Solar Charging station for Electric Vehicles, DoD, IITG, Shyam Prajapati & Pradeep Y

About IIT Guwahati

Indian Institute of Technology Guwahati, the sixth member of the IIT fraternity, was established in 1994.

At present the Institute has eleven departments covering all the major engineering and science disciplines, offering B. Tech., B. Des., M. Tech., Ph.D. and M.Sc. programmes. Within a short period of time, IIT Guwahati has been able to build up the necessary infrastructure for carrying out advanced research and has been equipped with state-of-the-art scientific and engineering instrument. It is involved in many national and International R&D projects.

IITG campus is on a sprawling 285 hectares plot of land on the north bank of the river Brahmaputra around 20 kms. from the heart of the city. With the majestic Brahmaputra on one side, and with hills and vast open spaces on others, the campus provides an ideal setting for learning.

Event supported by
Ministry of New and Renewable Energy
Government of India.

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IIT Guwahati

Proceeding : Hybrid Renewable Energy Sources For Public Transportation Systems

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी • Indian Institute of Technology Guwahati •

Proceeding

Editor: Pradeep Yammiyavar

Hybrid Renewable Energy Sources For Public Transportation Systems

A National Round-Table Technical Meet hosted by Indian Institute of Technology Guwahati | October 11-13, 2010

Proceedings

of

National Round-table technical meet on
Hybrid Renewable Energy Sources for Public Transportation Systems

11th, 12th, 13th October 2010.

Indian Institute of Technology Guwahati

Hosted Under the Patronship of Prof. Gautam Barua , Director IITG

Organized by Indian Institute of Technology Guwahati by the Dean R&D's office.
Event Funded & Sponsored by the Ministry of New and Renewable Energy - Govt. of India

Proceedings Editor: Pradeep G. Yammiyavar
Production team : Vikash Kumar, Debayan Dhar and Yogesh Deshpande.

Preface

The **National Round-table technical meet** on Hybrid Renewable Energy Sources for Public Transportation Systems was organised on 11th, 12th, 13th October 2010 by an interdisciplinary team at IITG from the departments of ECE, Design, Civil and Centre for Environment with the following theme:

Sustainability & Design viability of electric public transport vehicles running on hybrid renewable energy sources.

The Objectives of the meet were as follows:

- To review state of the art practices & potential in the field of Public Transportation using Hybrid Renewable Energy Sources.
- To formulate a specific plan of action for designing, developing and prototyping a demon stration vehicle that uses Hybrid Renewable Energy Sources.
- To present & discuss "out of the box' conceptual transportation solutions for the built environment that reduce usage of conventional fuels & encourage renewable energy sources.

The event was organised in Conference Rooms of ECE & Design Departments IITG and contained short presentations by the invited experts from Academia, Industry and Ministry of the Government of India.
The event had two sections. Industry - Institution - Ministry roundtable presentations cum discussions session by Invitation only and an open Technical paper session.

Two industries namely BHEL and Volvo Eisher participated from the Industry sectors. Other industries such as Mahendra - Reva, Crompton Greaves had sent in written views and commitments but could not be present at the meeting.
The **Ministry of New and Renewable Energy - Government of India** which was the main sponsor and financial supporter of the event was represented by Mr. Sohil Akathare, Director.

A tripartite meeting of IITG, Industry representatives and Ministry was convened under the Chairmanship of Prof. Gautam Barua, Director IIT Guwahati to discuss the new project proposal that resulted from the technical meet deliberations and form the Project execution strategy with the lead of IITG.

The hall mark of this event was its outcome of Multidisciplinary team formulation and interdisciplinary nature of the proposals made through the presentations. It is an example of transdisciplinary research at the Systems level with the emphasis on Design and Development activity within the broad paradigm of Research required at the national level. The topic cuts across traditionally inhibiting technical interdisciplinary barriers and is a viable attempt to work on complex large scale projects at IITG that necessarily involves many departments as well as Industry participation.

We thank all the IITG research scholars, students and administrative staff at IITG who helped make the even a success. We thank the MNRE in particular for its support and active encouragement extended to us through Mr. Sohil Akthaer and Dr. A. R. Shukla and look forward for further support for the proposal that has taken shape in this technical meet.

Pradeep Yammiyavar, S.K. Bose & Praveen Kumar, IITG

Contents

Contents

Programme Schedule

October 11 th Monday

9:00 am:Inaugural Meeting with Conveners, Visiting delegates & Students.

Morning Session: 10:00 am onwards

Concept papers on out of box solutions - presentation by research scholars & students of peer reviewed accepted papers and posters

Afternoon Session: 2.30 pm to 5.30 pm *(by invitation only)*

Industry Partners Presentations,
Industry- Institute Partners Discussion Meeting

October 12th Tuesday

Morning Session: 9.30 am to 12.30 pm *(by invitation only)*

Technical presentations from Design, ECE, Environment, Infrastructure & Civil Teams.
Industry partners presentations
MNRE presentation

Afternoon Sessions: 2:00 pm to 3.30pm *(by invitation only)*

Lunchion Meeting Chaired by Prof. Gautam Barua, Director Indian Institute of Technology Guwahati involving Round Table Discussion with Ministry, Industry and Institution Teams.
Concluding Deliberations and Strategy Formulation 4.30 -6. 00 pm.

October 13th Wednesday

Morning Session: 9.30 am to 12.30 pm.
Concluding Plenary Session

Afternoon Session: 2.30 pm to 5.30 pm
Departments, Campus and Local Visits

Event Chairs: Prof. Pradeep Yammiyavar & Prof. S. Bose

Event Conveners: Prof. Pradeep Y., Prof. S.Maji, Prof. S.K Bose, Prof. C.Mahanta

IITG Committee: Dr. P. Kumar, Dr. A Kalamdhad, Dr. B.Kumar, Dr. B.Singh,
Dr. A. Chakaraborthy

Departments / Centers Involved in this event: ECE, Civil, CenENV & DoD.

Participants

Participating Organisations:

Ministry of New and Renewable Energy - Government of India *(Sponsors)*.
Volvo - Eicher Commercial Vehicles.
Bharat Heavy Electricals Ltd.
Mahendra - Reva Electric Car company *(Expressed intent).*
Crompton Greves *(Expressed Intent).*
Indian Institute of Technology Guwahati *(Event Hosts).*

Invited Participants:

Dr. A. R. Shukla, Scientist G, (BG, R&D ,Cook-stoves ,NIC & NIRE) MNRE
Mr. Sohail Akthar Scientist F & Director, MNRE
Dr. B. R. Das - GUW representative of MNRE
Dr. B. L. Ram, MNRE
Mr. B. Anil Baliga, Vice President, Volvo Eicher Commercial Vehicles
Mr. A. K. Sharma, General Manager BHEL Bhopal
Mr. S.K. Biswas, Manager, Control Gear Engineering, BHEL
Mr. S.P. Singh, Manager, Traction Machine Engineering, BHEL
Mr. Rakesh Grover, General Manager, Volvo - Eicher Commercial Vehicles.
Dr. Ajay Kalamdhad, IITG
Dr. L. B. Singh, IITG
Dr. A. Chkarborty, IITG
Dr Praveen Kumar, IITG
Dr. A.K. Mishra, IITG
Dr. Bimlesh Kumar, IITG
Prof. S. Majhi, IITG
Prof. S.K.Bose, IITG
Prof. Pradeep Yammiyavar, IITG

Student Paper presenters

Kshitiz Godara, Department of ECE, IITG
Hari Singh Chaudhary, Department of ECE, IITG
Siddharth Mukherjee, Department of ECE, IITG
Vamsi Mohan A, Department of Civil Engineering, IITG
Ramizuddin Ahmed, Department of Civil Engineering, IITG
Pandu Ranga Rao B, Department of Civil Engineering, IITG
Kannan T, Department of ECE, IITG
Mohammed Nasir Ansari, Department of ECE, IITG
Kunwar Raghvenrda Singh, Department of Civil Engineering, IITG
Jyoti Chaubey, Department of Civil Engineering, IITG
Aman Gupta, Department of Design, IITG
Bharadwaj Radhakrishna, Department of Design, IITG
Thiyam Tamphasana Devi, Department of Civil Engineering, IITG
Gaurav Abnesh Kulshrestha, Department of Design, IITG
Kshitij Bhardwaj, Department of Design, IITG
Vikash Kumar, Department of Design, IITG

Call for Entries

Indian Institute of Technology Guwahati announces:

National Round-table technical meet on Hybrid Renewable Energy Sources for Public Transportation Systems.

Sponsor: Ministry of New and Renewable Energy Government of India

A multi departmental event organised by a team of Faculty members from ECE, Civil, Centre for Environment & Design with the theme : Sustainability & Design viability of electric public transport vehicles running on hybrid renewable energy sources.

Dates: 11 , 12 & 13th of October 2010.
Venue: ECE & Design Department premises.

Objective of the meet:

To review state of the art practices & potential in the field of Public Transportation using Hybrid Renewable Energy Sources.
To present & discuss "out of the box' conceptual technological and transportation solutions for the built environment that reduce usage of conventional fuels & encourage renewable energy sources.

Under the above event a **'Technical concept paper session '** has been specially earmarked for Students of IITG.

Entries are invited in the form of concept papers, design concepts / ideas, technical propositions write ups, reviews of local & traditional practices - surrounding the theme of Sustainability, Eco solutions, green design and Renewable energy as applied to transportation but not necessarily limited to Transportation.

Your submission will be reviewed by a panel of expert reviewers. All Accepted submissions will be published in the Proceedings of the event as Publications. The top entries will be allowed a personal presentation in the session and will be awarded a certificate of merit.

Format: ACM standard two column template.

Students from all departments / specialisations can take part. Students from Civil / Transportation, Environment, Energy, Electronics, Electrical, Mechanical, Biotech are particularly encouraged . Interdepartmental student teams will be especially welcome.

Deadline: Abstracts received up to 30th of September will be treated as Entry applications.
Notification of acceptance after review: 4 days from date of receiving your Entry.

Hence sooner you submit quicker you receive the review of the expert panel which is made up of members of the Interdepartmental team organising this event.
All Accepted papers / entries will get an additional week after the event to submit camera ready documents for inclusion into the proceedings to be published. A number of delegates from the Ministry and Industry are taking part in the event at IITG.

Section I

Invited Papers and Presentations.

IITG, Industry-MNRE Session *(by Invitation only)*

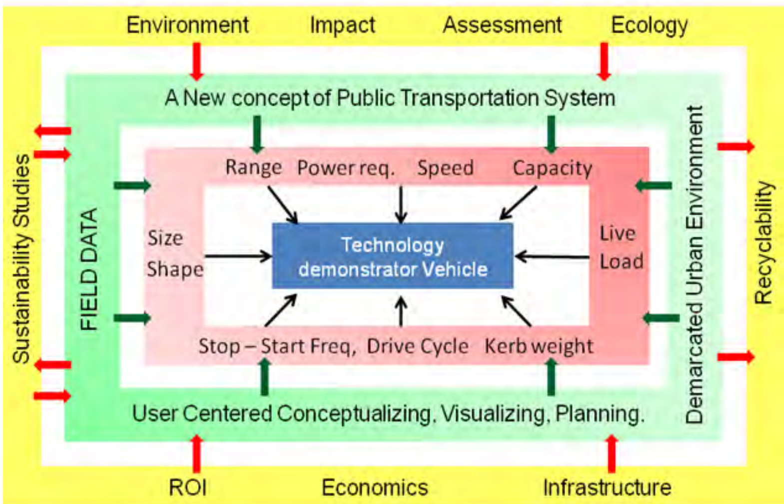
Chairs: Mr. Sohil Akthar, MNRE and Prof. S. Majhi, IITG

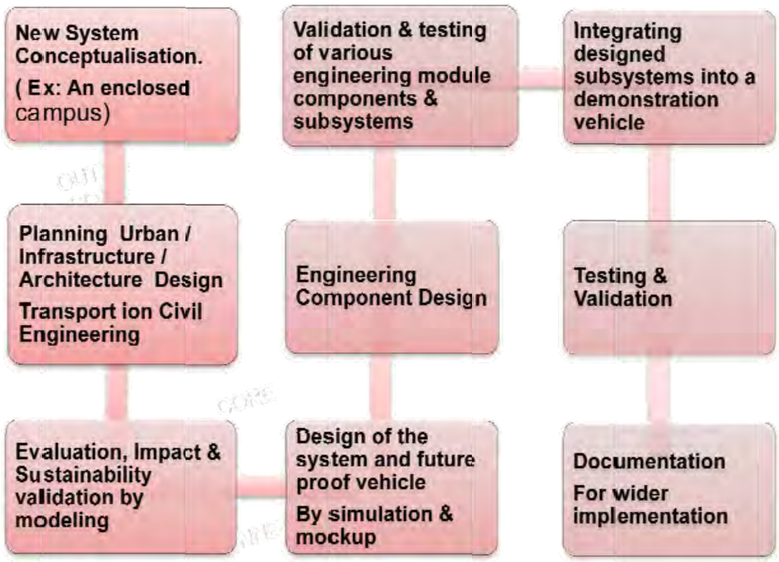
Project Overview

Prof. Pradeep Yammiyavar, IITG

Abstract

Transport energy consumption increased by 22 % between 1990 and 2000. It is the largest energy-consuming sector, being responsible for about 35 % of total energy consumption in 2000. It is well known that developed countries have already reached an unsustainable energy use consumption majority of which is for personalized vehicles such as cars and public transport such as airplanes resulting in large carbon footprints. India and China too show similar trends if intervention measures are not taken. Trends of personilised vehicles can only be countered by improving public transportation systems. In the proposed project at IITG with Industry partners a strategy has been evolved consisting of re-examining, re-inforcing, re-adapting, re-scaling, re-positioning, re-defining and re-engineering at a systems level by incorporating advances in energy storage, energy efficiency, hybrid source integration, grids, charging strategies, hybrid drives, renewable source mixing, innovation in vehicle body designs and related infrastructures. The systems approach in this project has a demonstrator electric bus prototyping as its inner core. Integration of subsystems such as Charging stations, Circuit, Passenger amenities and information system form its middle core of activity. The outer core of activity involves Sustainability, Green Design, Recyclability, Carbon Foot print Environmental Impact assessment & validation issues.





Infrastructure & Economics validation, Viability of PPP or PP modes also is part of the outer core. All the cores will be executed simultaneously by various teams.

Multidisciplinary and interdisciplinary teams formed by IITG and participating industry will be supported by MNRE in executing the research, design and development project at the Indian Institute of Technology Guwahati.

User Centred Design issues of renewable energy based public transport systems:a proposal based on Transit oriented urban infrastructure planning model.

Prof. Pradeep Yammiayavr , IITG

Abstract

While proven Planning models and strategies in transportation engineering exist for large cities of 10 million and above (such as Class A: Delhi, Mumbai, Kolkata) there are few reference to planning transportation Infrastructure for smaller semi urban centers/towns with less than 3 million population which constitute a typical rapidly urbanizing Class B Town in India. In 10 years from now it is such semi urban small towns that will join the numbers of densely populated urban centers contributing to pollution, energy inefficiency and low quality of life. There is an urgent need to gain experience of planning ahead for such small urban centers in-terms of sustainable, eco friendly, energy efficient public transportation systems. There is also a need to put in place (may be between just two points -10 kms apart within a small town) of a modern alternative - energy based public transportation systems, right now, so as to become visionary demonstration examples of feasibility and benefits when these small towns eventually spread into bigger urban chaos. If dedicated routes using simpler and smaller vehicles are built in such small towns, they can make way for future metro system introduction minus the difficulties as faced now in cities like Delhi, Bangalore and Kolkata. Planning models and strategies used for Metros and class A towns, though available, may not be suitable when scaled down for use in smaller towns. There is a need for first hand 'know how' and experience in understanding how to plan and design for such small townships utilizing alternative renewable energy and environmentally sustainable transportation modes. Mini townships / satellite townships, special purpose zones and large residential campuses, be they military or educational, are also other noticeable phenomena in Class A towns and metros. In such townships with controlled environments and 'point to point'- (closed loop) transport needs it is posited that alternative energy systems that are currently available (such as battery capacity, charge cycle times, range etc) can cater to small well planned urban pockets and yet become viable/feasible in-spite of their known limitations and constraints. There is also a need to make such demarcated special purpose campuses /zones/ mini townships pollution free and energy efficient at an early stage of their life cycles.

