163]

PRACTICAL WORK:

The reading of 100 Ah & 65Ah batteries charging & discharging voltage, current has been taken continuously for two months. There were 10 numbers of both the batteries. Readings has been taken from 1st September, 2014 to 31st October, 2014 (Appendix B) for 10-10 batteries of these two types. Readings for charging have been taken between 10.00 to 11.00 a.m. and for discharging it has been taken after 9.00 p.m. After charging process the readings for 100Ah lead acid battery have been noted about between 13V to 14V and for 65Ah Pb-acid battery it was average between 12V to 13.5V at about 31°C atmospheric temperature. After discharging the same for 100Ah it was average between 8.5V to 9.5 and for 65Ah it was average between 6V to 7V at about 28°C atmospheric temperature.

6.6 OBSERVATIONS – DATA COLLECTION :

Daily readings for two months are listed in APPENDIX B. According to the observed readings of necessary quantities the graphical representation is also shown for the correlation between two related quantities. The average readings for two months are shown in Fig. 6.1. This readings show the current stage of battery at the time when it is charged and at the time when it is discharged.

Table 6. 4 Observations for the Battery Charging

Months	Time	Temp (oC)	Ah	Voltage	Current (mA)	R (Ω)	Wh
September & October, 2014	10:00 a.m.	31	100	13.6	0.14	99	1360.26
	9:30 p.m.	27	100	9.42	0.01	99	942.27
	10:00 a.m.	31	65	13.1	0.13	100	851.69
	9:30 p.m.	27	65	6.92	0.05	137	450.076

6.7 MATHEMATICAL CALCULATIONS:

Dr. K. R. Kachot says Correlation methods are used to measure the ―association of two or more variables. Here two observations for each sampling unit are concerned. When a change in one variable is followed by a change in other variable, the two variables are said to be correlated with each other. In such away correlation is a statistical tool with the help of which the relationship between two variables is established.

After correlation between quantities stated in above section the equations are derived for the charging and discharging current as well as charging and discharging voltages for both 100Ah and 65Ah. The common equation for current & voltage in the form of I=a*V +b*R and

V=c*Wh +d*T respectively where I is charging/discharging current, V is charging/discharging voltage, R is resistant of battery, Wh and T are watt-hour and atmospheric temperature respectively and a, b, c & d are constants. The formulas AUTOSUM, AVERAGE, CORREL are used to solve the equations in Ms Excel.

A. Current

For 100Ah battery

I=13.6a+99b (charged), I=9.42a+97b (discharged)

For 65Ah battery

I=13.10a+100b (charged), I=6.92a+137b (discharged)

B. Voltage

For 100Ah battery

V=1359.261c+31d (charged), V=942.27c+28d (discharged)

For 65Ah battery

V=851.67c+31d (charged), V=450.076c+27d (discharged)

ERROR CALCULATION

For 100Ah battery

I=13.6a+99b (charged)

$$\therefore 0.14 = 13.6\,a + 99\,b$$

$$\therefore a = \frac{(0.14 * \; 10^{-3}) - \; 99\,b}{13.6}$$

and

I=9.42a+97b (discharged)

$$\therefore 0.05 = 9.42\,a + 97\,b$$

$$\therefore a = \frac{(0.05 * \; 10^{-3}) - \; 97\,b}{9.42}$$

Comparing both;

b= -1.65 * 10^{-6}

a = 0.022 * 10^{-3}

now

V=1359.261c+31d (charged)

$$\therefore 13.59 = 1359.261c + 31d$$

$$\therefore c = \frac{13.60 - 31d}{1359.261}$$

V=942.27c+28d (discharged)

$$\therefore 6.924 = 942.27c + 28d$$

$$\therefore c = \frac{6.924 - 28d}{942.27}$$

Comparing both we get

$$d = -0.384 \text{ and } c = 0.0187$$

For 65Ah battery

I=13.10a+100b (charged)

$$\therefore 0.13 = 13.10a + 100b$$

$$\therefore a = \frac{0.13 - 100b}{13.10}$$

and

I=6.92a+137b (discharged)

$$\therefore 0.05 = 6.92a + 137b$$

$$\therefore a = \frac{0.05 - 137b}{6.92}$$

Comparing both we get

$$b = -0.212 * 10^{-6} \text{ and } a = 0.0116 * 10^{-3}$$

now

V=851.67c+31d (charged)

$$\therefore 13.10 = 851.67c + 31d$$

$$\therefore c = \frac{13.10 - 31d}{851.67}$$

V=450.076c+27d (discharged)

$$\therefore 6.924 = 450.076c + 27d$$

$$\therefore c = \frac{6.924 - 27d}{450.076}$$

Comparing both we get

$$d = 0.033 * 10^{-3} \text{ and } c = 0.0153$$

After error calculation

C. Current

For 100Ah battery

I=0.005+13.6a+99bV (charged), I=0.053+9.42a+97b (discharged)

For 65Ah battery

I=0.001+13.10a+100b (charged), I=0.001+6.92a+137b (discharged)

D. Voltage

For 100Ah battery

V=0.074+1359.261c+31d (charged), V=2.56+942.27c+28d (discharged)

For 65Ah battery

V=0.07+851.67c+31d (charged), V=0.03+450.076c+27d (discharged) [166]

6.8 GRAPHS FOR CORRELATION

APPENDIX C-I shows diverse graphs for Correlation for 100Ah Pb-acid battery

100Ah Charging V-I graph, 100Ah charging V-Wh graph, 100Ah charging I-R graph, 100Ah charging V-T graph, 100Ah discharging I-V graph, 100Ah discharge V-Wh graph, 100Ah discharging I-R graph, 100Ah discharging V-T.

APPENDIX C-II shows diverse graphs for Correlation for 65Ah Pb-acid battery

65Ah Charging V-I graph, 65Ah charging V-Wh graph, 65Ah charging I-R graph, 65Ah charging V-T graph, 65Ah discharging I-V graph, 65Ah discharge V-Wh graph, 65Ah discharging I-R graph, 65Ah discharging V-T.

6.9 PROPOSED SCHEME OF HSS WITH DST PROGRAMMER

6.9.1 DST PROGRAMMER

DST programmer works on the bases of the probabilistic input and gives the effective results in charge management. There is one motor drive charge supply system block diagram is shown in figure which include the equipment like control circuit, dual inverter, rectifier, battery, supercapacitor and motor. Motor current I_b (+) is flowing according to the DST control signal. Battery voltage V_{ibe} produced is 60% of the total voltage. Motor rotation is Nm, rotate in clockwise direction. Torque Ʈ produces in the rotor.