Closed loop systems (a dedicated round route from point to point) like LRT and BRT have become popular and are being implemented in educational campuses in Canada, US and Europe. However there existing designs may not be suitable for Indian context of use. Such modes have huge potential in Indian towns and cities. Renewable energy based public transport modes, vehicles and supporting infrastructure need to be developed from basics to be adaptable and useful for the Indian user behavior and usage environment.

Not only new modes of internal transport (such as an electric Bus or Light rail) but also a new approach to designing transportation supporting infrastructure such as terminals, passenger information systems etc are the need of the hour. Existing known physical components of transportation Infrastructure may not be ideal for new upcoming urban demarcated zones such as Townships / satellite towns and Educational campuses. New designs of supporting components and sub components that take into considerations the energy and environmental sustainability issues as well as commuter behavioral characteristics need to be conceptualized designed and developed.

In the absence of reliable models, basic research starting form User surveys and ending with Environmental impact assessment needs to be done. This project proposal, part of larger interdepartmental project, intends to fill this gap. [Ref 3, 4] In terms of vehicle's product designs, existing vehicles bodies and chaises are too heavy for use in renewable energy systems especially for closed loop circuits such as point to point modes. Reducing the weight using newer light weight metals such as Aluminum & Plastics implies new ideation, visualization and design of the body. Travel behavior, capacity and inter-stop distances in planned corridors need a different paradigm for vehicle interior as well as exteriors.

Maintenance, recharging time and varying passenger loads may require a modular configuration so as to be able to vary the length of the vehicle according to variation in loads and build in flexibility. New body designs are required to be conceptualized and realized / simulated for modular configurations in terms of mock ups and scaled models for being validated by the future users of the system. There is a lack of data as well as planning and designing strategies for such new concepts. This has been widely reported in research publications. Renewable energy based public transport modes, vehicles and supporting infrastructure need to be developed from basics to be adaptable and useful for the Indian user behavior and usage environment.

This project intends to fill this gap as well as visually inspire future designers, engineers and administrators.

User Issues & schematics in Engineering Systems Design in an Electric Bus.

Dr. Praveen Kumar, Prof. S. Majhi & Dr. Amit, IITG

Abstract

This paper presented the engineering system requirements, their individual component designs and their testing and prototyping plans for the proposed Electric City Bus.

The vehicle involves development of novel drive trains involving batteries, super-capacitors, electric motors, DC-AC-DC converters energy management unit and the superfast charging of the battery and super-capacitor pack. Besides the development of cutting edge drive train technology the project will also involve development of components to make the vehicle semi-intelligent. The semi intelligent system is intended to enable the diagnostics of the components of the drive train. The purpose of the diagnostics is to predict the failure of the components before they actually fail. Reliability and safety of the engineering component system is an important part of the engineering development for the entire technology is being aimed at. Hybridization of Energy Sources and its modeling is being aimed at so as to develop a right mix of energy storage devices to achieve minimum Environmental Footprint on well-to-wheel energy efficiency basis.

Environmental issues in Public Transportation based on renewable energy fuels.

Dr. Ajay Kalamdhad & Dr. Bimlesh Kumar; IITG

Abstract

The depletion of fossil fuels and greenhouse gas emissions are major issues facing the world today. Conventional vehicles, such as combustion driven buses and cars, are major contributors to these issues. Sustainable electric vehicles (EV) can be being offered as an alternative for the future. As the biggest challenges in the EVs is the storage of energy in these vehicles and charging method has been also tried to overcome in the present proposed project, sustainable term is being used. In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. This is the case independently of the electricity production mix and is even more beneficial when using renewable energy sources. When analyzing electric vehicles, the battery is often considered to be the main environmental concern, be it pertinent or not. Anyhow, the environmental impact of the battery should be assessed. This paper propose guidelines to study the impact on the environment of the energy storage cells (batteries) used by these vehicles.

Structural & safety Issues in Public Transportation Systems.

Dr. A Chakraborty; IITG

Abstract

The key factors that affect the overall dynamics of the vehicle are the weight of the battery and its placement on the chassis along with other vehicular components and the control systems. This demands a detailed structural modeling using state-of-the-art finite element analysis (ProE & ANSYS) to forecast the performance of the vehicle at the actual operational environment. With this in view, a detailed simulation of multi-body dynamics of the EV will be performed. A detailed ergonomic evaluation of the passenger comfort and safety is proposed to be studied using simulation technique before evaluating the models of the EV for commercial production.

Design Methodology and facilities at Volvo-Eicher Commercial Vehicles.

Mr. Rakesh Grover & Mr. B. Anil Baliga; Volvo - Eicher

Abstract

The Product Life cycle and design methodology at Volvo- Eicher was presented in great detail. The resources required for any R&D group involved in multidisciplinary work was highlighted. Besides sharing experiences of their R&D teams, the paper outlined possible collaboration areas for this project.

The paper also emphasized that designing vehicles for public transportation necessarily required inputs from User behavior studies; market forecast studies, customer- end service projections, spare part inventory management etc apart from engineering component design and prototyping. The need to start from basic route planning, transportation studies and gathering data from primary users such as drivers and passengers, ergonomic and aesthetic norms as well as cultural factors was pointed out to be equally important during the paper presentation. Further the presentation pointed out the need for taking data on marketing, branding and other socio economic factors into consideration.

Infrastructure planning & Project Management issues in Public Transportation Systems.

Dr. L.B. Singh; IITG

Abstract

This paper intends to identify the key issues in infrastructure planning that could be encountered while scaling up the prototype electric bus for use in a public transportation system for a city or an urban area. It argued for an in depth analysis of PP and PPP models. Using the three pillars of sustainability viz Social, Economic and Environmental dimensions the consequences of not planning and designing for a sustainable transport system was highlighted in the paper. Development of a framework, based on Life cycle planning and risk assessment, is proposed which could form the basis for sustainability integration in the design and operation of the electric vehicles and electric vehicle based public transportation system.

Planning for R&D activity in the area for the Battery Operated City Bus.

Mr. A.K Sharma & S. P. Singh; BHEL

Abstract

The presentation outlined the experiences of BHEL in conceptualising, designing and prototyping eclectic vehicles. The need to focus on reducing the overall vehicle weight and seek alternative battery technology for buses was pointed out. The paper emphasised that concepts such as in wheel hub motors need to be carefully evaluated before being incorporated. Flooding, road conditions, driving habits, maintenance issues are likely to negate the benefits of hub motors in public vehicles.

The methodology followed by BHEL in designing components and drive chains; as well as in bus body prototyping was outlined. Evaluation of various possibilities in drives, power trains, motors, batteries etc was discussed.

Smart Cities: Some examples of application for Guwahati city planning.

Dr. B.R. Das; MNRE

Abstract

The concept of Smart cites is gaining respect of Planners and engineers. Using Information technology and a combination of existing practices as well as local practices it is possible to envisage a smart city that saves energy without having to sacrifice efficiency. Illustrating a few case studies of the efforts done in this direction in the City of Guwahati, the paper outlined a possible strategy for planners and infrastructure designers involved in service planning, electricity distribution and management. The paper discussed smart city initiatives such as Street Lighting, Energy efficient buildings, Devices, Waste management practices, and building by-laws.

Role of MNRE: Encouraging the Transportation Sector in India

Mr. Sohail Akhtar, Director , Ministry of New & Renewable Energy, GOI.

Abstract

This presentation highlighted the very positive and motivating role being played by the MNRE in encouraging R&D in the Energy sector. It made aware of the many organizations, projects and initiatives, for example the Jawaharlal Nehru national solar mission, that MNRE is currently involved along with the terms and conditions of R&D grants. It clearly brought out the huge gap and potential for generating renewable energy from wind power to solar power apart from conventional natural renewable sources. The MNRE's initiative in BOVs (battery operated vehicles) was highlighted giving special attention to problems and yet unresolved issues in battery technology and the promise fuel cells hold. The presentation was summed up with the encouraging statement " I don’t drink, (fuel) I don’t smoke, (Pollution) I don’t shout (noise) ' as the desired characteristics of vehicles of the future including the one being proposed in this project at IITG.

Section II

Reviewed Full Paper Submissions

Chairs: Dr. Praveen Kumar & Prof. Pradeep Y., IITG

Analytic model for Switched Reluctance Machines.

Kshitiz Godara, Department of ECE, IITG; *e-mail- k.godara@iitg.ac.in*

1. Abstract

Analytic model for shape optimization of Switched Reluctance machine has been developed here. The developed mode is much faster than the existing popular method i.e. finite element analysis. In this method, pure geometrical techniques have been used to compute the various parameters like torque, inductance, variation of torque and inductance with rotor position. This analytic model can be used for optimizing SRM geometric parameters like stator & rotor height, optimum stator and rotor angles, stator and rotor pole heights, stator, rotor, core, yoke areas etc. It can also be used for flux and mmf calculations of machine.

2. Introduction

Switched Reluctance Machine works on principle of variation of reluctance (Inductance). As rotor moves, the reluctance of path changes and so the torque. So, geometrical analysis is a powerful tool for analysis of such kind of machines. Because these machines have low manufacturing cost, simple construction techniques, and at high frequencies very good performance, they are used in industry at higher levels. Semiconductor devices played a crucial role in giving switching currents for these machines. Newly developed techniques minimized the torque ripple in such machines and problem of acoustic noise is not that much because used coating material is of good quality. So, if we develop some computational methods for these machines for shape optimization then there production may increase. This is an attempt to meet the needs of industry.

3. Model Description

This method is based on geometry and linear B-H characteristics have been assumed for calculation of inductances and torque. Inductance has been calculated from reluctance. Various steps used in calculation of inductance and torque are as described below

Step1. Machine dimensions have been calculated first.

Step 2. Then reluctances of various identified flux paths have been calculated.

Step 3. Calculated reluctance has been used for calculation of inductance.

Step 4. Inductance derivative with appropriate dimensional constants have been used for torque calculations.

Step 5. Various current excitations have been used for testing saturation of core material.

Model Verification has been done by taking various practical examples of Switched Reluctance Machines at industry level.

Designing of a Switched reluctance machine that develop a torque of 22 N-n and following parameters are given:

Stack length of machine = 200 mm

External diameter of machine = 100 mm

Maximum stator flux density = 2 Tesla

80% of maximum stator flux density has been assumed as Yoke flux density.

For maximum torque development stator and rotor angle must be optimized. Clearance between winding must be given otherwise at high currents in stator field winding may cause damage to winding as well as insulation which is required.

Here developed method gives following optimized parameters for the Switched Reluctance Motor (The optimized values for stator and rotor pole angles have been calculated by iterative method):

Stator Pole arc angle	0.38397 rad
Rotor Pole arc angle	0.40142 rad
Stator pole height	0.029185 m
Rotor Pole height	0.022741 m
Stator face area	0.003763 m^2
Rotor face area	0.003894 m^2
Yoke area	0.003763 m^2
Core area	0.002352 m^2
Developed torque value	24.24 N-m
Clearance between windings	0.005743 m
Peak current in stator windings	12 A
Ampere turns	1924
Shaft diameter	0.028 m
Aligned inductance	73.8 mH
Unaligned inductance	11.4 mH

Data which have been collected by FEM gives inductances as follows:

Aligned inductance = 65.41 mH
Unaligned inductance=11.35 mH

It has been observed that FEM inductance values and analytic model inductance values matched well. The plot of inductance vs. rotor position and torque generated vs. rotor position are shown below.

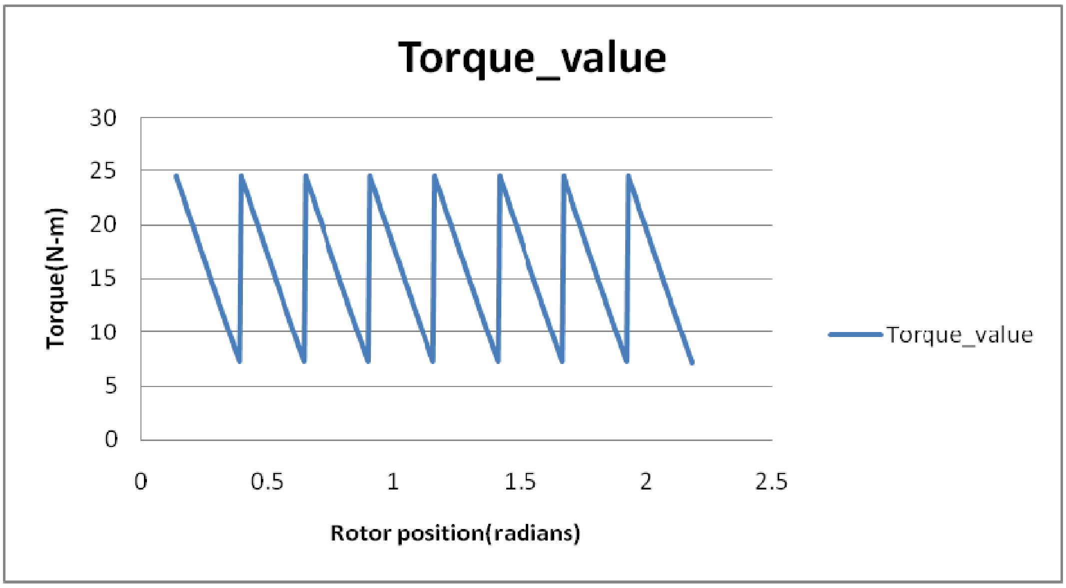


Figure 1: Torque values vs Rotar position plot for 8-6 SRM

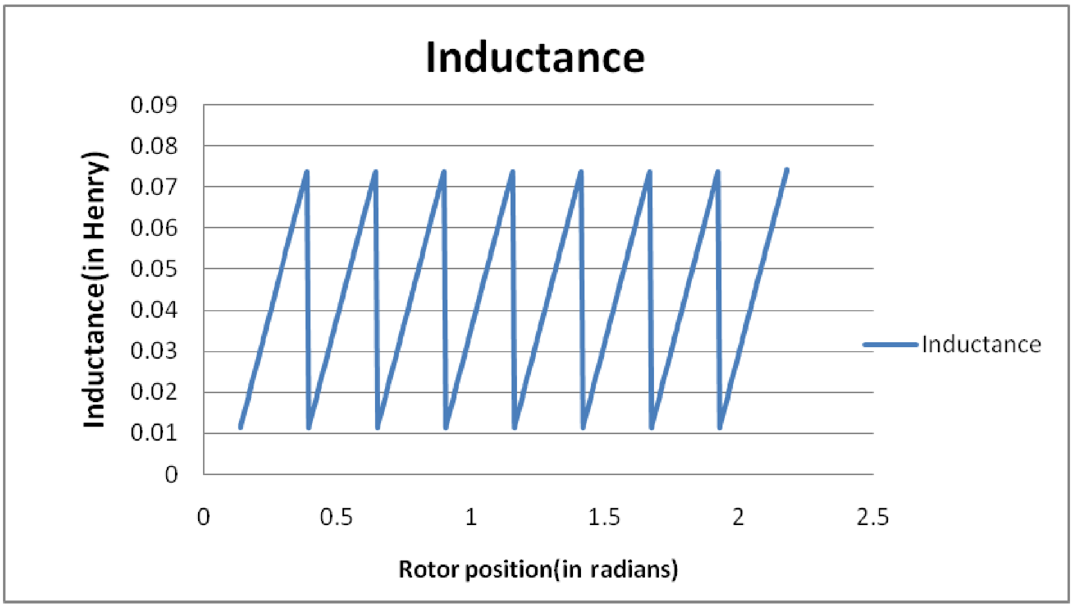


Figure 2: Inductance value vs Rotary position plot

It is seen that torque is nowhere zero in the plot, so if controller is improved further than sufficient starting torque can be obtained.

It can be seen that there are jumps in both the plots. Because it has been assumed that there are four square phases of current, so for an 8-6 SRM there are 8 jumps in inductance and torque.

This example compares the results for aligned and unaligned inductances for a 6/4 switched reluctance machine:-

Input Vector for this machine is as follows:

Number of stator poles	6
Number of rotor poles	4
Stator diameter	0 .19m
Rotor diameter (bore diameter)	0.102 m
Core length	0.06037
Air gap length	0.00025
Back iron thickness	1.0515
Stator pole arc	0.418 rad
Rotor pole arc	0.628
Turns per phase	536

Computed values for aligned and unaligned inductances have been given below. Values obtained by finite element analysis have been included. Comparison between these values shows that they are pretty close.By our analytic model and FEM the values are as follows:-

Unaligned inductance	26 mH
Aligned inductance	86 mH
Unaligned inductance by FEM	25.8 mH
Aligned inductance by FEM	82.4 mH

4. Conclusion

Even though finite element analysis is very useful tool for calculation of switched reluctance machine parameter evaluation but is very much time consuming. So, if we change one parameter in inputs of SRM then we have to do all process again. For rotor and stator pole arc optimizing FEM is not good because for that we have to take so many combinations of rotor and stator pole angles. In FEM if we do so then it will take days to give correct parameters. In our developed method it won't take even ten to twenty minutes. You have to add a 'for' loop for angles and you will get the results. The first benefit of our method is it gives almost similar results as that of finite element analysis as comparison shows. Secondly, after shape optimization, we can do finite element analysis to get whole information about machine with much less time because then you have to only once FEM and you will get the results. By this way designing process for switched reluctance machines becomes much easier and very less time consuming.

5. References

[1] "Switched reluctance motors and drives-modeling, simulation, analysis, design, and application" a book by Dr. R. Krishnan

Electric Vehicles and Carbon Emission

Hari Singh Chaudhary, Department of ECE, IITG; *E-mail- c.hari@iitg.ernet.in*
Siddharth Mukherjee, Department of ECE,IITG; *E-mail-m.siddharth@iitg.ernet.in*

Abstract

Using Electric vehicles (EVs) only in present scenario is not a complete solution to carbon emission reduction. This paper presents a different approach in reducing carbon emission using a combination of electric vehicles and renewable energy resources in India. Carbon emission due to EVs and internal combustion engine (ICE) vehicles is compared in the present scenario, where conventional energy resources play an important role, with the proposed future scenario when the use of renewable energy resources will be dominant. In future when renewable energy resources are more harnessed, the carbon emission due to EVs will be reduced significantly.

Keywords

Carbon Emission, Electric vehicles, Hybrid Renewable Energy Resources

1. Introduction

An important concern in today's world is the high soaring prices of oil, rapidly decreasing levels of conventional energy resources and increase in carbon emission which results in Green house effect. This motivates the use of Electric vehicles in the future and its increased penetration in market will lead to greater energy demand. In present scenario, thermal based power plants meet 70% [1] of the total energy demand in India. The extra demand will have to be met with a sustainable integration of both conventional as well as non-conventional energy resources. In future due to growth of EVs, increased use of conventional energy resources is not favorable (less efficient and high amount of CO2 (1000g/KWh) [2]). Therefore, renewable energy resources should play a more vital role to provide a clean and energy efficient environment. For healthier atmosphere, percentage of energy produced by coal should be decreased by a large extent and more stress should be placed on the abundant renewable energy resources such as solar, wind, rain [18], tidal energy and geothermal heat.

A comparison of carbon emission due to ICE vehicles and EVs suggests the use of Electric vehicles. In India, it is proposed that by 2020, 0.3 million EVs will be there on road [3]. Thus, in future EVs will play an important role in transportation. The paper presents the current scenario of electricity sector in India followed by the CO2 emissions due to different energy resources. This paper also explains how electric vehicle is better suited for transportation as compared to ICE vehicles. A new scenario is proposed where greater use of renewable energy resources in India along with EVs will help in reducing the CO_2 emission for sustainable development and greener planet.

2. Electricity Sector in India

India is world's 6th largest energy consumer, accounting for 3.5% of global energy consumption and 5th largest energy producer [4]. India's annual energy production increased from about 190 billion kWh in 1986 to more than 680 billion kWh in 2006. Thus, due to the rise in India's economy, the demand for energy has grown at an average of 3.6% per annum over the past 30 years. In June 2010, the installed power generation capacity of India stood at 162,366 MW while the per capita energy consumption stood at 612 kWh [5].

The total demand for electricity in India is expected to cross 950,000 MW by 2030[6]. About 53.4% of the electricity consumed in India is generated by Coal based thermal power plant, 24.8% by hydroelectric power plant, 10.2% by natural gas power plant, 1.6% by wind power plant and 3% by nuclear power plant. More than 50% of India's commercial energy demand is met through the country's vast coal reserves [5]. Current installed base of Renewable energy is 16492.42MW. By 2020 solar power will cross 20GW [7].

3. Carbon Emission in India

Due to rapid economic developments that typically occur as countries become industrialized: increasing traffic, growing cities and higher levels of energy consumption, air pollution increases. ICE vehicles and electricity generation is the major sources of carbon emission.

Table 1. **Current electricity sector in India**

Electrical Generation Technology	Percent of India Generating Capacity [8]
Coal	53.4%
Oil	0.9%
Natural Gas	10.2%
Solar	0.4%
Wind	1.6%
Hydro	24.8%
Nuclear	3.1%
Others	5.6%
Total	**100%**

Carbon monoxide (CO) and hydrocarbons (HC) account for 64% and 23%, respectively, of the total emission load due to vehicles [9]. Coal based thermal power stations deliver high amount of CO2 and contributes to the green house effect. Due to low quality of coal in India this ratio is increased by a significant factor.

Table 2. **Role of different energy resource in CO_2 emission - India**

Electrical Generation Technology	Grams of CO_2 per kWh[10]	Percent of India Generating Capacity	Contribution (g/kWh)
Coal	1000	53.4%	534.0
Oil	650	0.9%	5.85
Natural Gas	500	10.2%	51.0
Solar	150	0.4%	0.60
Wind	23	1.6%	0.37
Hydro	5	24.8%	1.24
Nuclear	5	3.1%	0.15
Others	100	5.6%	5.6
Total		**100%**	**598.81**

According to Table 2, 1000 grams of CO2 is released in the atmosphere per kWh in coal based generation technology. Since percentage of energy generating through coal based power plants in India is 53.4%, 534.0 grams of CO2 is released per kWh. Similarly for rest of the electrical generation technology, India's CO2 g/kWh share is calculated in Table 2. Therefore, on an average, kilowatt-hour energy results in the contribution of about 599 grams of CO2 to the environment. According to U.S. Environmental Protection Agency survey, the annual CO2 emissions from vehicles in U.S. using DOT fuel economy numbers [11] are as follows:

- Passenger Cars = 4.78 metric tons CO2
- Light Trucks = 6.00 metric tons CO2
- All passenger vehicles = 5.23 metric tons CO2

On an average the CO2 emission range for Internal Combustion Engine vehicle is 167 to 224 g/km [12]. In 2008-2009, the annual production of passenger vehicles in India was 1,838,593[13].

Thus assuming the lowest CO2 emission i.e. 167 g/km, in that year 1,838,593*167 = 307,045,031 g/km more of CO2 was released in the atmosphere.

This amounts to a significantly high carbon emission. Considering the future growth trends in annual production of passenger vehicles in India, CO2 emission will increase.

3.1 Reduction of carbon emission by electric vehicles

A modern electric car requires 0.2 to 0.3 kWh/km [14]. There is about 10% electrical power losses between the generating plant and the charging station of the car [15]. For every kWh an electric vehicle runs on road, 1.1 kWh of energy should be produced by the generating plant. Driving an electric car with an energy requirement of 0.2 kWh/km results in the generation of 0.2*1.1*599= 132 grams of CO2 /km. By the same methodology, an EV with an energy requirement of 0.3 kWh/km results in the generation of 198 grams of CO2 /km. Assuming the lowest CO2 emission for EV i.e. 132 g/km; for the same annual production trend as observed in 2008-2009 for ICE vehicles, the CO2 emission for EVs is calculated as, 1,838,593*132 = 242,694,276 g/km of CO2 released. Therefore, only a 20% reduction in emission is observed. Including the carbon emission during the process of battery production for EV, CO2 emission will increase and there will be insignificant change in carbon reduction. If 2008-2009 annual production trend in passenger vehicles is observed in future for EVs, keeping the present scenario of electricity generation in India unchanged, no major change in CO2 emission will be seen. Hence electricity generation from renewable energy resources should be exploited more to cut back the carbon emission.

4. Proposed Scenario for Electricity Generation in Future.

Renewable energy resources are clean sources of energy. In the new proposed scenario, percentage of total energy supplied by renewable resources should be increased. Harnessing of tidal energy, solar energy, water and biomass should be higher than the thermal energy, which can reduce the consumption of fossil fuels and in turn reduce air pollution. If demands of future Electric vehicle are met by clean sources of energy, there will be a drastic change in carbon emission and other climatic effects.

Table 3. Capacity of renewable energy resources and current contribution to total energy of India

Renewable Electrical Generation Technology	Capacity (MW) [16]	Contribution (MW) till June 2010
Wind	45,000	2,598(1.6%)
Hydro	1,50,000	40,267(24.8%)
Solar	30,00,000(Desert)	650(0.4%)
Geothermal	10,600	-
Total	32,05,600	

As given in Table 3, India is blessed with an abundance of solar energy (Thar Desert), hydro, wind (large offshore and onshore area) and biomass. Contribution of small hydro power plants in rural areas, base power stations on rivers, solar panels, offshore and onshore wind power stations and nuclear energy should be increased. As in July 2009, India unveiled a US$ 19 billion plan, to produce 20 GW of solar power by 2020[17]. A new proposed scenario for electricity generation and carbon emission by 2020 is given in Table 4.

As explained in section 3.1, driving an electric vehicle with an energy requirement of 0.2kWh/km results in the generation of 0.2*1.1*454=100 grams of CO2/km in the proposed future energy scenario. By the same methodology, an EV with an energy requirement of 0.3 kWh/km results in the generation of 150 grams of CO2/km.

Table 4. Proposed New electricity generation scenario

Electrical Generation Technology	Grams of CO_2 per kWh [10]	Percent of India Generating Capacity	Contribution (g/kWh)
Coal	1000	40%	400.0
Oil	650	0.6%	3.90
Natural Gas	500	8%	40.0
Solar	150	2.3%	0.34
Wind	23	5%	1.15
Hydro	5	35%	1.75
Nuclear	5	3.1%	0.15
Others	100	6%	6.0
Total		**100%**	**453.4**

An ICE vehicle emits 167 to 224 g/km whereas a pure EV emits 100 to 150 g/km. Assuming the lowest CO2 emission for EV i.e. 100 g/km; for the same annual production trend as observed in 2008-2009 for ICE vehicles, the CO2 emission for EVs is calculated as, 1,838,593*100 = 183,859,300 g/km of CO2 released. Therefore 40% reduction in CO2 emission is observed as compared to ICE vehicles.

This reduction is further increased if more percentage of renewable energy resources is employed along with increased efficiency of EV battery and EV as a whole.

5. Conclusion

The paper presented a comparison in carbon emission due to EVs in present scenario as well as in the new proposed future scenario for electricity generation in India. The result was compared with ICE vehicles and was observed that EVs along with the increased harnessing of renewable energy resources will bring down the CO2 emission. The paper also illustrated that that simply switching to EVs would not help save the planet from global warming.

If the efficiency of electrical grid is further improved (transmission and distribution losses are reduced) and a higher proportion of wind power, tidal power and possibly more nuclear power is exploited, the advantage of EVs will improve further. Government policies regarding renewable energy resources will play a vital role in deciding the future of our planet.

6. Acknowledgements

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Green House Gas Emissions of Conventional Vehicles and Electric Vehicles .

Vamsi Mohan A, Department of Civil Engineering,, IITG;
E-mail- a.vamsi@iitg.ac.in

Abstract

Transport marks the development of a region. The demand for infrastructure expansion increases with the region's expedition of development goals. The basic infrastructures required for the region's economic growth are roads, railways, and water and air connectivity. With the increase in economic activities, the dependence of fossil fuel based energy sources and consequent green house gas (GHG) emissions have increased rapidly in recent times. The major countries like India mainly consume non-renewable fossil fuels for the vehicles, and are a major contributor of green house gases, particularly CO_2 emissions. The current study is to evaluate Green House Gas emissions of conventional and electric vehicles in the transportation sector. The transportation sector has the characteristic of spending petroleum. Even when the cost of petroleum rises, conventional vehicles cannot switch fuels to alternative energy right away. Cleaner vehicles, such as Electric vehicles, would be one of the alternative technologies in the transportation sector. It is supposed to have excellent performance in energy efficiency and has strong possibility to reduce CO_2 drastically. The analysis that petroleum consumption can be reduced using Electric vehicles will have effects on perspectives on energy systems in India and also reduction in GHG emissions.

Keywords

GHG-green house gases, Electric Vehicle, economic growth, non-renewable fossil fuels.

1. Introduction

Reducing carbon dioxide (CO_2) and other GHG emissions to lessen global warming has become an international issue in recent years. The fact that vehicles emit 90% of carbon emissions in the transportation sector suggests that additional changes in transportation are needed to meet the Kyoto Protocol. Although the Kyoto Protocol has called for substantial reductions in the emissions of carbon from the world's energy systems, it is uncertain how these reductions should be achieved. Each country has its own unique considerations of energy resources, economic demand patterns, and energy security concerns. Thus, the best strategy in energy policy for each country will be different based on the situation of energy security and economic potential.

In mega-cities like Tokyo, urban environment is still getting worse and worse. For example, the concentration of Nitrogen dioxides (NO_x) and Suspended particulate matter (SPM) is still above the regulated value in Tokyo metropolitan area [1]. In addition, concentration of CO_2 in the urban area is higher than that in the background area. These stresses of the urban environment can be mainly attributed to increase of automobiles in this area. In order to resolve the problems caused by the conventional internal combustion engine automobiles which depend mostly on fossil fuels, the adaption of energy efficient electric vehicle, which runs about ten times more efficient than the conventional automobiles? The current paper deals with the brief study of carbon and other green house gas emissions of ordinary conventional vehicles and the electric vehicles.

1.1 Green House Gas (GHG) Emission in Indian Scenario

Coming to the Indian scenario, the transport sector in India consumes about 16.9% (36.5 mtoe: million tonnes of oil equivalent) of total energy (217 mtoe in 2005– 2006), which emits 18% of total CO_2 emitted in India. Various energy sources used in this sector are coal, diesel, petroleum (gasoline) and electricity. Road, rail and air are responsible for emission of 80%, 13% and 6% respectively [2]. Vehicular emissions account for about 60% of the GHG's from various activities in India [3].

Globalization and liberalization policies of the government has erupted the economic activities. Consequent to this policy change are increase in urbanization and concentrated economic activities in certain load centers resulting in higher mobility. This fuelled the rapid increase in number of vehicles and traveling distance resulting in the higher consumption of energy with an average annual rate of 2.9%. During the last two decades, number of registered motor vehicles has increased dramatically from 5.4 million in 1980–1981 to 72.7 million in 2003–2004 [2]. Energy consumption also varies with the modes of transport and public transport system has least average energy consumption per passenger kilometer [4].

The urban population of India, which constitutes 28% of the total, is predominantly dependent on road transport. Around 80% of passenger and 60% of freight movement depend on road transport [5]. Traffic composition of six mega cities of India (Delhi, Mumbai, Bangalore, Hyderabad, Chennai and Kolkata) shows that there is significant shift from the share of slow moving vehicles to fast moving vehicles and public transport to private transport [6]. Among different type of motor vehicles, percentage of two wheelers has shown rapid growth (doubling in every 5 years) and it constitutes 70% of total motor vehicles of India [7]. Total number of road vehicles in India as per the latest available statistics (March 2004) were 72.7 million [8].