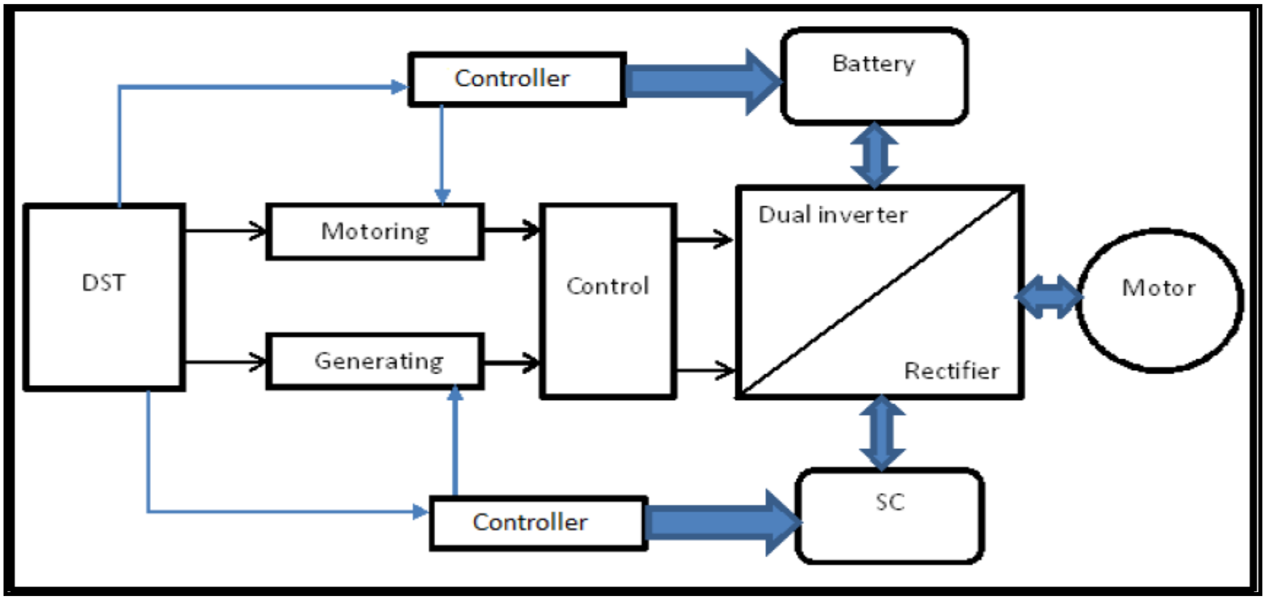

Fig. 6.1 Motor charge supply system (HSS) with DST programmer

The HSS includes the battery/supercapacitor and inverter rectifier to control the switching and make it more efficient compare to normal EV. The battery is used as source supply which supplies 12V to the inverter; the inverter fulfils the need of recharging the need of recharging the battery during the deceleration and produces 24V across 24 volt capacity SC.

The SC gets charged and provides the voltage to the motor pin parallel. During the deceleration while the downhill motion the SC gets recharged highly and in the condition when battery voltage decreases, it charges up the battery.

6.9.2 BATTERY FOR ELECTRICAL VEHICLE

The source voltage of 12V can be supplied by following types of batteries. Table shows the diverse types and application of the battery.

Table 6. 5 Battery Types and Applications

Rechargeable	Voltage	Applications
Rechargeable Alkaline	1.5	MP3 players, toys, electronic games, camera, solar lightening
Ni – Cd	1.2	Power Tools
Ni – MH	1.2	Digital Camera, Toy cars
Lead Acid	12	Car Starter Battery, Golf Car, Marine, UPS, Standby Power, Lift Trucks, Solar Lightening
Li – Ion	3.6 – 3.7	Note Book, Computers, PDAs, Mobile Phones, Digital Cameras

6.9.3 SUPERCAPACITOR DETAILS

The SCs are available with diverse values and in modules, following data for SCs;

Table 6. 6 Supercapacitors Available in the Market

Manufacturer	Capacitance – Voltage Rating	ESR Rating
Power Star China Make (Single Unit)	50 F/ 2.7 V, 300 F/2.7 V, 600 F/ 2.7 V	Less than 1 mΩ
Panasonic Make (Single Unit)	0.022-70 F/2.1 – 5.5 V,	200 mΩ – 350 mΩ
Maxwell Make (Module)	63 F/125 V, 94 F/75 V	18 mΩ, 15 mΩ
Vinatech Make (Single Unit)	10 – 600 F/2.3 V 3 – 350 F/ 2.7 V	400 – 20 mΩ 90 – 8 mΩ
Nasscap Make (module)	33 F/ 15 V 51 F/ 340 V	27 mΩ 19 mΩ

6.9.4 SELECTION OF MOTOR FOR ELECTRIC VEHICLE

It is an important part to select the motor for electrical vehicle design. The motor and its characteristics plays a vital role for the energy saving concept of EVs. The decision for the selection of the motor type, motor drive system, battery, other energy system and its interfacing for power control system for the vehicle propulsion system is based on the specifications the vehicle. The need of vehicle and its performance characteristics plays requisite role in choosing the parameters; the method of starting and the overall weight and volume of the system, location of the system, average – torque, speed and distance of route, a peak power and energy density. The basic requirement of the motor for the HEV drive train is:

- High starting torque, running torque for climbing and also for maximum power.
- High efficiency over the minimum and maximum speed range at constant power characteristics
- Larger speed range in both constant power and torque region.
- Immediate torque rise.
- Possibilities of regenerative braking with excellent efficiency.
- Least weight.
- High reliability and robustness for operating conditions
- Affordable initial as well as running cost.

With respect to the speed and torque characteristics, the motors selected for hybrid vehicles are the same as those used for other industrial applications with some minor modifications where the motors are directly used as the hub of the wheel. The motor can be coupled with axle using specific mechanical technique. Usually BLDC motors are used as the hub motors. In hybrid electric drive, the rate of change of torque is large and much accurate because of electric motors.

6.9.5 WORKING OF DST PROGRAMMER

DST programmer has two signal modes they are motoring and generating. The codes (+1, -1, 0) generated when the changes are detected in the above stated quantities. There are three variations dN_m/dt, dI_b/dt and dƮ/dt according to the time has these three codes and dƮ/dt has two codes 1(for large torque) and 0 (otherwise).

This coding generated according to four functions as the function format f (dN_m/dt, dI_b/dt, dƮ/dt) are shown further :

A. f (dN_m/dt, dI_b/dt, dƮ/dt) = f (+1, +1, 0): In this stage the operation motoring performed. Here the supply current is flowing through the battery.

B. f (dN_m/dt, dI_b/dt, $d\tau/dt$) = f (+1, +1, 1): Here also the operation motoring performed but the supply current flows through the supercapacitor.

C. f (dN_m/dt, dI_b/dt, $d\tau/dt$) = f (-1, -1, 0): In this mode the operation regenerating performed. Here the supply current flows through the supercapacitor.

D. f (dN_m/dt, dI_b/dt, $d\tau/dt$) = f (-1, -1, 1): Here the generation performed. The supply current flows through supercapacitor.

The flowchart for the various modes of DST programmer is shown in Fig. 6.18.