Indian railways has important role for long journey movement of both people and freight. In last ten years, there is a sharp increase in number of passenger and goods movement and consequent fuel consumption. Current energy consumption in railways is around 5.1% of total transport energy with about 77.5% from diesel and balance is through electricity [9].
During 2004–2005 Indian civil aviation accounted for more than 24% increase in the number of international and domestic flights, with consequent increase of aviation fuel from 0.98 million tonnes (mt) (1976–1977) to 6.2 mt in 2005–2006. Shipping sector has aided in the movement of about 18 mt of cargo [9]

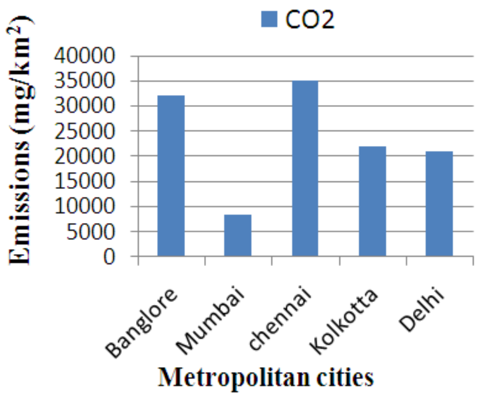

Figure 1: Vehicular emission in major metropolitan cities of India (Source: Ramachandra, T.V., Shwetmala, Emissions from India's transport sector, 2009**)**

1.2 IITG Scenario

Coming to IITG scenario, there are around 270 faculty members, 150 supporting staff and 50 officers in the campus. On an average, each faculty members consists of at least 2 vehicles (tentative). Thus, there are around 750 vehicles in the campus in which 300 are cars and 450 are two wheelers (excluding research scholars). On an average each car can emit around 110 to 150 g/km of CO_2 emissions and 2-wheeler can emit 25 to 27 g/km. Besides this, there are around 20 buses for campus services each can emit around 5500 g/km (assuming 60 peoples travel per day and which gives a per passenger figure of 85 g/km for a bus according to transport direct.info). Due to rapid expansion of IIT the deforestation is going on. If this continuous, after 10 to 15 years the environment may become worse than ever in the campus. In order to resolve the problem a major step has to be taken.

2. Green House Gas Emission of Conventional Vehicles

Emissions from the transport sector depend mainly on type of transport and fuel apart from type of combustion engine, emission mitigation techniques, maintenance procedures and vehicle age. The major pollutant emitted from transport are Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Nitrogen oxides (NO_x), Nitrous oxide (N_2O), Sulfur dioxide (SO_2), Non -methane volatile organic compounds (NMVOC), Particulate matter (PM) and Hydrocarbon (HC). Diesel is used in public passenger and cargo vehicles, while private two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. In the National capital, Delhi, most of the buses and omni buses and 5% of total cars and jeeps use Compressed Natural Gas [10].

2.1 Emission Factors

According to the various literatures and regulatory agencies [11][12][13][14][15], the specific emission factors of road transport, based on the type of vehicle are listed in the Table 1.It is assumed that, diesel is used as fuel in buses, Omni buses, taxi, trucks, lorries, light motor vehicles (goods), trailers and tractors, while two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. In Delhi, most of the buses and Omni buses and 5% of total cars and jeeps also use Compressed Natural Gas [10]. CO, HC, NOx and PM emissions from CNG based buses were 1.77, 0.88, 2.81 and 0.032 g km^{-1} and for cars and jeeps were 0.78, 1.55, 0.92 and 0.02 g km^{-1}, respectively [13].

3. Electric Vehicles

Electric vehicle is a vehicle driven entirely by an electric motor powered by a rechargeable battery that is usually plugged in overnight. Electric vehicles include electric cars, electric trains, electric Lorries, electric airplanes, electric boats, electric motorcycles and scooters, and electric spacecraft. Electric vehicles first came into existence in the mid-19th century, when electricity was among the preferred methods for automobile propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time.

The internal combustion engine (ICE) is the dominant propulsion method for automobiles, but electric power has remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.

During the last few decades, increased concern over the environmental impact of the petroleum-based transportation infrastructure, along with the presence of peak oil, has led to renewed interest in an electric transportation infrastructure. Electric vehicles differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable. The electricity may then be stored onboard the vehicle using a battery, flywheel, or super capacitors. Vehicles making use of engines working on the principle of combustion can usually only derive their energy from a single or a few sources, usually non-renewable fossil fuels. A key advantage of electric or hybrid electric vehicles is regenerative braking and suspension; their ability to recover energy normally lost during braking as electricity to be restored to the on-board battery.

In 2003 the first mass produced hybrid gasoline-electric vehicle, the Toyota Prius, was introduced worldwide, and major auto companies have plans to introduce plug-in hybrid and true battery electric vehicles in showrooms in 2010 and 2011.

Table 1: Emission factors for road vehicles (g km^{-1})

	Bus	Omni buses	Two wheeler	Light motor vehicles (passenger)	Cars and jeeps	Taxi	Trucks and lorries	Light motor vehicles	Trailers and tractors	Others[a]	Reference
CO_2	515.2	515.2	26.6	60.3	223.6	208.3	515.2	515.2	515.2	343.87	Mittal, 2003
CO	3.6	3.6	2.2	5.1	1.98	0.9	3.6	5.1	5.1	3.86	CPCB, 2007
NOx	12	12	0.19	1.28	0.2	0.5	6.3	1.28	1.28	3.89	CPCB, 2007
CH_4	0.09	0.09	0.18	0.18	0.17	0.01	0.09	0.09	0.09	0.11	EEA, 2001
SO_2	1.42	1.42	0.013	0.029	0.053[b]	10.3[c]	1.42	1.42	1.42	1.94	Kandlikar, 2000
PM	0.56	0.56	0.05	0.2	0.03	0.07	0.28	0.2	0.2	0.24	CPCB, 2007
HC	0.87	0.87	1.42	0.14	0.25	0.13	0.87	0.14	0.14	0.54	CPCB, 2007

[a] Average of above value are used for others.
[b] Indian Institute of Petroleum (IIP), Automotive Research Association of India (ARAI) used in UNEP, 1999.
[c] Mittal and Sharma, 2003

3.1 Electricity Sources

There are many ways to generate electricity, some of them more ecological than others:

- On-board rechargeable electricity storage system (RESS), called Full Electric Vehicles (FEV). Power storage methods include:
  - chemical energy stored on the vehicle in on-board batteries: Battery electric vehicle (BEV)
  - static energy stored on the vehicle in on-board electric double-layer capacitors
  - kinetic energy storage: flywheels
- direct connection to generation plants as is common among electric trains, trolley buses, and trolley trucks
- renewable sources such as solar power: solar vehicle
- generated on-board using a diesel engine: diesel-electric locomotive
- generated on-board using a fuel cell: fuel cell vehicle
- generated on-board using nuclear energy: nuclear submarines and aircraft carriers

It is also possible to have hybrid electric vehicles that derive electricity from multiple sources. Such as:

- on-board rechargeable electricity storage system (RESS) and a direct continuous connection to land-based generation plants for purposes of on-highway recharging with unrestricted highway range
- on-board rechargeable electricity storage system and a fueled propulsion power source (internal combustion engine): plug-in hybrid

Batteries, electric double-layer capacitors and flywheel energy storage are forms of rechargeable on-board electrical storage. By avoiding an intermediate mechanical step, the energy conversion efficiency can be improved over the hybrids already discussed, by avoiding unnecessary energy conversions.

Furthermore, electro-chemical batteries conversions are easy to reverse, allowing electrical energy to be stored in chemical form. Another form of chemical to electrical conversion is fuel cells, projected for future use.

For especially large electric vehicles, such as submarines, the chemical energy of the diesel-electric can be replaced by a nuclear reactor. The nuclear reactor usually provides heat, which drives a steam turbine, which drives a generator, which is then fed to the propulsion.

A few experimental vehicles, such as some cars and a handful of aircraft use solar panels for electricity.

3.2 Energy Sources

Although electric vehicles have few direct emissions, all rely on energy created through electricity generation, and will usually emit pollution and generate waste, unless it is generated by renewable source power plants. Since electric vehicles use whatever electricity is delivered by their electrical utility/grid operator, electric vehicles can be made more or less efficient, polluting and expensive to run, by modifying the electrical generating stations. This would be done by an electrical utility under a government energy policy, in a timescale negotiated between utilities and government.

Fossil fuel vehicle efficiency and pollution standards take years to filter through a nation's fleet of vehicles. New efficiency and pollution standards rely on the purchase of new vehicles, often as the current vehicles already on the road reach their end-of-life. Only a few nations set a retirement age for old vehicles, such as Japan or Singapore, forcing periodic upgrading of all vehicles already on the road.

Electric vehicles will take advantage of whatever environmental gains happen when a renewable energy generation station comes online; a fossil-fuel power station is decommissioned or upgraded. Conversely, if government policy or economic conditions shifts generators back to use more polluting fossil fuels and internal combustion engine vehicles (ICEVs), or more inefficient sources, the reverse can happen. Even in such a situation, electrical vehicles are still more efficient than a comparable amount of fossil fuel vehicles. In areas with a deregulated electrical energy market, an electrical vehicle owner can choose whether to run his electrical vehicle off conventional electrical energy sources, or strictly from renewable electrical energy sources (presumably at an additional cost), pushing other consumers onto conventional sources, and switch at any time between the two.

3.3 Carbon Emissions of Electric Vehicles

Electric cars produce no pollution at the tailpipe, but their use increases demand for electricity generation. Generating electricity and producing liquid fuels for vehicles are different categories of the energy economy, with different inefficiencies and environmental harms, but both emit carbon dioxide into the environment that must be accounted for in a "well to wheel" (WTW) comparison. An electric car's WTW emissions are much lower in a country like Canada, whose electricity supply is dominated by hydro and nuclear, than in countries like China and the US that rely heavily on coal.

An EV recharged from the existing US grid electricity emits about 115 grams of CO_2 per kilometer driven, whereas a conventional US-market gasoline powered car emits 250 g(CO_2)/km (most from its tailpipe, some from the production and distribution of gasoline) [16]. The savings are questionable relative to hybrid or diesel cars, (according to official British government testing, the most efficient European market cars are well below 115 grams of CO_2 per kilometer driven, although a study in Scotland gave 81.4g CO2/km[18]), but would be more significant in countries with cleaner electric infrastructure. In a worst case scenario where incremental electricity demand would be met exclusively with coal, a 2009 study conducted by the WWF, World Wide Fund for Nature, and IZES found that a mid-size EV would emit roughly 200 g(CO_2)/km, compared with an average of 170 g(CO_2)/km for a gasoline powered compact car [17]. This study concluded that introducing 1 million EV cars to Germany would, in the best case scenario, only reduce CO_2 emissions by 0.1%, if nothing is done to upgrade the electricity infrastructure or manage demand [17]. Like any other vehicles, EVs themselves of course differ in their fuel efficiency and their total cost of ownership, including the environmental costs of their manufacture and disposal. 45% of the electricity generated in the U.S. comes from coal-fired power plants

According to the US Department of Energy, most electricity generation in the United States is from fossil sources, and 45% is from coal [15]. Coal is more carbon-intensive than oil. Overall average efficiency from US power plants (33% efficient) to point of use (transmission loss 9.5%) is 30 %[15]. Accepting a 70% to 80% efficiency for the electric vehicle gives a figure of only around 20% overall efficiency when recharged from fossil fuels. That is comparable to the efficiency of an internal combustion engine running at variable load. The efficiency of a gasoline engine is about 16%, and 20% for a diesel engine [22][23]. This is much lower than the efficiency when running at constant load and optimal rotational speed, which gives efficiency around 30% and 45% respectively [19]. The electric battery suffers a smaller decrease in efficiency when running at variable load [20], which accounts for the modest increased efficiency of hybrid vehicles. The actual result in terms of emissions depends on different refining and transportation costs getting fuel to a car versus a power plant. Diesel engines can also easily run on renewable fuels, biodiesel, vegetable oil fuel, with no loss of efficiency. Using fossil based grid electricity partially negates the high in-vehicle efficiency advantages of electric cars, though even with that drawback, the operation of a electric vehicle has a smaller carbon footprint than a gasoline car. This is because internal combustion engines, when used for propelling a vehicle, operate throughout their power band, which is hardly optimal for efficiency. A major potential benefit of electric cars is to allow diverse renewable electricity sources to fuel cars. An electric vehicle, recharged from renewable resources, would produce no CO_2 emissions at all.According to the US Department of Energy, CO_2 emissions for electricity generated from coal result in 0.93 kg of CO_2 per kW·h or roughly 0.14 kg(CO_2)/km. CO_2 emissions from electricity produced from all types of fuel using the mix of sources in the US as of 2008 results in 0.61 kg of CO_2 per kW·h or 0.337 pounds of 0.095 kg(CO_2)/km from an electric vehicle with a 0.250-kilowatt-hour-per-mile (0.155 kWh/km; 0.56 MJ/km) energy consumption (typical). Gasoline used in Internal Combustion Engine automobiles produces 2.34 kg (CO_2)/L directly and an undetermined amount of CO_2 in refining the crude oil, and transporting the gasoline to retail point of sale. With a US fleet average of 11.0 L/100 km in 2008, this would indicate a CO_2 production of 0.258 kg/km driven. Electric powered automobiles, even using the most CO_2 intensive coal produced electricity, produce half the emissions of gasoline powered automobiles [24].

If solar, wind, hydro, or nuclear electric generation, or carbon captures for fossil fuel powered plants were to become prevalent, electric vehicles could produce less CO_2, potentially zero. Based on GREET (The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) simulations, electric cars can achieve up to 100% reductions with renewable electric generation, against 77% with a B100 car. At present only a 32% reduction of CO_2 is available for electric cars recharging from non-renewable utilities on the US Grid, because of the majority use of fossil fuels in generation, and inefficiency in the grid itself [25-27].

4. Conclusion

The total CO_2 emission for Indian transport was 258.10 Tg in 2003–2004. Among all type of transport, road and aviation were first and second major contributor of air pollution. The road transport sector has contributed 94.5% and 53.3% of total transport emission of CO_2 and CO. Among all the states and UT, Maharashtra's contribution is the largest, 28.85 Tg (11.8%) of CO_2, followed by Tamil Nadu 26.41 Tg (10.8%), Gujarat 23.31 Tg (9.6%), Uttar Pradesh 17.42 Tg (7.1%), Rajasthan 15.17 Tg (6.22%) and, Karnataka 15.09 Tg (6.19%). The total of these six states accounts for 51.8% of the CO_2 emissions from road transport. The aviation has contributed 2.9% and 45.1% of CO_2 and CO of total transport emission. Shipping is most environment friendly mode of transport. It has contributed only 0.6% of CO_2 emission, while railways have contributed 2.0% and 1.2% of CO_2 and CO of total transport emission. For aviation, railways and shipping, emissions were also calculated for 2004–2005 and 2005–2006. Total emission of CO_2 from railways, shipping and aviation has increased by 24.2% from 14.29 Tg in 2003–2004 to 17.74 Tg in 2005–2006. Similarly CO and CH_4 emissions have increased from 32.3% to 31.8%, respectively [21]. Reductions beyond this level will not be possible, however, unless a practical solution is found to the problem of extra urban travel. Reducing CO_2 emissions for extra-urban travel will require either a revolutionary breakthrough in electrical energy storage, significant improvements in the TTW(tank to wheel) efficiency of conventional engines, a substantial uptake of low-Carbon 2nd or 3rd generation bio-fuels, or most likely some combination of these factors. In the short term (to 2020), improvements in ICE offer significant hope and, in combination with progressive electrification of urban passenger car, useful reductions in CO_2 and other GHG emissions are possible. Finally, solving the problem remains, for the moment, a significant and separated challenge.

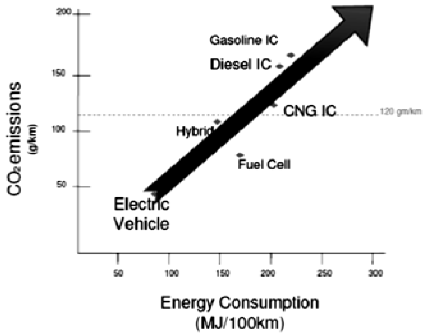

Figure 2. Comparisons of the different energy consumption vehicles

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Environmental Impact of Hybrid Electric Vehicle in Public Transportation System.

Ramizuddin Ahmed, Department of Civil Engineering, IITG;
E-mail- r.ahmed@iitg.ernet.in
Pandu Ranga Rao B, Department of Civil Engineering; IITG;
E-mail- pandu@iitg.ernet.in

Abstract

A general study on environmental impact of hybrid vehicle in public transportation system is done. Its different components, used fuels, different electric appliances like batteries, fuel cells, electric machines and their relative impacts on human health, Green house gases, and acidification are studied. Some socioeconomic factors like effect on future employment scenario and vehicle market are also given an enlightment. This paper proposes environmental impact indices to evaluate the environmental effects of hybrid vehicle in public transportation system.

Key words

Environmental impacts, transportation system, renewable energy, Electric batteries.

1.0 Introduction

The relationships between transport and the environment are multidimensional. Some aspects are unknown and some new findings may lead to drastic changes in environmental policies, as it did in regards of acid rain and chlorofluorocarbons in the 1970s and 1980s. The 1990s were characterized by a realization of global environmental issues, epitomized by the growing concerns between anthropogenic effect and climate change. Transportation is an important dimension of the concept of sustainability, which is expected to become the prime focus of transport activities in the coming decades, ranging from vehicle emissions to green supply chain management practices. The main factors considered in the physical environment are geographical location, topography, geological structure, climate, hydrology, soil, natural vegetation and animal life. Worldwide, motor vehicles emit well over 900 million metric tons of carbon dioxide (CO_2) each year, accounting for more than 15 percent of global fossil fuel-derived CO_2 emissions. In the industrialized world alone, 20-25 percent of GHG emissions come from the transportation sector. [1]

During the last few decades, increased concern over the environmental impact of the petroleum-based transportation infrastructure, along with the spectra of peak oil, has led to renewed interest in an electric transportation infrastructure. Electric vehicles differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable. The electricity may then be stored onboard the vehicle using a battery, flywheel, or super capacitors.

One of the intensively discussed technical solutions to environmental problems arising from transportation system is the combined fossil fuel and battery powered acceleration systems. A ‘hybrid electric' (HEV) is a type of hybrid vehicle and electric vehicle which combines a conventional internal combustion(ICE) propulsion system with an electric engine (ICE) propulsion system with an electric propulsion for better performance. A variety of types of HEV exist and the degree to which they function as EVs varies as well. The most common form of HEV is the hybrid electric car, although hybrid electric trucks (pickups and tractors) and buses also exist. These hybrid electric vehicles (HEVs) allow driving quietly and locally emission-free because the internal combustion engine is run in a more favorable load range, while the highly efficient electric motor supports at low speeds and in acceleration phases. Further reductions in fuel consumption are achieved by downsizing the combustion engine and by recuperating brake energy back into the battery. [3]

Hybrid vehicles are defined as vehicles which are powered by both, an internal combustion engine plus a battery powered electric motor. Other forms of hybrid solutions are possible, such as the combination of fuel cell and electric motors or the combination of different fuels, but here we concentrate on hybrid electric vehicles (HEVs).

2.0 Components of Hybrid Vehicles

2.1 Major components:

The components of Hybrid vehicles are

a) The internal combustion engine (ICE): This may be diesel or gasoline powered. But commonly gasoline engines are used as they are more complementary to electric motors across all engine speeds than diesel engines. In most cases combustion engines are downsized in hybrid drive trains.

b) Electric motors are constantly energy efficient across a wide range of engine speeds while combustion engines are less efficient at low speeds. Electric motors can thus either support the internal combustion engine while starting or accelerating the vehicle or may fully take over vehicle propulsion in certain situations.

c) Electric energy storage on board is one of the key issues for designing hybrid vehicles. Due to safety reasons contemporary models use nickel-metal hybrid (NiMH) batteries. But advances in the safety and durability of lithium-ion batteries promise an extended range of the electric power train and thus more efficient hybrid or pure battery powered vehicles. The plug-in hybrid concept uses the electric motor for driving purposes only and fuels the battery via the electricity grid network.

d) The transmission systems and the on-board electronics to regulate and combine in parallel. In contrast, serial concepts simply use the combustion engine to fuel the battery through an onboard power generator. More advanced concepts use hub motors directly at the wheels to further increase the energy efficiency.

Hybrid technologies are frequently considered an intermediate step towards fully electric powered vehicles or fuel cell cars. They have the charm of not being restricted to a particular technology, but can make use of improvements in battery as well as in common combustion engine technologies. The plug-in technology is further promoted by the power generation industry via the vehicle-to-grid concept. This should help to temporarily store supply peaks in the grid network, e.g. caused by renewable energy sources such as wind or solar power. Besides less fuel consumption across the whole driving cycle hybrid vehicles emit less exhaust emissions and are, depending on their configuration, able to drive completely emission-free on parts of their journey. Further, they are quieter in start and acceleration phases. This makes them particularly attractive for use in urban areas. These obvious advantages have to be balanced against the production and disposal externalities of the battery and, in case of plug-in hybrids, the efficiency of electric energy generation.

2.2 Fuel sources

2.2.1 Fossil fuels

The two power sources of a hybrid vehicle are critical. Using epicyclic or planetary gears the power of both engines can be run free-piston engines used in HEVs can be used to generate electricity as efficiently as, and less expensively than, fuel cells.

2.2.2 Gasoline

Gasoline engines are used in most hybrid electric designs, and will likely remain dominant for the foreseeable future. While petroleum-derived gasoline is the primary fuel, it is possible to mix in varying levels of ethanol created from renewable energy sources. Like most modern ICE powered vehicles, HEVs can typically use up to about 15% bio-ethanol.

2.2.3 Diesel

Diesel-electric HEVs use a diesel engine for power generation. Diesels have advantages when delivering constant power for long periods of time, suffering less wear while operating at higher efficiency. The diesel engine's high torque, combined with hybrid technology, may offer substantially improved mileage. Most diesel vehicles can use 100% pure bio-fuels (biodiesel), so they can use but do not need petroleum at all for fuel. If diesel-electric HEVs were in use, this benefit would likely also apply. Diesel-electric hybrid drive rains have begun to appear in commercial vehicles (particularly buses); as of 2007, no light duty diesel-electric hybrid passenger cars are currently available, although prototypes exist.

2.2.4 Liquefied petroleum gas

Hyundai introduced in 2009 the Hyundai Elantra LPI Hybrid, which is the first mass production hybrid electric vehicle to run on liquefied petroleum gas (LPG).

2.2.5 Hydrogen

Hydrogen can be used in cars in two ways: As a combustible heat source, or as a source of electrons for an electric motor. The burning of hydrogen is not being developed in practical terms; it is the hydrogen fuel-cell electric vehicle (HFEV) that is garnering all the attention. Hydrogen fuel cells create electricity that is fed into an electric motor to drives the wheels. Hydrogen is not burned, but it is consumed. This means that molecular hydrogen, H2, is combined with oxygen to form water. 2H2 (4e-) + O2 --> 2H2O (4e-). The molecular hydrogen and oxygen's mutual affinity drives the fuel cell to separate the electrons from the hydrogen, to use them to power the electric motor, and to return them to the ionized water molecules that were formed when the electron-depleted hydrogen combined with the oxygen in the fuel cell. Recalling that a hydrogen atom is nothing more than a proton and an electron; in essence, the motor is driven by the proton's atomic attraction to the oxygen nucleus, and the electron's attraction to the ionized water molecule.

An HFEV is an all-electric car that has an open-source battery in the form of a hydrogen tank and the atmosphere. HFEV's may also contain closed-cell batteries for the purpose of power storage from regenerative braking, but this does not change the source of the motivation. It means that the HFEV is an electric car with two types of batteries. So, since HFEV's are purely electric, and do not contain any type of heat engine, they are not hybrids.

2.2.6 Bio-fuels

Hybrid vehicles might use an internal combustion engine running on bio-fuels, such as a flexible-fuel engine running on ethanol or engines running on biodiesel.

2.2.7 Electric machines

In split path vehicles (Toyota, Ford, GM, Chysler) there are two electrical machines, one of which functions as a motor primarily, and the other functions as a generator primarily. One of the primary requirements of these machines is that they are very efficient, as the electrical portion of the energy must be converted from the engine to the generator, through two inverters, through the motor again and then to the wheels. Most of the electric machines used in hybrid vehicles are brushless DC motors (BLDC). Specifically, they are of a type called an interior permanent magnet (IPM) machine (or motor). These machines are wound similarly to the induction motors found in a typical home, but (for high efficiency) use very strong rare earth magnets in the rotor. These magnets contain neodymium, iron and boron, and are therefore called Neodymium magnets. The magnet material is expensive, and its cost is one of the limiting factors in the use of these machines [13].

3.0 Environmental Impact

Hybrid cars should not create as much emissions while driving, because the IC engine is not on all of the time. The whole concept of a second power source, however, adds weight to a car without being able to remove any weight. Electric engines are made up of large amounts of copper wires which ultimately just add mass to the car. Hybrids are commonly the same weight and sometimes heavier than a similarly sized car, which means more power has to be produced than usual to achieve comparable performance. The need to produce more power adds emissions to the hybrids lowered emission levels which brings them closer to even with conventional cars. In cities or stop and go traffic hybrids are great for the environment, creating almost zero emissions, but when hybrid cars are driving on roads such as highways they are in essence normal cars because the electric motor is not running at all. Taking all of these factors into account, hybrid cars, on average only create about a 20 percent reduction in CO2 emissions.

Again, cars with different propulsion devices are going to need different types of materials. Materials like lead and nickel make a large difference between cars. Traditional ICE cars have lead based batteries and zero nickel components, while hybrids have large nickel based batteries and no lead. Emissions levels, specifically CO2 levels, for the processing of the material that make up cars can be looked at and compared against each other to help understand if hybrids are better for the environment. In the case of the batteries, for example, from the raw material state, the production of lead based batteries produces 9 kg C, and the production of nickel based batteries produces 24-30 kg C and as high as 215 kg C in the case of a strictly electric car. If companies were to use 100% recycled materials, the difference between the CO2 emissions levels would be even more severe.

3.1 Effect due to uses of batteries

In hybrid electric vehicle used battery types are:

i) Lead acid
ii) Alkaline batteries
iii) Nickel cadmium
iv) Nickel metal hydride
v) Nickel zinc
vi) Lithium batteries
vii) High temperature batteries
viii) Metal air batteries
ix) Redox batteries

When considering the life cycle (fig 1) of the batteries, it appears that the energy losses in the battery and the energy losses due to the additional mass of the battery (battery efficiency and battery mass) have a very significant impact to the environment. However, this impact is strongly dependent on the way electricity is produced. The impact would be strongly decreased if renewable energy sources were used more intensively (fig 2). When looking at the rest of the environmental impact of the battery (excluding the use phase completely), it appears that the lead–acid battery has got the highest impact, followed by nickel–cadmium, lithium-ion, nickel–metal hydride and sodium–nickel chloride. Additionally, it is noticeable that the recycling phase allows compensating the environmental impacts of the production phase to a great extent. The inclusion of the battery efficiencies results in a higher environmental impact for nickel–cadmium and nickel-metal hydride batteries and a lower one for lithium-ion batteries comparatively to the others. (Fig 3) [6]

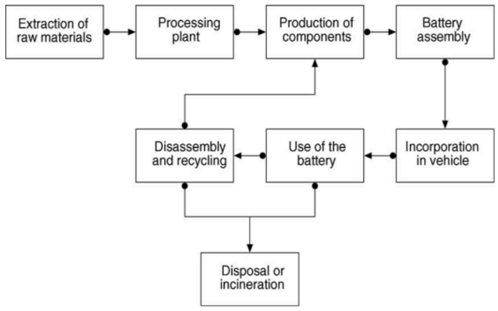

Fig 1: The schematized lifecycle of a battery [6

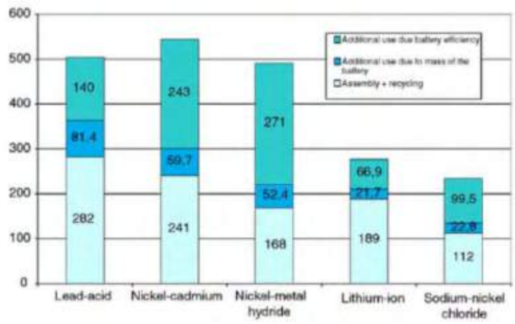

Fig 2: Environmental impact of the assessed technologies, including the Losses due to the battery during the use phase [6].

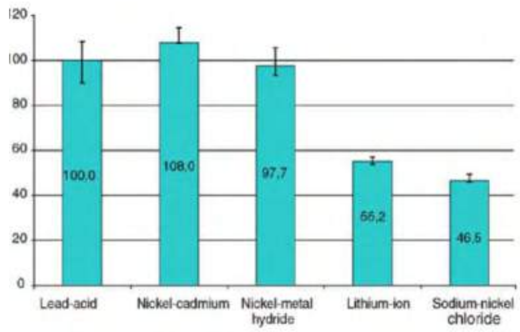

Fig 3: Graphical overviews of the relative environ- mental Scores (including the sensitivity analysis) [6]

Nickel Batteries:

Although the materials and chemicals in NiMH batteries are much safer for the environment than NiCd or lead-acid batteries but the process by which the nickel is extracted from the earth can be environmentally damaging. This process is called nickel mining. Nickel mining works are done by extracting one of its two types of ores from the ground. An ore is a large piece of rock composed of an array of minerals, including the metal(s) that need to be extracted from it. The two types of ores containing nickel are -lateritic and sulfuric ores. It has a very devastating effect on environment.

3.1.1 Effect on water bodies

Converting sulfuric ores into pure nickel by means of smelting emits sulfur dioxide (SO2). SO2 releases can be as high as 4 metric tons of SO2 per metric ton of nickel produced (Cheremisinoff). When SO2 mixes with the gases in the atmosphere, acid rain is produced. Acid rain is harmful for general water bodies and to all lives in the area.

3.1.2 Effect on air

a) The release of particulates and soot into the atmosphere is another side effect of nickel smelting. Particulates are liquid droplets suspended in the air that act as pollution. Depending on the type of furnace used for the smelting process, the release of particulate matter can range from 0.2 – 5.0 kg/t of nickel produced. Using 68.68 as the number of battery packs produced per metric ton of nickel mined, dividing 0.5 kg by 68.68 yields about 7.28 grams. 7.28 grams is approximately how much particulate matter is released into the atmosphere from producing one battery pack.

b) The dust accumulated from digging up the sulfuric ores is a source of air pollution.

c) A NiMH cell releases hydrogen gas while venting, and when the hydrogen gas mixes with the gases in the atmosphere potentially explosive combinations could be formed.

3.1.3 Effect on vegetation

The area surrounding the various nickel mining facilities around the world have some of the poorest air quality of anywhere on Earth and look desolated. The high concentrations of SO2 being released from the mine cause heavy amounts of acid rain, which in turn kill many of the nearby trees. An image from NASA‘s Earth Observatory website shows the SO2 concentration at a nickel mine in Norilsk, Russia is shown in figure 4

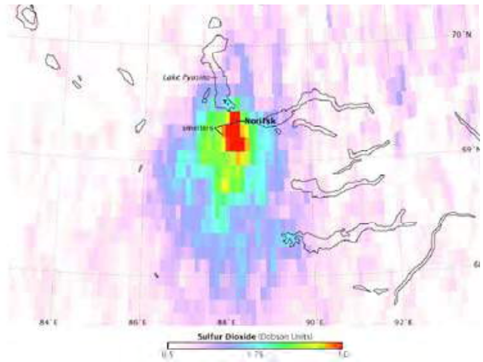

Fig4: SO2 from Norilsk, Russia Nickel Mine (http://earthobservatory.nasa.gov)

3.1.4 Effect on Surface water

Soot and metal particles fly into the air while digging up the ores and processing them. The soot then settles into the water of nearby rivers and ponds creating large amounts of sludge.

3.1.5 Effect on Land

Another measure of the pollution from nickel mines by how much they affect the land they reside in can be seen from a nickel mine in Tanjung Buli, which is located just off the shore of Indonesia. The World Bank, an organization dedicated to the funding of reconstructing poor countries, documented their sightings upon visiting that particular mine. They observed notable heavy sedimentation in the coastal zone, muddy gullies marking the slopes below the mine site, as well as oil discharges just offshore (The Impact of a Nickel Mine in Tanjung Buli, ndonesia). Images from the mining site are shown in figure 5

Fig 5: Mudslides near Nickel Mining Plant in Indonesia (The Impact of a Nickel Mine in Tanjung Buli, Indonesia)

3.2 Health effect due to high voltage HEV components

The battery pack is a source of high voltage in an HEV. The placement, the enclosure, and the thermal management/operation of the battery pack all affect the safety of the vehicle. Serious damages can occur if the battery pack were exposed to extremely high temperatures for a long period of time. The battery pack can be found underneath or behind the rear seats in an HEV. Because the pack is in these locations, there are vents on either side of the seats that must never be blocked. A concept called thermal runaway can occur if the batteries were to be severely overcharged or overheated. While the battery is being overheated, the temperature is rising causing the nominal cell voltage to decrease. Charge current then increases exponentially to increase cell voltage to match the charger voltage (Linden). The most thermal runaway prone types of batteries are Li-ion and NiCd. Venting is another safety issue for the battery pack. A NiMH cell releases hydrogen gas while venting, and when the hydrogen gas mixes with the gases in the atmosphere potentially explosive combinations could be formed.