6.9.6 FLOW CHART

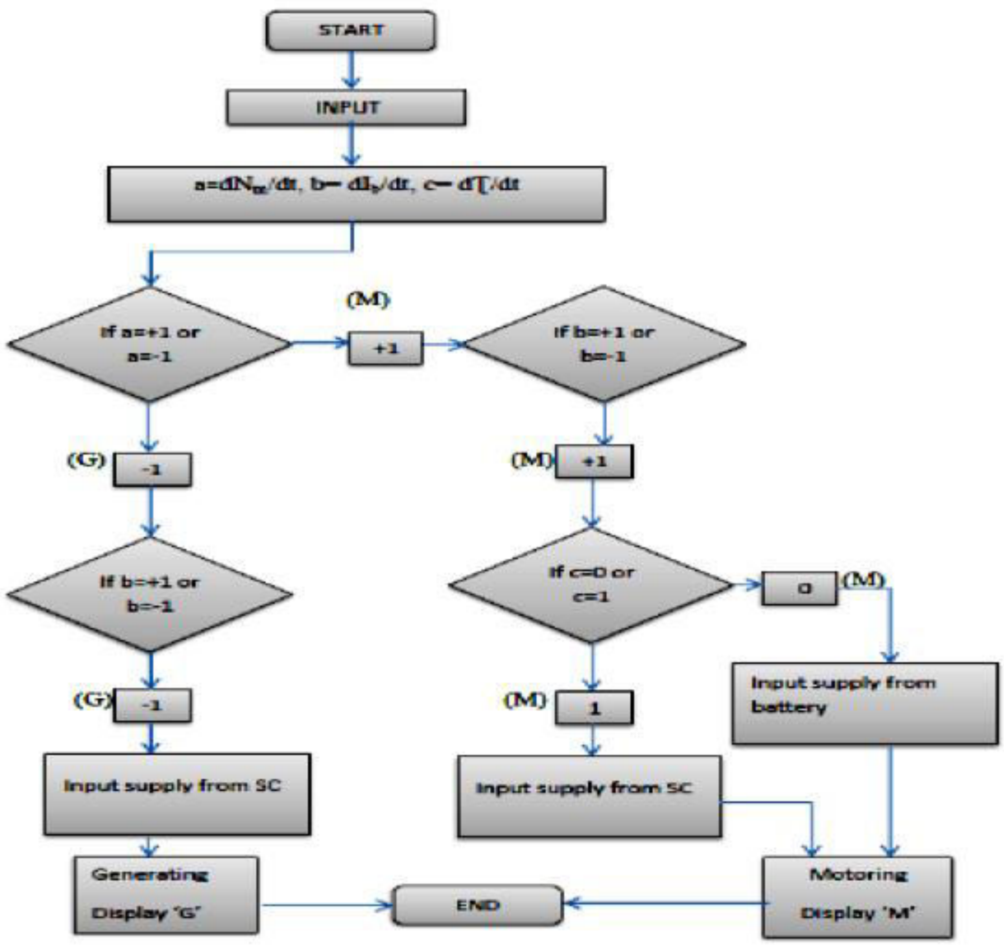

Fig.6.2 Flow Chart of Charge Management process by DST Programmer

6.10 FACTORS CONSIDERED FOR DST PROGRAMMER

6.10.1 Number of standard cycles

Driving cycle represents the graph of the speed with time duration of rotation of vehicle motor. It shows the speed of the vehicle. On the basis of the speed the programmer is set. There are mainly four types of standard cycles:

1. UDC (Urban Driving Cycle)

2. SUDR (Sub Urban Driving cycle)

3. RDC (Road Driving Cycle)

4. EWDC (Express Way Driving cycle)

The trips analysis has allowed to set-up a typology into above stated classes, through the analysis of their composition in the various driving. This classification of the cycles makes possible to analyze and group the driving conditions occurring during each of the trip category. The high differences in the driving conditions between these trips categories justify fully the need to get diverse driving cycles to characterize these conditions. It is then possible to derive driving cycles (i.e. urban, rural and motorway) corresponding to this structure. For each of these test cycles, charge supplied should be sampled from the battery or supercapacitor, so that consumption measurement over one cycle represents one consumption factor. Standard driving cycles shows the graphical representation of vehicle speed versus the time duration. In the initial time period the acceleration is performed so that the time 0 to t_1 shows the accelerating time. Then time t_1 to t_2 represent the constant time when the graph fall down represent the deceleration time.

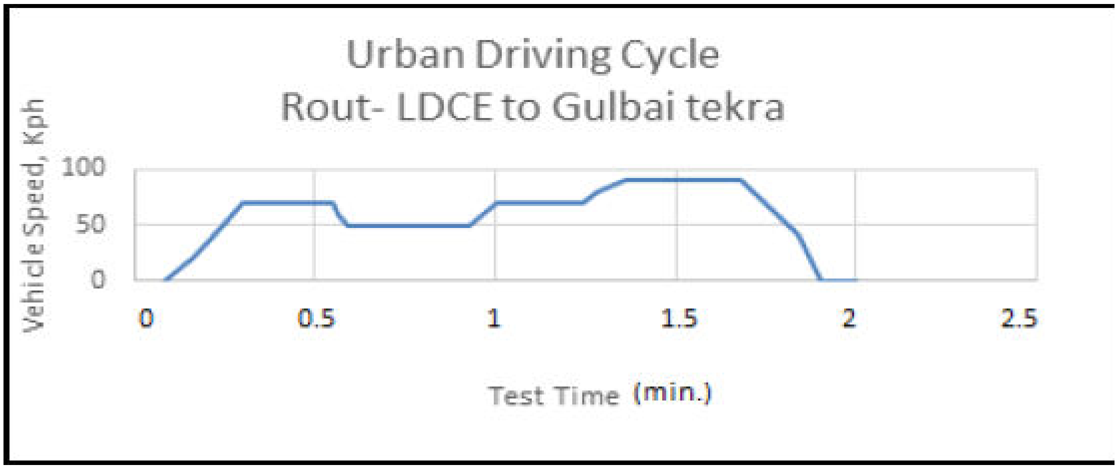

Fig. 6.3 Standard driving cycle

According to the path of the vehicle the driving cycle are concerned for the particular vehicle. The driving cycle for diverse types of path which include the traffic volume is diverse so that the evidence for speed of motor can be taken from the type of the paths.

The City Suburban Cycle (CSC) is a chassis dynamometer test for heavy-duty vehicles. The CSC is also abbreviated as CSHVC (City Suburban Heavy Vehicle Cycle). The test is also available in a ―route‖ version—the City Suburban Heavy Vehicle Route (CSHVR)—where the vehicle speed is given as a function of travelled distance, rather than time. Vehicle speed over the duration for the CSC of the vehicle is shown in Fig. 6.20.

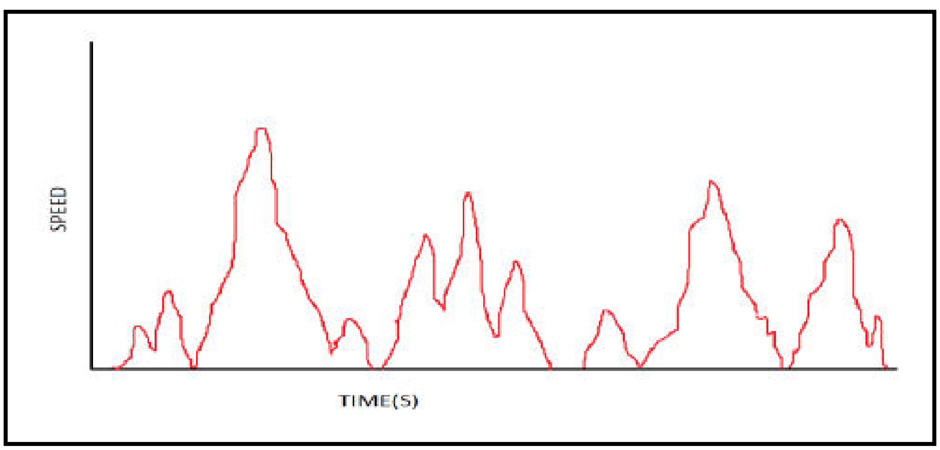

Fig. 6.4 City suburban cycle

6.10.2 Driver mentality

This concern creates two various paths that are

1. Habitually (normal)

2. Fixed path

Driver has its own path to reach at any destiny. Driver can create his path according to which the driver habituated and can make the path according to the experience with which driver is habituated and another mode is based on fix path in which the driver have to drive the vehicle in such a way that acceleration or braking performed on the predefined points. e.g. BRTS transports system in big cities so that the probability for charge management in battery and supercapacitor is based on these two methods.