3.3 GHG emissions

Both hybrid and battery-powered electric vehicles can result in considerable GHG Emission reductions compared to conventional petroleum-fueled vehicles. However, the associated emission reductions vary, depending on the power generation mix used to charge the electric batteries and the fuel type used for fueling the hybrid vehicle. Because vehicle efficiency of EVs and HEVs is determined by several factors, including fuel type and propulsion system, no single value for potential emission reductions can be provided. Emission estimates will have to be determined for each vehicle model and fuel type used.

3.3.1 GHG Emissions from EVs

Because electric vehicles use batteries as the sole source of power generation, the procedures for measuring and estimating GHG benefits of EVs is different from hybrid electric and conventional vehicles. Battery-powered electric vehicles have no tailpipe emissions of GHGs and local air pollutants, but there are emissions associated with generating electricity for battery recharging. There are also some emissions associated with producing and scrapping the batteries. However, these emissions represent a small share relative to the total. More than 90 percent of the GHGs emitted from EVs come from the process of producing, transporting, and storing fuel. The remaining GHG emissions are emitted during the feedstock-related stage, which includes feedstock recovery, transportation, and storage. No GHG emissions are associated with the vehicle operation stage, covering vehicle refueling and operations. The share of fuel-cycle energy use and emissions of conventional gasoline vehicles by stage. More than 80 percent of GHGs emitted from gasoline vehicles come from vehicle operation. Another 15 percent is emitted during the fuel production, transport, and storage stages. As most of the GHG emissions associated with the use of EVs are emitted during the downstream process, a full fuel cycle analysis of emissions should be used to estimate the GHG benefits of EV projects. Depending on the power generation mix in use for the area where an electric vehicle is recharged, the overall emissions can be much less than those from conventional gasoline vehicles. If the battery of the electric vehicle is recharged in a region with a very coal intensive electricity generation mix, GHG emissions will be higher than if the battery is recharged with electricity from mainly renewable or natural gas-based electricity. EVs may have nearly zero total emissions when recharged with electricity generated by nuclear power or renewable sources. For example EVs recharged in California result in much lower emissions than EVs recharged in Northeastern U.S. The GHG benefits of California vehicles are even higher if compared with EVs recharged with electricity similar to the U.S. average fuel mix.

3.3.2 GHG Emissions from HEVs

HEVs run on conventional fuels, and thus the vast majority of their GHGs are emitted from the emissions during each stage of the HEV fuel tailpipe during vehicle operation,

At least 80 percent of GHGs emitted are released during the vehicle operation stage. Similar to the case with gasoline vehicles, another 15 percent of GHGs are emitted during the fuel production, transport, and storage stages. Advanced HEVs, such as fuel cell vehicles using Hydrogen, are like EVs in that some or all of their GHG emissions may be produced during the fuel production and distribution stages.

4.0 Comparing Environmental Impact between CVS, HEVS, BEVS etc

Results of three calculation methods are shown below

i) The Greenhouse Effect 2007 (100 years)
ii) Human Health
iii) Air Acidification

In the Figure 7 the ranking of the vehicles are different according to the considered impact categories. When dealing with the Greenhouse Effect (GHE), gasoline cars have a big impact compared to the others. This is due essentially to the released emissions during the combustion of the gasoline. It is followed by the LPG car because of the combustion emissions of the LPG made with a propane and butane. But due to the contribution of the NiMH battery, the gasoline consumption of the hybrid car has been reduced and as a consequence its GHE is lower compared to other internal Combustion engines (ICE) vehicles. The BEV has the lowest GHE because it has zero tailpipe emissions. This is also the case when including the production and the distribution of the electricity which are not greenhouse emission free. In case of air acidification, unlike the GHE, the hybrid car is contributing more than the gasoline. This is due to the production of the nickel contained in the NiMH battery. The production of nickel is responsible for a higher emission of nitrogen oxides and sulphur oxides which are the main pollutants leading the acidification process. The emissions of the same pollutants during gasoline production explain the results of the gasoline car. The assessment of the different life cycle steps of the different vehicles (Figure 8) [4] shows that the use phase is the main cause of the GHE for all the analyzed vehicle technologies. In the specific case of gasoline cars, moving to recent euro standard cars (euro 4 and 5) does not reduce their GHE. However, in the case of LPG cars, euro 4 cars seem to contribute slightly more to the GHE compared to euro 2 and 3 vehicles. This is probably due to the fact that new cars are becoming heavier because of extra options. The calculation of the human health impact (Figure 8) with the Impact confirmed the ranking given by the air acidification assessment. This is due to the fact that the Nitrogen oxides and sulphur oxides are pollutants with high contribution for both air acidification and human health. Thus the BEV again scores better than the other technologies for this impact category. In order to have a clear comprehension of this result, the different vehicle technologies have been compared to each other at all the life cycle steps. The comparison revealed that the use phase is the main responsible of this impact for all the technologies. The step by step comparison showed that the hybrid impact has a relatively high impact for the manufacturing phase (raw material and assembly). For the battery production, the impact of the hybrid car is very high compared to the other technologies. This is due essentially to the nickel production which emits more nitrogen oxide and sulfur oxide. (Fig 6) [4]

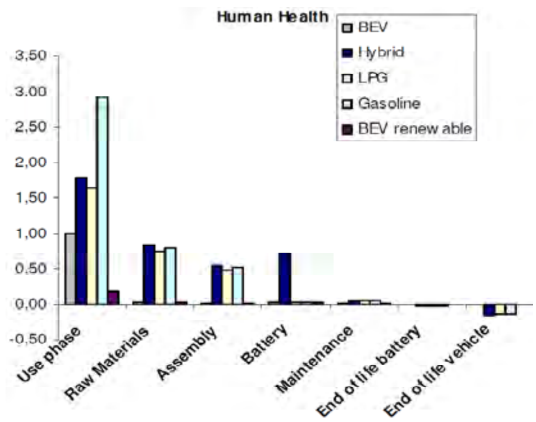

Fig 6: Human health step by step different vehicle technologies. [4]

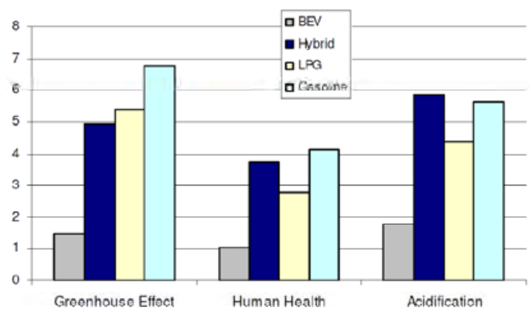

Fig 7: Comparative results of BEV, of the Hybrid, LPG and gasoline cars [4].

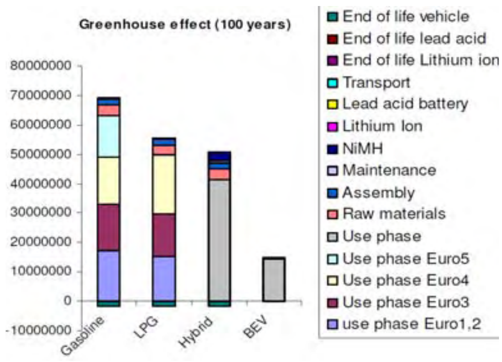

Fig 8: Contribution of the different life cycle steps to the GHE [4]

5.0 Effect on Socio-Economics

5.1 Effect on Employment

The deployment of electric cars will trade of employment gains in new "green collar" industries with losses in industries involved in petroleum delivery and internal combustion engine maintenance. [10] The net Effect is significant job creation. The projections for employment gains are made for both the charging network and battery manufacturing industries will likely be additional job creation in the domestic electricity sector. It is assumed that the deployment of electric cars does not directly impact the employment in automobile manufacturing and that the share of domestically produced light vehicles remains stable. Again other assumption is that domestic petroleum production continues at full capacity, as determined by the price of oil and the federal and state regulations on oil extraction. Estimates for the employment in the charging infrastructure and automotive battery manufacturing industries are based on the annual revenue projections for each industry and the revenue-to-employee ratio of industries with similar characteristics. The employment gains under each adoption scenario are substantial, with between 130,000 and 250,000 net new jobs created up to year 2030 (Becker et al ,University of California, Berkeley, 2009). The largest source of job creation comes from the deployment of a nationwide charging infrastructure. These jobs include construction, electrical services, and service sector jobs associated with the deployment, operation, and maintenance of public charge spots and batteries witching stations. Though the eventual market size of the high price and the operator-subsidized scenarios are the same, there is great ernet job creation under the operator- Subsidized scenario due to the larger share of electric vehicles in the U.S. under that scenario. The adoption of electric cars, driven primarily by their lower purchase price and costs of maintenance and fueling, will negatively affecting industries that supply parts and services for the petroleum-based light-Vehicle fleet. Job losses are projected to occur among gas station attendants, auto parts suppliers, and mechanics. Gas station attendant employment declines linearly as a proportion of the fleet that converts to electric cars. The maintenance cost savings of electric drive trains stems from their being much simpler mechanical devices than combustion engines and having fewer components. As such, the parts supply industry and mechanics will have fewer parts to produce and maintain on electric vehicles. Overall, these Job losses are more than offset by the gains in domestic battery manufacturing and charging infrastructure deployment.

5.2 Effect on future Car market

HEVs cost more to produce for manufacturers and more to buy for consumers than internal combustion engine (ICE) cars. Manufacturers add a price premium to HEVs based on a comparable conventional vehicle (CV). The CV gives a basis for calculating the price premium. Most hybrid vehicles on the market today are modifications to existing models of cars. For example, Honda markets the Honda Civic and the Honda Civic Hybrid. Not many car companies start from scratch when making an HEV, however, Toyota succeeded in doing so with the Prius. The CV used to compare the Prius with is the Toyota Corolla. Added electrical drive components, the complex drive train and additional weight are factored into the price premium. The question is then; does the money saved from spending less on gasoline make up for the extra expense of the HEV. There are many factors to consider when attempting answering this question, such as tax breaks for HEV owners, cost to insure, cost for maintenance, repairs, and other incentives and need to do a detailed study.

Conclusions

1. Hybrid power systems in vehicles can offer solutions and value to customers that individual technologies cannot match.

2. The impact of hybrid car on human health is higher for the manufacturing step. The nickel contained in the NiMH battery is the main cause of this bad score.

3. In case of batteries its impacts of the assembly and production phases can be compensated to a large extent when the collection and recycling of the batteries is efficient and performed on a large scale.

4. Looking at the global results, the following environmental ranking is obtained: nickel–cadmium, lead–acid, nickel–metal hydride lithium ion and sodium–nickel chloride decreasingly. Globally three battery technologies (lead–acid, nickel–cadmium and nickel-metal hydride) appear to have very comparable impacts on the environment.

5. Three of the technologies (lead–acid, nickel–cadmium and nickel-metal hydride) have a comparable environmental burden and this burden is higher than the ones of the other two technologies, being lithium-ion and sodium–nickel chloride.

6. In case of Nickel–cadmium batteries, cadmium has a fatal by-product of zinc production. Because for every produced ton of zinc, approximately 3 kg of cadmium are produced.

7. Venting is a safety issue for the battery pack. A NiMH cell releases hydrogen gas while venting, and when the hydrogen gas mixes with the gases in the atmosphere potentially explosive combinations could be formed.

8. The greenhouse effect analysis shows that the Gasoline car has the worst score and the BEV the best one. The hybrid car is slightly better than the LPG car. These results are directly linked to the type and the consumption rate of vehicle fuels.

9. When assessing the air acidification, one can notice that the hybrid car has the highest impact. This is due essentially to the use of the nickel during the NiMH battery production. The BEV scores again better, followed by the LPG and the gasoline. These results are function of the nitrogen oxides and sulfur oxides emissions.

10. The assessment of the impact on human health confirmed the best score of the BEV compared to all the assessed vehicle technologies. Like for the GHE, the gasoline car has the worst score for human health, due to the high nitrogen oxides and sulphur oxides emissions during its use phase.

11. Hybrids offer market entry strategies for technologies that cannot currently compete with the lowest-cost traditional options.

12. The Job losses due to introduction of HEVs are more than offset by the gains in domestic battery manufacturing and charging infrastructure deployment.

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Selection and Requirements of Hybrid Electric Drive-train Based on Energy Storage Devices

Kannan T, Department of ECE, IITG;
E-mail- kannan@iitg.ernet.in
Mohammed Nasir Ansari, Department of ECE, IITG;
E-mail-m.ansari@ iitg.ernet.in
Praveen Kumar, Department of ECE, IITG;
E-mail-praveen_kumar@iitg.ernet.in

Abstract

This paper describes a comparative study allowing the selection of the most appropriate electric-propulsion system for hybrid electric vehicles (HEV) requirements, selection of energy storage devices (ESD) for HEV such as battery, supercapacitor (SC) and fuel cell and selection of converter. The requirements of HEV depend on efficiency, reliability and controller performance. Considering the battery technologies, the energy density is high, but with a poor power density. The opposite is the main characteristic of capacitors: a limited energy density with a high power density. New components, such as the SCs, offer today an alternative to this dilemma. This leads to new applications for energy storage, even if the energy density is still lower than that one of the batteries. The fuel cells directly convert fuel and an oxidant into electricity through an electrochemical process; they produce very low emissions and have higher operating efficiencies.

Keywords

Energy management system, fuel cell, hybrid electric drive train, lithium-ion battery, SC and voltage source converter.

1. Introduction

The developments of global economy integration, with the environmental problems have become the important factors that influence the future situation of the world and the development and safety of each country. Therefore, the environmental problem is one of the focus problems that we must concern seriously in the process of the development of society and economy in our country. The treatment of environment pollution is an effective way in solving the environmental pollution in our country [1-4]. One of the environmental pollution problems due to burning of fossil fuels (coal, oil, and natural gas) are becoming dominant issues in our society. The pollutant gases causes global warming, acid rain and urban pollution problem. The pollution problems can be mitigated by emphasizing safe and clean environment, to development of the HEV fulfills and reduce the environmental pollution issues [5-6]. The advantage of an HEV is that the fuel cell is most efficient operating point for ESDs; the fuel cell usually produces its lowest levels of emissions. The HEV has an electric drivetrain like an electric vehicle (EV) and a regenerative breaking mode recharge the ESD, such as SC, battery (lithium- Ion). The SC is electrical ESD, which offer significantly better energy densities than conventional capacitors, better power densities than conventional batteries, its provides the lowest costs per farad, has extremely high cycling capability and environmentally safe [7-8]. SC is utilized for a wide range of applications, such as electric vehicles [9-10], distributed generation systems [11-12] and wind energy generation [13-14] etc. Lithium-ion batteries are suitable as HEV because of their high energy densities and long lifetimes. Moreover, lithium-ion is a low maintenance battery, an advantage that most other chemistries can’t claim. There is no memory effect and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to nickel cadmium and making lithium-ion well suited for energy storage systems for traction applications [15-16]. Fuel-cell generation systems have been receiving more attention in recent years because of their high efficiency, low adverse effects on the environment, lack of moving parts and superior reliability and durability [17]. Fuel cells are especially attractive because it is the only current technology capable of reducing vehicle emissions and fuel consumption by a large amount in a short period of time [18]. Those ESD stores the energy with a high energy and power density, then energy are transferred to motor via DC-DC regulator (Boost converter) and voltage source converter (VSC). The selection of a DC-DC converter based on determine overall HEV charging and discharging system specifications, determine converter specifications, losses and volt – ampere (VA) utilization of potential, compare converters, and select converter & implement [19]. The selection of VSC based on high-frequency link, soft switching for the main devices, fixed operating frequency, operating over wide load range, high efficiency and reliability, and less electromagnetic interference. A hybrid drivetrain in which two power sources feed a single electric motor as shown in figure. 1, it consists of primary power source (fuel cell), secondary power source (lithium-ion battery), energy management system, power electronic converters and traction motor (PMSM). The typical primary power source is fuel cell coupled to a power converter unit. The output of the fuel cell is (DC voltage) connected to a voltage source converter (VSC). The secondary power source is a lithium-ion battery (LIB), which is connected to power electronic converter (DC-DC regulator). The VSC is connected to the electric traction motor. The traction motor can be controlled as a motor or a generator and either in forward or reverse operation. This drivetrain may need a battery charger to charge the battery by plug-in from the power source.