6.10.3 Based on history or routine time

The past data of the driving cycles for the vehicles are saved in the system. The history of the data like consumed battery voltage, current, power, energy density, power density, route kilometers, route time, accelerating and braking distances etc. are saved. These data can be observed from the history of the vehicle parameter reading. DST programmer takes such data as evidence and creates the probability for further process.

Routine time is based on the fixed path of the vehicle. In the mega cities the BRTS system has the fixed path in the daily routine time in the sense that it is fixed that every day the bus will be on the particular point or station on the particular time so that the programmer has the probability about the particular place of the vehicle at any particular time.

The automotive industry consist of five segments; multi-utility vehicles and passenger cars, two wheelers, three wheelers, and tractors. The two-wheeler sales have got a spectacular growth since the mid-nineties. India is the second largest producer and manufacturer in the whole world. Indian two wheeler industry has got wide growth in last few years.

Two wheelers are useful for the transport mode for lower distance. The market of two-wheeler is in growth because of its lower running cost, rapid urbanization, lack of public transportation and the rising population growth. In India the two wheeler market was estimated at 56 million units in 2010. The most popular market segment is for small urban commuter vehicle is with petrol engine < 125cc. Three wheelers are less common worldwide than two wheelers, but may provide an important transport service to people without access to a private vehicle or public transport. India has the largest market in the whole world with annual sales around 0.5 million.

6.10.4 TWO WHEELER

Due to the low cost and reduced recharging periods, electric bikes and scooters gives niche application for promoting cleaner vehicle technology. Some manufacturer details are shown in Table 6.7.

Table 6. 7 Two Wheelers Available in Market

2 Wheeler	CURB WEIGHT	Traction MOTOR	BATTERY	Economy	BATT. WEIGHT	TOP SPEED	RANGE	PAYLOAD
TYPE	kg	TYPE	TYPE	Wh/Km	kg	Km/Hr	Km	kg
EVT	127	DC	L.A.	37	60	48	65	150
EGO	54	AC	L.A.	22	32	37	40	112

6.10.5 SMALL CARS

Due to high vehicle cost and lack of public refusing infrastructure, the small cars, regarded as private cars, have also economic obstacles. In the scheme of rental vehicles they can be depot-based, which simplifies maintenance and reduce costs of refueling. Two commercially available examples are shown in Table 6.8..

Table 6. 8 Car Available in Market

4 Wheeler (CAR)	CURB WEIGHT	Traction MOTOR	BATTERY	Economy	BATT. WEIGHT	TOP SPEED	RANGE	PAYLOAD
TYPE	kg	TYPE	TYPE	Wh/Km	Kg	Km/Hr	Km	kg
ZYTES Smart	848	BLDC	ZEBRA	106	210	100	100	140
THINK	940	AC	NiCd	135	250	90	85	205

6.10.6 CITIVANS

In urban area, City vans utilized as vehicles, delivery couriers in postal organizations, local taxis and light duty vans are ideal for demanding applications. Small electric citivans like Berlingo have proved good performance for payloads up to 500kg. Table 6.9 shows the example of light and medium duty electric vehicles with specifications

Table 6. 9 Citivans Specifications

4 Wheeler (VAN)	CURB WEIGHT	Traction MOTOR	BATTERY	Economy	BATT. WEIGHT	TOP SPEED	RANGE	PAYLOAD
TYPE	kg	TYPE	TYPE	Wh/Km	kg	Km/Hr	Km	kg
BERLINGO	1950	DC	NiCd	0.25-0.55	345	90	80	500
SPRINT	4000	AC	ZEBRA	0.88	630	90	90	1500

6.10.7 ELECTRIC BUSES

Public urban transport can offer as many advantages for demonstrating of new technologies as buses. They run on short and regular rout. They have limited availability of supporting infrastructure for recharging, retail supply and maintenance but that is not a barrier. Public ownership often facilitates the payment of a cost premium in return for a batter environment in the city.

6.11 TYPES OF SERVICES

H. Partab [167] mentions that there are mainly three types of services which traction system has to cater namely urban, sub urban and main line services. In urban and sub urban service the distances between the stops are small. Fast speed schedule can only be achieved with high acceleration and backing. This made possible by use of equipment developing high tractive effort. Fast speed schedule enables more train to run on a heavily loaded rout or alternatively a given traffic can be handled in less number of hours. Characteristics of each type of services are given in table Table 6.10 Characteristics of passenger services

Table 6. 10 Characteristics of Passenger Services

Parameter	Urban Service	Sub urban service	Main line Service
Acceleration	1.5 – 4 kmph	1.5 – 4 kmph	0.6 – 0. 8 kmph
Retardation	3 – 4 kmph	3 – 4 kmph	1.5 kmph
Maximum Speed	120 kmph	120 kmph	160 kmph
Distance between stations	1 km	2.5 – 3.5 km	More than 10 km
Remark	Free running period is absent and costing is small	Free running period is absent and costing is long	Long free running as well as costing periods. Acceleration and Braking small.

6.11.1 SPEED-TIME CURVE

It is the curve showing instantaneous speed of train in kilometers per hour along ordinate and time in seconds along abscissa. Area between the curve and abscissa give the distance travelled during given time interval. Slop at any point on the curve towards abscissa given the acceleration or retardation at that instant.

Typical speed-time curve of a train running on main line is shown in Fig. 6.21.

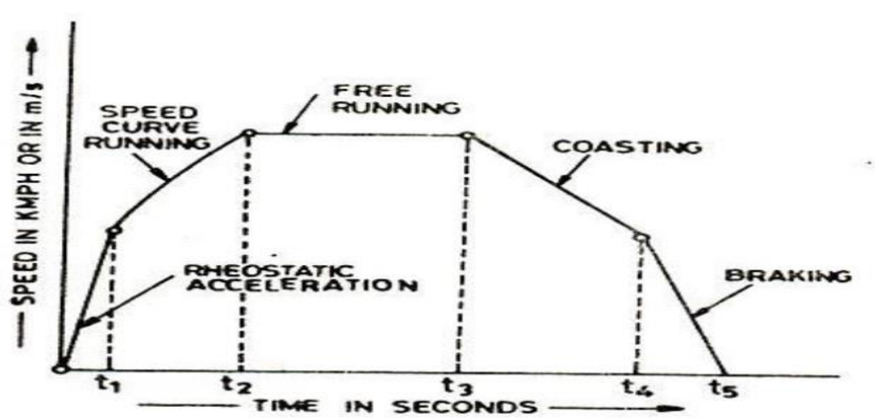

Fig.6. 5 Speed-time curve

(a) Notching up period (0 to t_1)

During this period of run, starting resistance is gradually cut so that motor current is limited to certain value. To cut the starting resistance, handle has to be moved from one notch to another. Tractive effort is defined as the force in Newton exerted by driving wheel to produce the movement. Sum of the tractive effort which is proportional to the combined torque exerted by the motors.

Motor current, during notching up period, fluctuates between certain maximum and minimum limits therefore torque developed by motor and tractive effort also fluctuate since average tractive effort during notching up period remain same and there is no appreciable rise in the train resistance, acceleration remains constant. Speed time curve therefore is a straight line.

(b) Acceleration on speed curve (t_1 to t_2)

When the starting resistance has been cut out, tractive effort exerted by the motor is more than the train resistance. The difference of the two is responsible for further acceleration. We should, however, mark one difference between the acceleration which decreases with speed during period (t_1 to t_2).

(c) Free running period (t_2 to t_3)

During this period train runs at constant speed attained at the end of speed curve running.

(d) Coasting period (t_3 to t_4)

At the end of free running period, supply to motor is cut off and train is allowed to run under its own momentum. Due to train resistance, speed of train gradually decreases.[167]

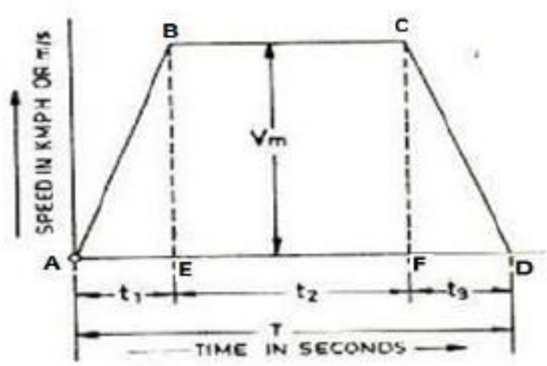

Fig. 6.6 Simplified speed time curve

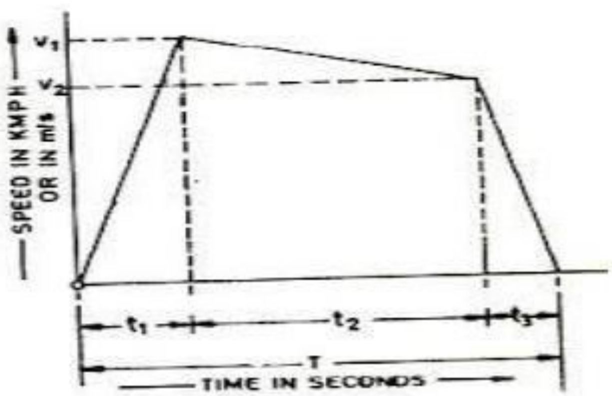

Fig. 6.7 Quadrilateral speed time curve

6.11.2 AVERAGE SPEED AND SCHEDULE SPEED

○ Average speed= Distance between the stops/Actual time of run

○ Schedule speed= Distance between the stops/ (Actual time of run + stop time)

6.11.3 TRACTIVE EFFORT

It is the force developed by the traction unit at the wheel rims for moving the traction unit and its train. Tractive effort exerted by the traction unit has to perform the following functions:

○ To give necessary linear and angular acceleration to the train mass

○ To overcome the gravity component of the weight of the train

○ To overcome the wind and friction resistance of the train

○ To overcome curve resistance

6.11.4 SPECIFIC ENERGY CONSUMPTION

It is the ratio of Specific energy output at driving wheels to Overall efficiency of transmission gear and motor.

6.11.4.1 Factors affecting specific energy consumption

(a) Distance between stops

Greater the distance between two stops, less will be the specific energy consumption.

For suburban service the specific energy consumption is 50 to 75 Wh per ton km

(b) Retardation and acceleration values

Greater the value of acceleration, the specific energy consumption will be less

(c) Gradient

Steep gradient will naturally involve more energy consumption

(d) Train resistance

(e) Type of train equipment

6.12 SPACE MANAGEMENT FOR BATTERY AND SUPERCAPACITORS IN E-BUS

The transportation system for human being for intercity is very comfortable and easy going through the public transport like BRTS. Nowadays BRTS is becoming the most effective medium for public transportation in megacities. It has very advantageous concept for local city public and also for the people from nearby the city in the manner that it is fully passenger oriented scheme with less time consumption and high speed transportation system. It has separate path between two stations.

The conventional buses are running through internal combustion engine, but nowadays the research is motivated by the premise that the hybrid storage system (HSS) represents an economical and technical feasibility option for automobile and transportation systems. Designing an E-bus is dependent upon the energy source that provides power for all of the electrical loads. The energy source needs to have suitable storage to meet the demands that the vehicle may encounter under each and every conditions. EVs have been in existence since the introduction of the automobile (1972), nowadays much research has been under taken on technologies like E-bus for future vehicles. This would encourage opportunities to create public transportation vehicles as it is required today. At present, Electrical vehicle, Electro chemical batteries, Super capacitors and flywheels are energy storing when regeneration braking, as we have studied that supercapacitors are high power density and low energy density and Batteries are having very low power density and high energy density compared to the super capacitors.

Space management for batteries and supercapacitor plays a important role in the improvement of the efficiency of hybrid electric bus. The weight of the battery-bank and supper capacitor-bank is calculated and involved in the total weight of the bus. The separate weight of each and every part of bus-body can be calculated and that after the centre of gravity can be evaluated for the bus. But practically it is very difficult or time consuming to carry out the weight of each and every part so that the weight of highly affected parts like chairs, engine, electrical system, chases, axle, braking system, wheels etc. can be noted and the centre of gravity be evaluated.

According to the point of centre of gravity the batteries and supercapacitors are arranged in the manner that the total weight of the electrical bus can be balanced and more efficient for transportation in constrain of passengers. Fig. 6.24 shows the basic lay out of the dimensions of electric bus.

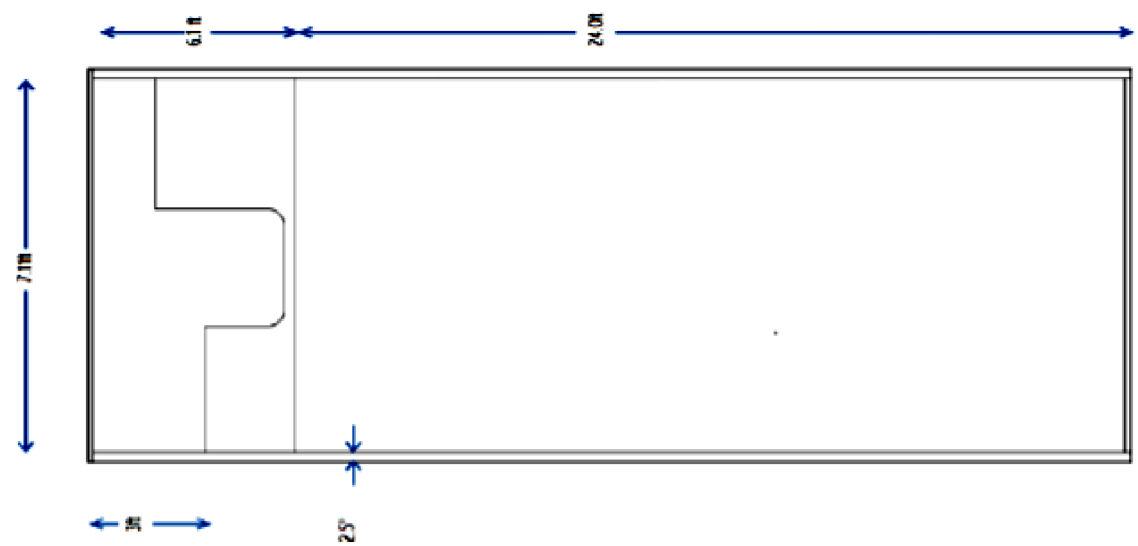

Fig. 6.8 Top view of BRTS bus

Some important specifications like window area, door area, glass area etc. are considerable to find the centre of gravity of the bus body. The detailed measurements are stated as below:

1. Size of the windows

Biggest window = (4.9*3.4) ft.

Medium window = (3.7*3.4) ft.

Small window = (2.8*3.4) ft.

Smallest window = (1.4*3.4) ft.

Ceiling window = (3.3*1.9) ft.

2. Door area = (4*6.2) ft.

Front door = (3.11*6.6) ft.