2. HEV Drivetrain

2.1 Requirements of HEV

In this section discuss the major requirements, different operating modes, advantages and disadvantages of HEV. The electric powertrain basically required to develop sufficient power to meet the demands of vehicle performance, carry sufficient energy onboard to support vehicle driving in the given range, high efficiency, and emit less environmental pollutants. The HEV consists of two power sources; one is primary power source and another one is secondary power source. For the purpose of recapturing part of the breaking energy, HEV has at least one bidirectional energy source, typically chemical battery (LIB) or SC.

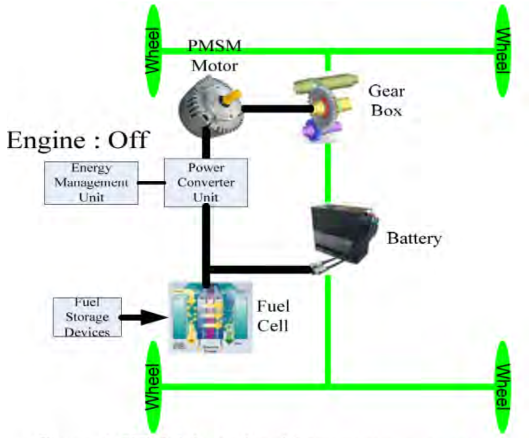

Figure 1. HEV drivetrain with two energy sources.

The major requirements of electric propulsion HEVs are summarized as follows [20-21]:

1. Very high instant power and a high power density.
2. High torque at low speeds for starting and climbing, as well as a high power at high speed for cruising.
3. Very wide speed range, including constant-torque and constant-power regions.
4. Fast torque response.
5. High efficiency over the wide speed and torque ranges.
6. High efficiency for regenerative braking.
7. High reliability and robustness for various vehicle operating conditions, and
8. Reasonable cost

The configuration of the fuel cell HEV powertrain with the battery as the ESD is shown in Figure 2.

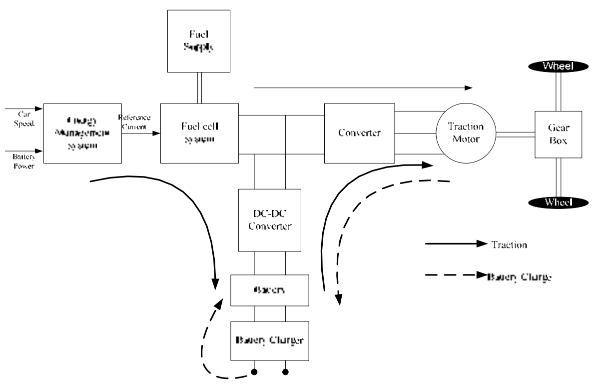

Figure 2. Configuration of fuel cell HEV powertrain with battery

The fuel cell HEV Powertrain with battery consists of a fuel-cell stack, a lithium-ion battery, a DC-DC converter, an inverter, an AC traction motor and a gear box. The fuel-cell stack is paralleled with the battery to multiplies the motor torque via gear reduction [22]. The different operating mode of a HEV are summarized as follows, 2.1.1 Start When the vehicle is started the fuel cell warms up, if

2.1.2 Cruising

The fuel cell powers the vehicle at cruising speeds and, if needed, provides power to the battery for later use.

2.1.3 Passing

During heavy accelerating or when additional power is needed, the fuel cell and electric motor are both used to propel the vehicle. Additional power from the battery is used to power the electric motor as needed.

2.1.4 Regenerative Breaking

Regenerative braking converters otherwise wasted energy from braking into electricity and stores it in the battery. In regenerative braking, the electric motor is reversed so that, instead of using electricity to turn the wheels, the rotating wheels turn the motor and create electricity. Using energy from the wheels to turn the motor slows the vehicle down. If additional stopping power is needed, conventional friction brakes are also applied automatically.

2.1.5 Stopped

The vehicle is stopped, such the fuel cell and electric motor shut off automatically so that energy is not wasted in idling.

2.1.6 Electric Motor Drive

The electric motor provides additional power to assist the engine in accelerating and passing or hill climbing. This allows a smaller; more efficient motor to be used in some vehicles, the motor alone provides power for low speed driving conditions.

make the dc link. The DC-DC converter regulates the dc-link voltage. The inverter converts the regulated dc voltage to an AC voltage to drive the ac motor. The transmission is a gearbox that necessary the electric motor acts as a generator, converting energy from the engine into electricity and store in the battery.

2.1.7 Automatic Start and Stop

Automatically shuts off the motor when the vehicle comes to a stop and restarts it when the accelerator is pressed. This prevents wasted energy from idling.

2.2 Advantage of HEV

1. Use less fuel, get better mileage, cost less to run.
2. Provide a quieter, better-quality ride.
3. High efficiency.
4. Emit less environmental pollutions.
5. Emit fewer greenhouse gases that contribute to global warming.
6. Reduce our dependence on foreign oil and enhance national security.

2.3 Disadvantage of HEV

1. Have expensive batteries that might wear out before vehicle does.
2. Less safe (batteries may pose a danger to people unfamiliar with them, like mechanics or rescue workers at an accident scene)
3. Create hazardous waste (used batteries need to be recycled or disposed of in a safe manner)

In this section discuss the requirements of HEV, different operating mode, advantage and disadvantages. In next section discuss the ESDs

3. Flow Chart for HEV

In this section discuss the overall HEV flow chart as shown in Figure 3. It consist energy management system, ESDs, power electronics converter, PMSM motor and vehicle dynamics.

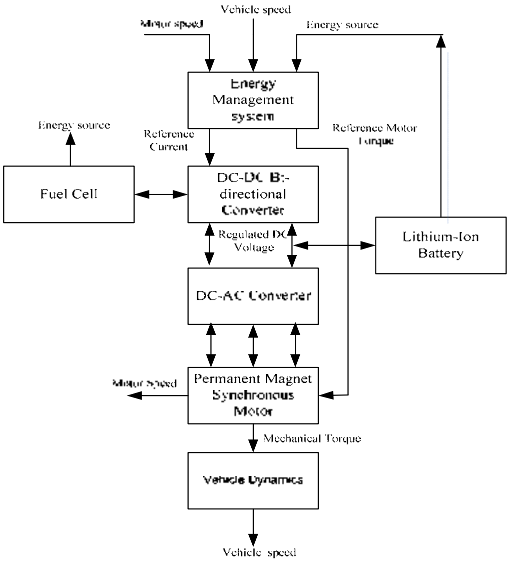

Figure 3. Flow chart for HEV

4. Energy Storage Devices

4.1 Lithium-Ion Battery

In this section discuss the different ESDs requirements, advantages and disadvantages. The selection is a battery is best achieved by setting a list of minimum requirements, conditions and limitations as follows:

1. Maximum permissible voltage at the beginning of discharge.
2. Normal voltage during discharge (voltage stability on load).
3. End-voltage, that is, voltage at which equipment ceases to function properly.
4. Current-voltage relations: constant current (amps), constant resistance (ohms), and constant power (watts).
5. High energy storage and service life.
6. Environmental conditions in storage and in service.
7. Physical restrictions such as dimensions and weight.

The sealed LIB are especially well suited to applications of a HEV where a self-contained power source increases the versatility or reliability of the end product. Among the significant battery futures and benefits of sealed lithium-ion batteries which lead to their selection as the battery of choice for demanding applications are following:

1. High energy density
2. High rate discharge and fast recharge
3. Long operating and storage life
4. Rugged construction
5. Operation over a broad range of temperatures
6. Operation in a wide range of environments
7. Continuous overcharge capability

4.1.1 LIB advantages

The major advantages of the lithium-ion battery are follows:

1. Virtually unlimited shelf life
2. Wide operating temperature range
3. High energy and voltage density.
4. No gassing , corrosion or leakage and safety

4.1.2 LIB Disadvantages

1. Low voltage regulation
2. High initial cost
3. Environmentally unfriendly-the electrolyte and the lead content can cause environmental damage.
4. Allows only a limited number of full discharge cycles

The configuration of the HEV powertrain battery with the SC as the energy-storage device is shown in Figure 4. The HEV powertrain with battery with SC consists of a lithium-ion battery, a DC-DC converter, an inverter, a traction motor and a gear box. The battery is paralleled with the SC to make the dc link. The DCDC converter regulates the DC-link voltage. The inverter converts the regulated DC voltage to an AC voltage to drive the AC motor.

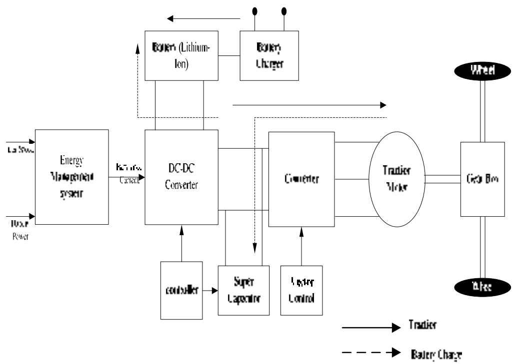

Figure 4. Configuration of HEV powertrain battery with SC.

4.2 Supercapacitor

SC is electrical ESDs which offer high power density and extremely high cycling capability.

Recent developments in basic technology have made SCs an interesting option for short-term energy storage in low-voltage power electronic systems [23-24]. Usually, SCs are modeled using simple RC circuits. However, these models cannot accurately describe the voltage behavior and the energy efficiency of these devices during dynamic current profiles [25-27]. The advantages of secondary ESD are follows:

4.2.1 SC Advantages

1. Long life cycle (> 500000) and efficiency (>95%)
2. Power density is higher there are no chemical reactions during charging and discharging.
3. Less weight, cost and size.
4. Large current/power capabilities over a wide range of operating temperature
5. High power density in both directions (charge and discharge)
6. Very high rate of charge and discharge.
7. Require less maintenance

4.2.2 SC Disadvantages

1. Low energy density
2. Requires sophisticated electronic control and switching equipment.

4.3 Fuel Cell (Hydrogen)

A fuel cell by definition is an electrical cell, which unlike storage cells can be continuously fed with a fuel so that the electrical power output is sustained indefinitely. Fuel cells are electrochemical devices that convert chemical energy stored in a fuel into electrical energy through electrochemical reactions without combustion [28]. Fuel cell electric vehicle have received considerable attention recently due to their high-energy efficiency, low-exhaust emissions, low-operating noise and long vehicle range [29]. It converts hydrogen, or hydrogen containing fuels, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water.

4.3.1 Fuel cell advantages

1. Fuel cells eliminate pollution caused by burning fossil fuels.

2. Using fuel cell to eliminates greenhouse gases.
3. Fuel cells do not need conventional fuels such as oil or gas and can therefore eliminate economic dependence on politically unstable countries.
4. Fuel cells have a higher efficiency than diesel or gas generator.
5. Low temperature fuel cells have low heat transmission which makes them ideal for military applications.
6. Operating times are much longer than with batteries,
7. Fuel cells have no “memory effect” when they are getting refueled.
8. The maintenance of fuel cells is simple since there are few moving parts in the system.

4.3.2 Fuel cell Disadvantages

1. Fuelling fuel cells is still a problem since the production, transportation, distribution and storage of hydrogen is difficult.
2. Reforming hydrocarbons via reformer to produce hydrogen is technically challenging and not clearly environmentally friendly.
3. Fault diagnosis requirement.
4. The refueling and the starting time of fuel cell vehicles are longer and the driving range is shorter than in a “normal” car.
5. Fuel cells are in general slightly bigger than comparable batteries or engines. However, the size of the units is decreasing.

In this section discuss the advantage and disadvantage of
HEV ESD.

5. Converter Selection

5.1 Converter Topologies

In this section, select the converter topologies for HEV drivetrain selected based on the power electronics switching losses, electromagnetic interference, switching frequency, total harmonic distortion, reliability and efficiency of a converter. The schematic diagram of voltage regulator and VSC as shown in figure 5, it consists of controller circuit, energy sources, voltage regulator and VSC [30].

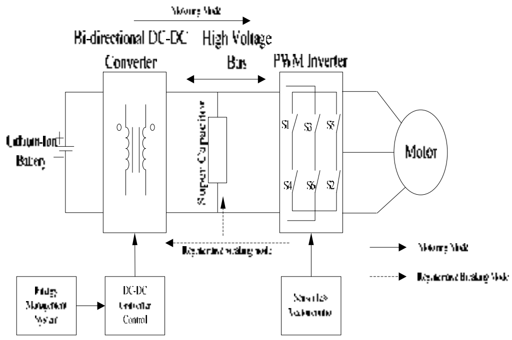

Figure 5. Schematic diagram for DC-DC regulator and VSC converter

5.2 Energy management system

The ultimate goals of energy management system to achieve maximum energy efficiency based on the fundamental objectives are following

1. Achieving maximum energy efficiency
2. Providing a high level of vehicle performance
3. Maintaining a low emission level.

The optimal performance of the overall vehicle system rather than that of each individual subsystem, it's imperative to carefully study all power subsystems including power sources, ESDs, electric motors, power converters and develop a well defined problems decision.

The constraints in automotive electric energy and power management systems are imposed by

1. Dynamic resource allocation requirement
2. Practical component constraints
3. Uninterruptible power availability requirement
4. Power quality requirement
5. System stability requirement

6. Conclusion and Future Work

This paper discussed, to reduction of our environmental pollutant problems in our society using requirements of HEV drivetrain, advantages and disadvantages of ESDs and selection of ESDs (ESD) such as lithium-ion battery, SCs, of HEV, because to achieve high raiding comfort to select proper ESD and power electronic converter. The selection of the ESD and power electronic converter based on above comparative study, which is hydrogen fuel cell, lithium-Ion battery, SC and bi-directional power electronic converter. In future, to make a mathematical modeling and analysis of HEV, LIB, SC and fuel cell, to compare the performance of a HEV using the combination of battery plus fuel cell and battery plus super capacitor.

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Life Cycle Assessment of Lithium Ion Battery.

Kunwar Raghvendra Singh, Department of Civil Engineering, IITG;
Email- kunwar@iitg.ernet.in
Jyoti Chaubey, Department of Civil Engineering, IITG;
Email- c.jyoti@iitg.ernet.in

Abstract

Battery powered electric cars are often promoted as the ideal solution to the challenges of future mobility, since they produce no exhaust gases in operation. Li-ion batteries have established themselves over competing lead-acid and nickel metal-hydride (NiMH) types because they are lighter and can store more energy. Li-ion batteries are also basically maintenance-free, display no memory effect (loss of capacity when repeatedly charged after partial discharge), have a low self-discharge rate and are regarded as safe and long-lived. Present study discusses aspects of Life Cycle Assessment (LCA) methodology which come into focus when applying LCA to lithium ion battery. Different aspects right from production to disposal and even recycling of lithium ion battery were considered and then LCA methodologies were applied to each of the aspects.

Keywords

Life Cycle Assessment, Lithium ion battery, Electric Vehicle

1.0 Introduction

Rapid advancement of science and technology has become the engine for great industrial and economic growth. Although this advancement has many advantages but along with it, many disadvantages also. Global warming has become one of the serious issues which we are facing today due to this rapid urbanization and industrialization. One of the reasons behind the global warming is the emissions from the transportation sector. The scientists reported that within the transport sector, road transportation (cars, buses and trucks) contribute the most greenhouse gases, which includes CO2, ozone, methane, and others. Globally, about 15 percent of manmade CO2 comes from cars, trucks, airplanes, ships, and other vehicles. Reducing transportation emissions is one of the most vital steps in fighting global warming. Shifting away from fossil fuel-powered vehicle dependence and the suburban sprawl that accompanies it, toward alternative fuels technology is needed for the benefit of the planet [1].

Along with the above reason the another reason is that, with oil again approaching $70 a barrel and gasoline prices at the pump over $3.00 per gallon, vehicle owners are feeling increased economic pain and looking for relief. The solution offered is again incorporation of efficient electric motors to displace conventional internal combustion engine (ICE) power with batteries [2].