3. Back side glass = (7*2.7) ft.

4. No. of seats = 34+1

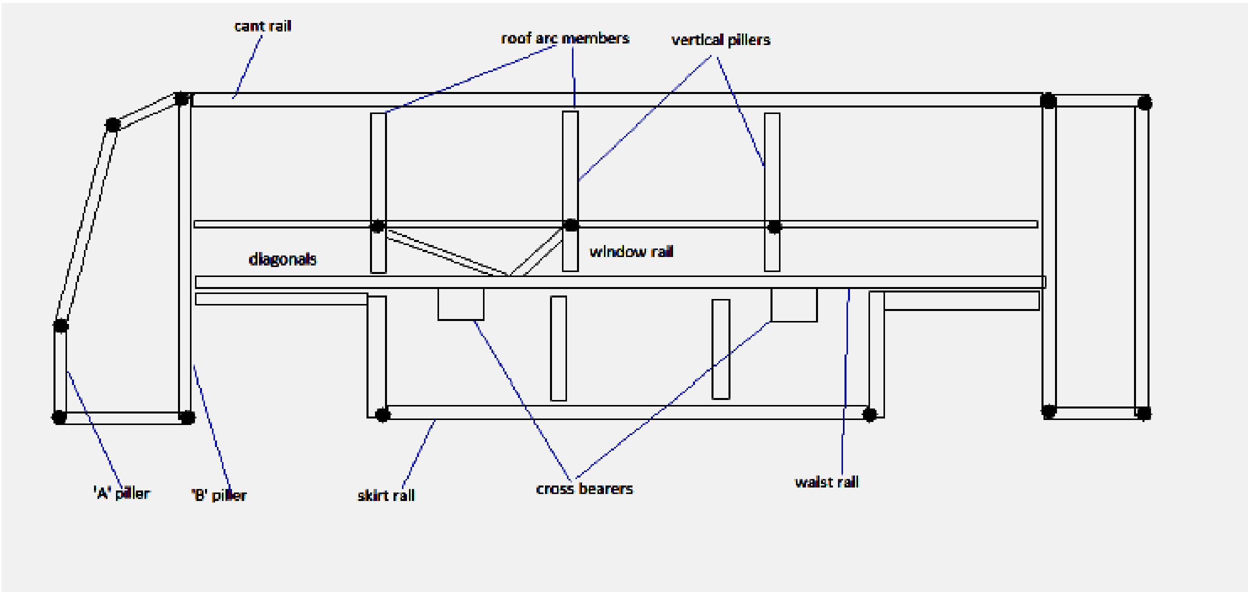

Fig. 6.9 Bus structure- nomenclatures

Fig. 6.25 shows the nomenclature for the bus body structure. It can be conclude from figure that the comfortable space for the battery and supercapacitor is in the clearance between the waist rail and skirt rail according to the centre of gravity.

6.13 BRTS BUS SURVEY

According to the survey of BRTS Jan-marg bus currently running in Ahmedabad city, there are some specifications and data regarding to its cost has been referred for any public passenger vehicle it is most important to minimize the cost because of acceleration. It is widely beneficial for both the government and passengers. These are the conventional buses like diesel engine and CNG buses.

Factor that affect the overall efficiency, cost, time, distance and area of the bus are listed in the Table 6.11.

Table 6. 11 Data of BRTS Bus Specifications

Property	Bus Type A	Bus Type B
Weight of Bus (With A. C.)	16 Ton	15 Ton
Weight of Bus (Without A. C.)	14 Ton	13 Ton
Engine Capacity in cc/hp	210	167
Minimum Halt at Bus Stop	20 Secs.	
Distance to be covered in a day by a bus	235 km.	
Time to cover between two stops	2.30 min.	
Floor Foot Area in Bus	275.18 Square Feet	
Ceiling Area	255.42 Square Feet	
Rear Area	31.34 Square Feet	
Passenger Capacity in Weight	3300 kg	
Minimum Axle Clearance	190 mm	
Wheel Area Clearance	220 mm	
Minimum Ground Clearance	270 mm	

[1.Nehru nagar-2.LDCE-3.CGRoad-4.Law garden-5.Gadhigram-6.Ellis bridge-7.Dana pith-8.Astodia-9.Gitamandir]

Fig. 6.10 BRTS route of study

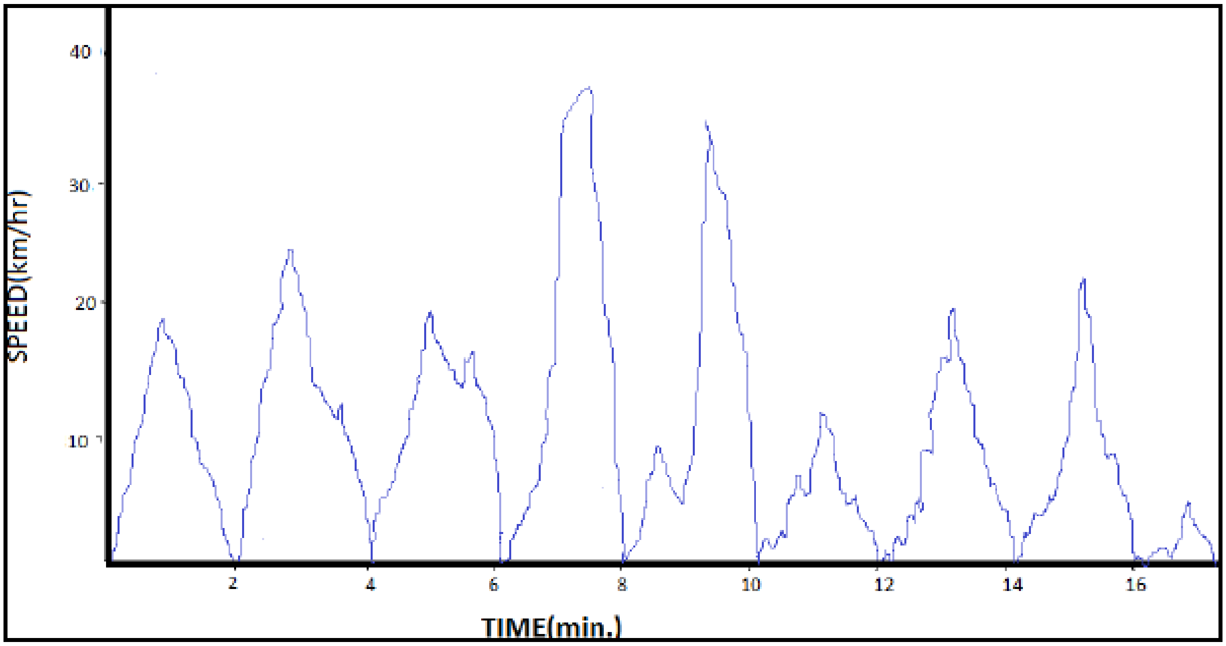

Fig. 6.11 Driving cycles for the BRTS rout path

As shown in table bus takes approximately 2 minutes between two stops, Fig. 6.27 shows the driving cycle of the bus which indicates the speed-time curve between two stations.

If the conventional buses like diesel bus and CNG bus are converted in the electric bus the fuel storage parts will be replaced by the electrical charge storage devices. The fuel tank and gas cylinders are replaced by the battery supercapacitor configurations. Table. 6.12 is the list of usually running conventional buses.

Table 6. 12 Conventional Urban Bus – Weight

TYPE OF BUS	Weight (kg)	
	Chasis + Body {With Full Diesel Tank / CNG Cylinder}	**Chasis + Body {Without Full Diesel Tank / CNG Cylinder}**
TATA (SUPER)	8320	8130
TATA (SEMI)	8660	8495
LEYLAND (SUPER)	8190	8000
LEYLAND (SEMI)	8435	8260
12 CNG CYLINDER F MADE	8240	8108

Table 6. 13 Weight of Buses after Replacement by HSS

TYPE OF BUS	Weight of Bus with HSS (kg)	Weight of Engine (kg)
TATA (SUPER)	8526	450
TATA (SEMI)	8891	413
LEYLAND (SUPER)	8396	450
LEYLAND (SEMI)	8656	413
12 CNG CYLINDER F MADE	8504	413

Table 6.13 shows the weight of buses after replacement the conventional parts by HSS. The weight of battery has been counted 255kg and the weight of SC has been counted as 141kg so that the total weight of HSS is measured 396kg.

6.14 CENTRE OF GRAVITY (CG)

It is the most considerable factor for any vehicle to balance the whole body structure of the vehicle. To prepare the model of E-bus the centre of gravity of the conventional buses has been found out in AUTOCAD software. It can be seen in the Fig. 6.12 – 6. 14.

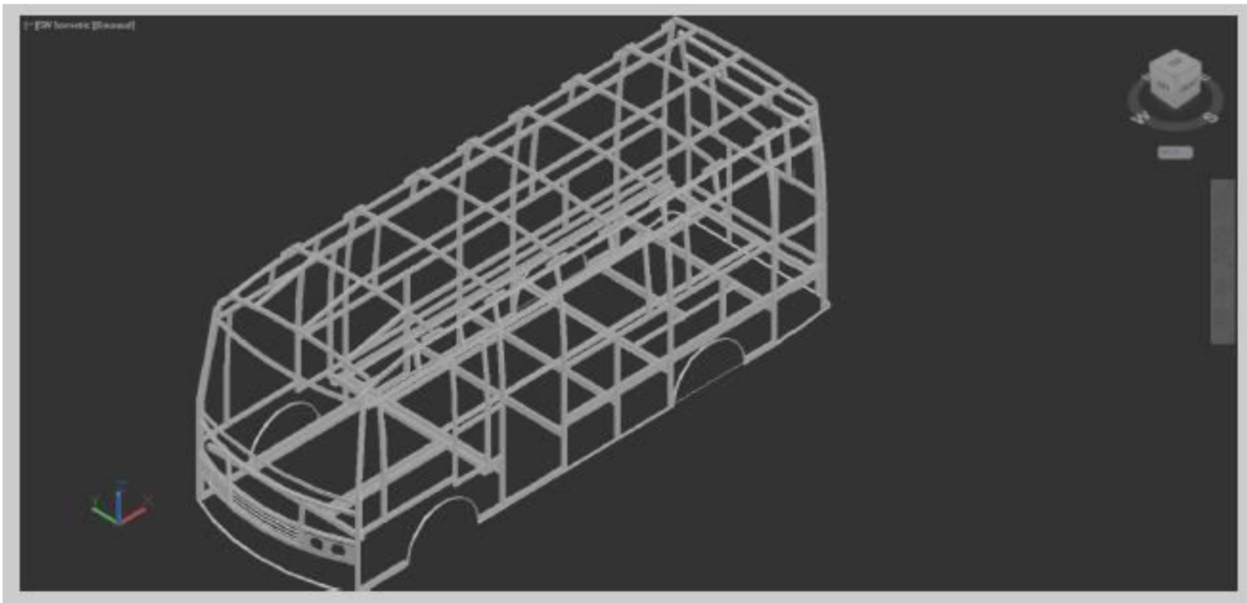

Fig. 6.12 3-D model of city bus with (chasis + body) by AutoCAD

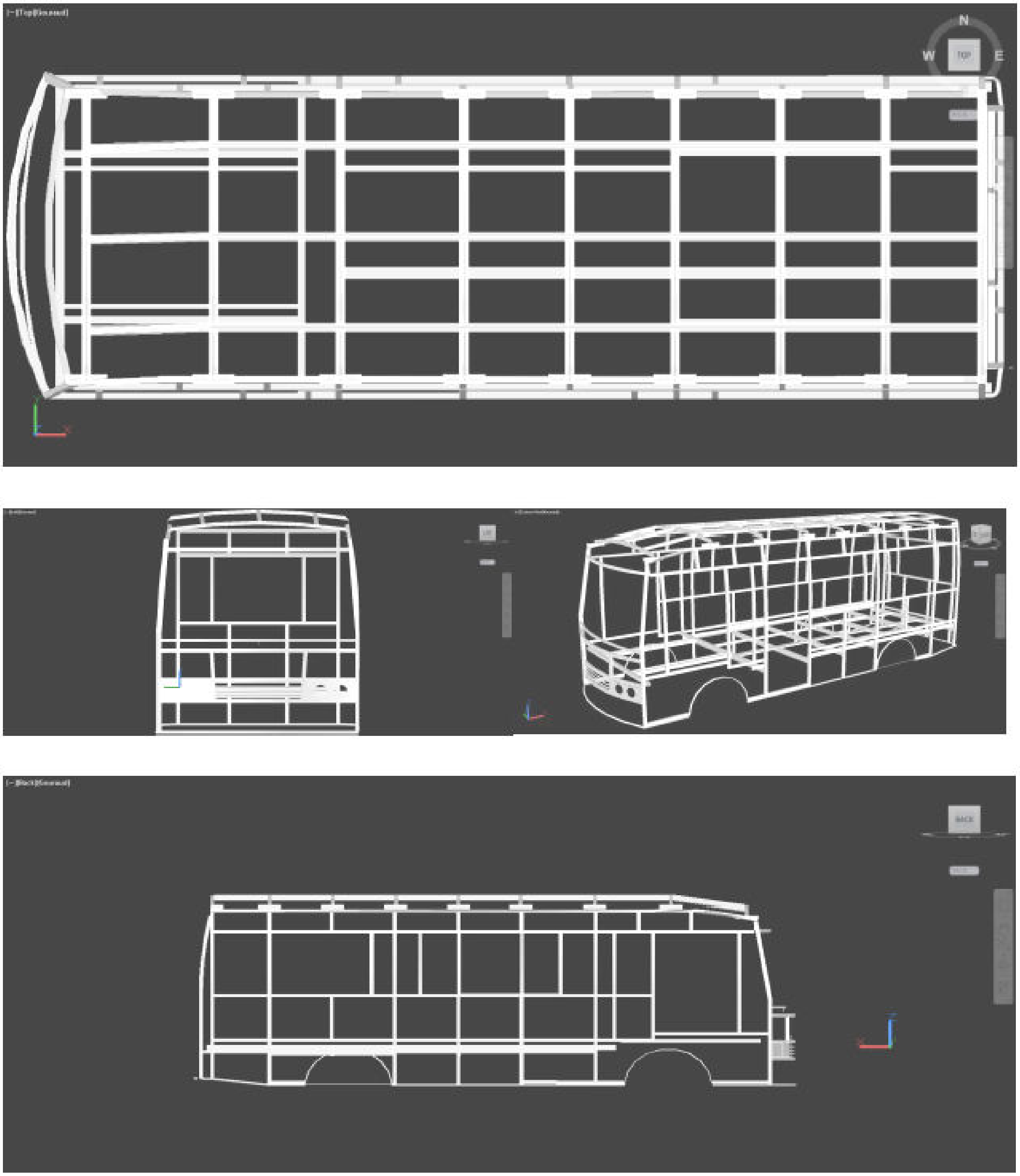

Fig. 6.13 Diverse views of 3-D model of city bus

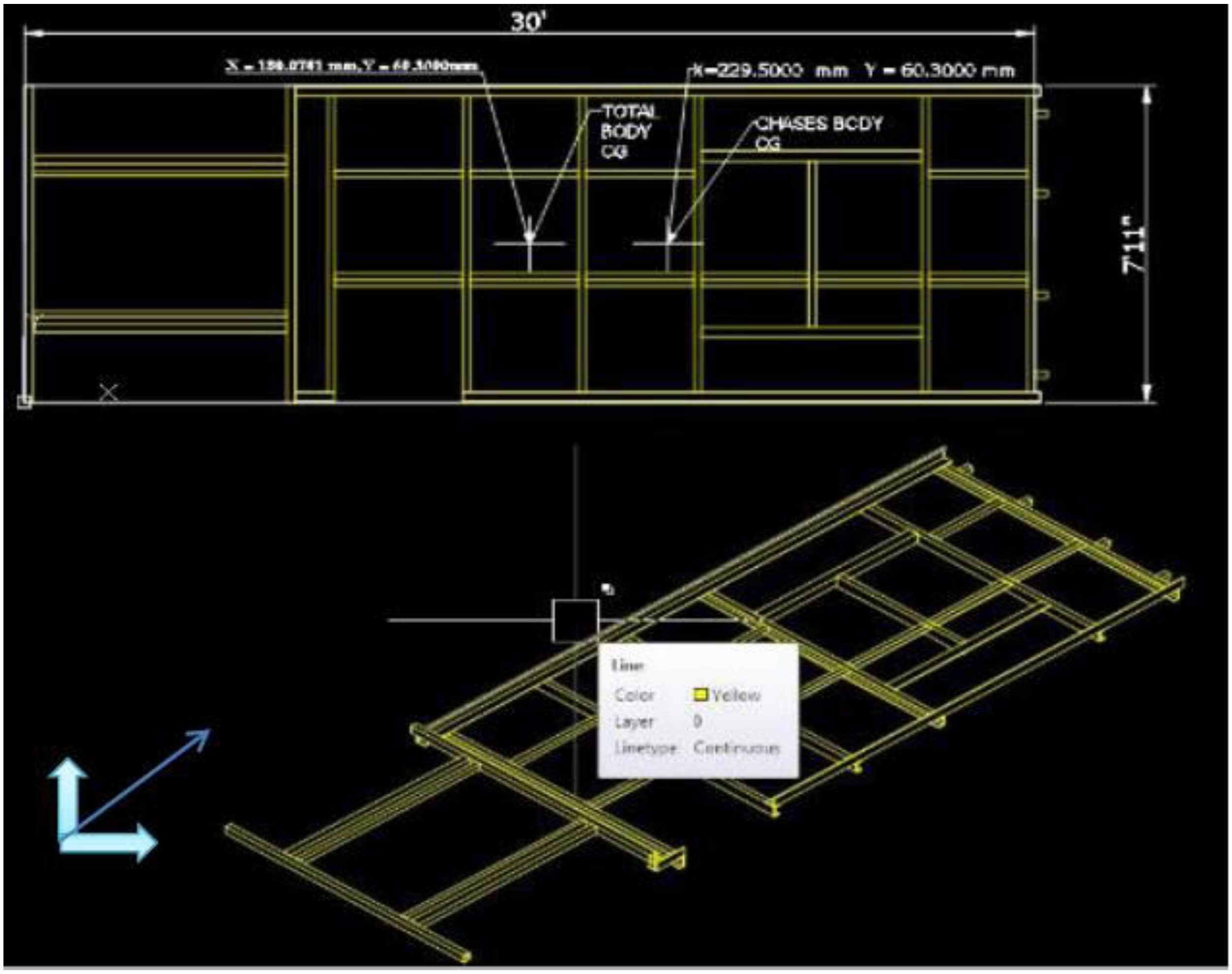

Fig. 6.14 Centre of gravity for bus body with chases by AutoCAD

As shown in Fig.6.30 the centre of gravity for whole body of the bus is indicated is 180.0781mm on X-axis and 60.3000mm on Y-axis. CG for only chases is 229.5000mm on X-axis and 60.3000mm on Y-axis. Sign indicates the place of CG of the bus from top view. HSS can be situated in reference to the measured CG so that the load distribution on the chases or other base components can be symmetrical and system works efficiently.

6.14.1 EFFICIENCY OF DIESEL ENGINE

The efficiency of diesel engine is observed from the Carnot cycle.

Efficiency Ƞ= 1-[r1-ɤ (r_cɤ-1)/ɤ (r_cɤ-1)]

Where r= compression ratio, ɤ= specific heat ratio

r_c= cut-off ratio

Table 6.14 Diesel Engine Bus Efficiency

TYPE OF BUS	ENGINE EFFICIENCY (%)
TATA (SUPER)	52
TATA (SEMI)	52-58
LEYLAND (SUPER)	50
LEYLAND (SEMI)	50-55
12 CNG CYLINDER F MADE	63

6.15 EFFICIENCY OF BATTERY-SUPERCAPACITOR SYSTEM

Total electrical efficiency is defined as the ratio of use full power output to total power input.

Electrical efficiency= useful power output/total power input

Battery watt-hour is useful quantity to find the efficiency.

Table 6.15 Energy estimation & Observation of the E – bus driven train

Mode	Initial Speed km / hr	Final Speed km / hr	Time Sec	Energy Generated WSec
Braking I	30	0	4	26847
Braking II	65	30	8	40861
Motoring I	0	30	4	-26847
Motoring II	30	65	8	-40861

Efficiency for supercapacitor is given by

Ŋ= energy required/ (energy required+ losses)

As the SC discharges energy up to half of the voltage rating of it;

Ŋ= 2*energy required/0.75(Energy required + losses)

Energy desired= 2*energy required/0.758* Ŋ

Table 6.16 Efficiency of the E-bus

TYPE OF BUS	Efficiency (%) – Estimated
TATA (SUPER) BUS A	80
TATA (SEMI) BUS B	85
LEYLAND (SUPER) BUS C	80
LEYLAND (SEMI) BUS D	85
12 CNG CYLINDER F MADE	87

6.16 HARDWARE TESTING & RESULTS

The testing of the hardware is done on the two wheeler, three wheeler and four wheeler with their in built specifications with required electrical and electronic changes and the results (average value) obtained are shown in the Table 6.17, 6.18 and 6.19 for the two wheeler, three wheeler and four wheeler respectively. The detail observation sheets are kept in APPENDIX E-1, E-2, E-3 for two wheeler, three wheeler and four wheeler respectively.

The necessary photographs also shown in the APPENDIX F. The photographs showed in APPENDIX F clearly represent the picture of images of protections, controllers two wheeler, three wheeler and four wheeler, too.

Table 6.17 Observations for Two Wheeler

Parameter	dN/dt	dI/dt	I	V	Watt	Watt.Sec
Average	4.44	-1.54	-3.49	46.8	-163.28	-398.86

Table 6.18 Observations for Three Wheeler

Parameter	dN/dt	dI/dt	I	V	Watt	Watt.Sec
Average	9.74	12.33	19.76	51.6	1016.67	1646.45

Table 6.19 Observations for Four Wheeler

Parameter	dN/dt	dI/dt	I	V	Watt	Watt.Sec
Average	5.24	10.42	20.64	50.84	1049.44	1789.54