Thus Electric vehicles are seen as the main answer to the transport sector's problems of diminishing oil supplies and global warming. Several studies have shown the potential benefits of electric vehicles (including hybrid versions) compared to the traditional internal combustion engine vehicle. Potential fuel savings between 25% for hybrid electric vehicles and up to 50%-80% for plug-in hybrids depending on the battery size have been reported [3]. Assuming that the electricity (which is replacing the fuel) can be generated by renewable energy sources, considerable reductions of CO2 emissions from the transport sector are thus possible. Therefore, substantial efforts are today being made to develop battery systems for vehicles with electric power trains**.**

LCA is currently being used in several countries to evaluate different strategies for the product development stage in order to identify environmental hot-spots and aid in directing development efforts in relevant areas [4,5,6]. The concept of Environmental LCA of a product or a process is a relatively recent one (early nineties) which emerged in response to increased environmental awareness on the part of the general public, industry and governments. The immediate precursors of life cycle analysis and assessment (LCAs) were the global modeling studies and energy audits of the late 1960s and early 1970s. These attempted to assess the resource cost and environmental implications of different patterns of human behavior. A 'Life Cycle Assessment' (also known as 'eco-balance' and 'cradle-to-grave analysis') is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a given product or service throughout its life cycle. The LCA studies the environmental aspects and potential impacts throughout a ‘product’s’ life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal [7]. This is done by compiling an inventory of relevant inputs and outputs of a system (the inventory analysis), evaluating the potential impacts of those inputs and outputs (the impact assessment), and interpreting the results (the interpretation) in relation to the objectives of the study (defined in the goal and scope definition in the beginning of a study) [7].

Present study discusses aspects of LCA methodology which come into focus when applying LCA to lithium ion battery.

2.0 Why implement LCA?

All products/processes have some impact on the environment. Since some products/processes use more resources, cause more pollution or generate more waste than others, LCAs aim is to identify those which are most harmful and enable to choose the least burdensome one. Even for those products/processes whose environmental burdens are relatively low, the LCA helps to identify those stages in the processes which cause or have the potential to cause pollution, and those which have a heavy material or energy demand. Breaking down the processes of a system into such fine detail can also be an aid to identifying the use of scarce resources, showing where a more sustainable product could be substituted.

The term 'life cycle' refers to the notion that a fair, holistic assessment requires the assessment of raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence. The sum of all those steps or phases is the life cycle of the product. The concept also can be used to optimize the environmental performance of a single product (eco design) or to optimize the environmental performance of a system. For Lithium ion battery, it is accepted that LCA concepts and techniques provide an overview of all the environmental issues related to the use of lithium ion batteries.

3.0 LCA Phases and LCA of Lithium Ion Batteries

There are four ISO (International Organization for Standardization) standards specifically designed for LCA application:

ISO 14040: Principles and framework
ISO 14041: Goal and Scope definition and inventory analysis
ISO 14042: Life Cycle Impact assessment
ISO 14043: Interpretation

Currently (early 2006) two draft standards have been published that will replace these four standards:

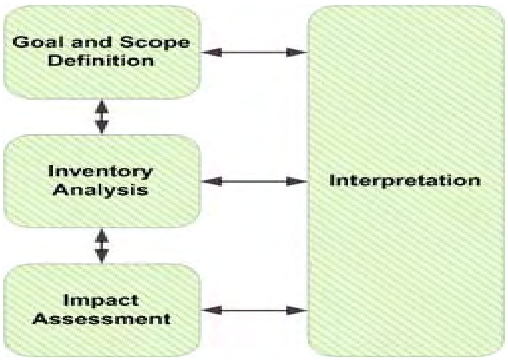
ISO/DIS 14040: Principles and Framework
ISO/DIS 14044: Requirements and Guidelines
According to ISO 14040, an LCA comprises four major stages: goal and scope definition, life cycle inventory, life cycle impact analysis and interpretation of the results.

3.1 Goal and scope

In the first phase, the goal and scope of study in relation to the intended application is specified and formulated. The goal and scope addresses the overall approach used to establish the system boundaries. The system boundary determines which unit processes are included in the LCA and reflects the goal of the study. Finally the goal and scope phase includes a description of the method applied for assessing potential environmental impacts and which impact categories those are included.

To diminish the transport sector’s problems related to oil supplies and global warming, Electric car came into the picture. In electric vehicles Lithium Batteries, in place of conventional engines, are proving themselves as a better option. From transport perspective, Lithium Batteries are performing very good task but on a broader perspective then the impact of Lithium Batteries right from the production to the disposal and even again recycling needs to be assessed.

Fig1: LCA phases
(Source:http://en.wikipedia.org/wiki/Life_cycle_assessment)



The system boundary is based on the general rules of the EPD system [8]. The principle is to separate the product systems at the point where the waste products have their lowest value. Furthermore, the product system that pays money at this "lowest-value-point" (either to get rid of the waste or to get the waste resource) should carry future environmental impacts. The system boundary for the study is shown below (Fig. 2).

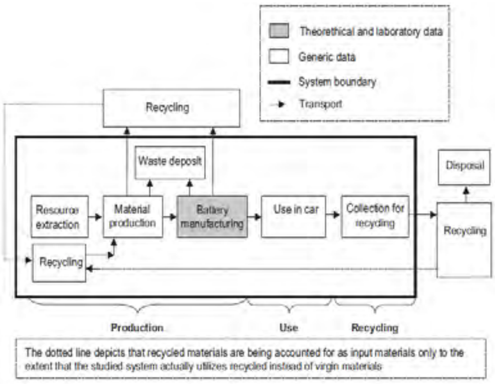


Fig 2: System Boundary for the LCA of lithium ion Battery (Source: Mats Zackrisson et al., 2010)

3.2 Life cycle inventory (LCI)

This second phase 'Inventory' involves data collection and modeling of the product system, as well as description and verification of data. This encompasses all data related to environmental (e.g., CO2) and technical (e.g., intermediate chemicals) quantities for all relevant unit processes within the study boundaries that compose the process system. Examples of inputs and outputs quantities include inputs of materials, energy, chemicals and other and outputs of air emissions, water emissions or solid waste. Other types of exchanges or interventions such as radiation or land use can also be included. The results of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved in the study.

Main components of Lithium ion batteries are: Cathode, Anode, Separator, Cell packaging, Electrolyte and Some other electronics. Raw materials for Cathode are generally Lithium, Phosphate, Iron and Carbon. Anode is generally made of graphite coated on copper foil and binder. The separator is made of equal proportions of polypropylene and polyethylene [9]. Cell packaging is made of polypropylene and aluminum foil [10]. The electrolyte is usually an expensive 1-M solution of a lithium salt in an inexpensive organic solvent such as propylene carbonate or dimethyl carbonate [10]. Salts under consideration are among others lithium hexafluorophosphate, LiPF6 and Lithium tetrafluoroborate, LiBF4.

The high price of electrolytes and low price of lithium chloride indicate that there is very often a strong correlation between price and environmental impact [11]. However, immature technologies like these electrolytes may have other causes for commanding a high price. The cell electronics are assumed to be a semiconductor to enable switching on and off and a resistor for temperature measurements.

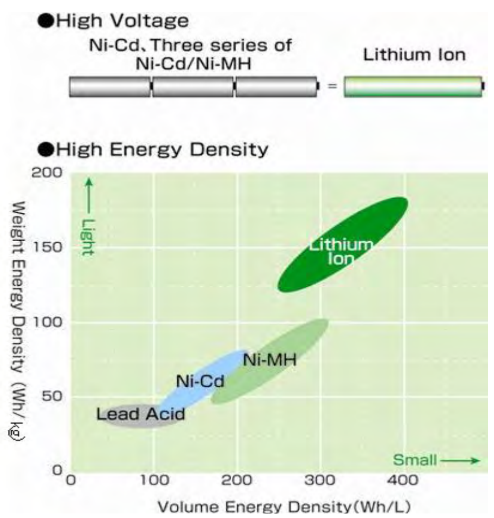


Fig 3: Features of Li-ion battery (Source: http://www.eco-aesc.com/en/liion.html)

Lithium Ion batteries (e.g. Panasonic) are classified by the federal government as non-hazardous waste and are safe for disposal in the normal municipal waste stream. These batteries, however, do contain recyclable materials and are accepted for recycling by the Rechargeable Battery Recycling Corporation's (RBRC) Battery Recycling Program [2].

3.3. Life cycle impact assessment

The third phase LCA is aimed at evaluating the contribution to impact categories such as global warming, acidification, etc. Common categories of assessed damages are global warming (greenhouse gases), acidification, smog, ozone layer depletion, eutrophication, eco-toxicological and human-toxicological pollutants, habitat destruction, desertification, land use as well as fuels. Assessment consists of three main steps:

1. Characterization: Here, impact potentials are calculated based on the LCI results.
2. Normalization: Normalization provides a basis for comparing different types of environmental impact categories (all impacts get the same unit).
3. Weighting: It implies assigning a weighting factor to each impact category depending on the relative importance. The weighting step is not always necessary to create a so called "single indicator".

Researchers at Empa's "Technology and Society Laboratory" calculated the ecological footprints of electric cars fitted with Li-ion batteries, taking into account all possible relevant factors, from those associated with the production of individual parts all the way through to the scrapping of the vehicle and the disposal of the remains, including the operation of the vehicle during its lifetime. Data with which to evaluate the rechargeable batteries were not available, were obtained specifically for this purpose. Other relevant LCA information was obtained from the "ecoinvent" database [12], managed by Empa.

The LCA study finds that the environmental burden caused by the lithium-ion battery is of at most 15% of the total impact of the electric car (which includes making it, using and maintaining it, and disposing of it at the end of its useful life). Interestingly, the lithium itself represents just a small part of that; about 7.5% of the impact occurs when "refining and manufacturing the battery's raw materials, copper and aluminium". The lithium itself is only responsible for 2.3% of total. The study showed that the electric car's Li-ion battery drive is in fact only a moderate environmental burden. At most only 15 per cent of the total burden can be ascribed to the battery (including its manufacture, maintenance and disposal) [13].

The outlook is not as rosy when one looks at the operation of an electric vehicle over an expected lifetime of 150'000 kilometers. The greatest ecological impact is caused by the regular recharging of the battery, that is, the "fuel" of the e-car. "Refueling" with electricity sourced from a mixture of atomic, coal-fired and hydroelectric power stations, as is usual in Europe, results in three times as much pollution as from the Li-ion battery alone. It is therefore worth considering alternative power sources: If the electricity is generated exclusively by coal-fired power stations, the ecobalance worsens by another 13 per cent. If, on the other hand, the power is purely hydroelectric, then this figure improves by no less than 40 percent [13].

3.4 Interpretation

The phase stage 'interpretation' is an analysis of the major contributions, sensitivity analysis and uncertainty analysis. This stage leads to the conclusion whether the ambitions from the goal and scope can be met. More importantly: what can be learned from the LCA? All conclusions are drafted during this phase. Sometimes an independent critical review is necessary, especially when comparisons are made that are used in the public domain.

"Lithium-ion rechargeable batteries are not as bad as previously assumed," according to Dominic Notter, coauthor of the study which has just been published in the scientific journal "Environmental Science & Technology."

When comes to the metal lithium supply, world has ample of this metal and lithium isn't destroyed when used in a battery, so it can be recycled and reused. The total impact of EV batteries can be further reduced if at the end of their "vehicle" life they are used for other forms of energy storage. Indeed, they can still hold up to 80% of their charge even after having been used for years in a vehicle, so before recycling them, they could be used to store power on the grid (such as intermittent power from wind farms). But the most important thing when it comes to electric cars will be to clean up the power grid. That's the best bang for the buck when it comes to fighting global warming; a cleaner source of power for homes and industry combined with an electrified transportation sector would drastically cut greenhouse gas emissions [14]. These batteries have an improved cell-structure and new electrode materials designed to improve the energy and power density, and give them ten times the capacity of the batteries currently in hybrid electric vehicles.

4.0 Conclusion

Lithium ion battery is the ideal solution to the challenges of future mobility, since they produce no exhaust gases in operation with electric vehicle. Li-ion batteries have established themselves over competing lead-acid and nickel metal-hydride (NiMH) types. Reduced fuel consumption, reduced emissions and increased energy security/ diversification.

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Natural Vehicle Cooling System (NVCS).

Aman Gupta, Department of Design, IITG;
Email- g.aman@iitg.ac.in
Bharadwaj Radhakrishna, Department of Design, IITG;
Email- r.bharadwaj@iit.,ac.in
Pradeep Yammiyavar, Department of Design, IITG;
Email- pradeep@iitg.ac.in

Abstract

Today, we live in a world where every drop of petrol and every unit of electricity is precious. Not only are the reserves depleting at an alarming rate, but we are finding it hard to discover alternative fuels which are as efficient, cost effective and as accessible as petroleum. Today in a huge market of AC cars a single innovation that could minimize fuel use would add up to a big sum both in terms of natural and monetary resources. Automobiles fixed with air conditioners take up more fuel, pollute environment, decreases the mileage of the vehicle etc. As being the second fastest growing automobile industry in the world, India is a hub to lot of vehicles. And one problem which is very common in Indian context is the absence of adequate car shades or covered parking lots. Hence vehicles have to be parked generally in open parking lots and India, being a sunny country, leads to heating up internal atmosphere of any vehicle parked in the sun, be it a 4-wheeler, Bus or lorry. Today, people try solving this problem by different methods, most of which are either too costly or just not effective in cooling the car. The fact is, we tend to be discomfortable when entering into the car and a huge amount of energy is wasted in actually bringing the temperature down in the case of vehicles fitted with AC units leading to different complications. We are planning here to solve this common yet unsolved problem using simple yet effective use of natural forces. The solution lies in the problem itself. The very fact that this green house effect created inside the car creates temperature zones around/inside the vehicle is used to generate the forces required for ventilation and cooling of the vehicle in the stationary state.

Keywords

Cars, AC, Green House Effect, Heating, Pressure, Cooling, Temperature Difference.

Introduction

As said already, changing a little thing can result in a huge impact on the environment as it is multiplied millions of times and more. As a result, not only are we actually saving the resources put into this field but once developed, it can probably be implemented in various other areas thus giving a huge scope as it uses nothing more than basic principles of physics and fluid dynamics. So, the question is, in simple words, How can we cool a vehicle parked in the sun without wasting energy or causing discomfort to the user? To solve this, we are assuming that the user need/did not switch on the AC before closing the door of the car and parking. From research, we know that the environment in/around the car is basically divided into three broad zones.

T1 zone above the car (is the same as environment temperature)
T2 zone inside the car (under the effect of green house effect)
T3 zone under the car (created by the shade of the car parked in the sun)

Whenever there is a pressure difference created as a result of temperature difference, we have, relatively speaking, a high pressure and low pressure region. Because of pressure variation we have fluid transfer. Simply put, cold air rushes into hot air region and occupies the space as hot air is less dense and rises up. This motion of air from two points of different pressures is what causes monsoon in India. So how is that applicable here?

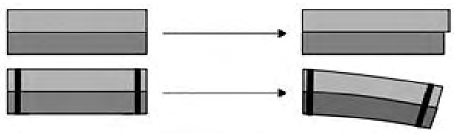
Research has shown that, a stationary car parked on any surface on a hot day, independent of air humidity, T2>T1>T3. [The inside car temperature (T2) is dependent on the amount of sunlight and time the car is left in the sun. T2 is greater than T1 because of green house effect. Whenever there is a temperature difference there is a creation of pressure variation between the two points (T2 (low pressure) and T3 (High pressure)).Using this pressure, a suction and air blower mechanism is automatically created without any external power source using a temperature sensitive material/membrane. The sensitive material that actually helps to open up the valves is bi-metallic strips. These bimetallic strips can be placed between the vent cap and the base material such that, whenever the temperature inside is increasing, it will in turn expand (bend) the sensitive material and thus increasing the gap between the vent cap and the base material thus facilitating the flow of air (cross ventilation modes). These vents will be placed at proper locations on the car for maximum flushing out of the hot air and input of cold air.

Background Research

- The value of air temperature variation between shade and sun was found to have its maximum value as 5 degree C [Source: WATER CONDITIONS AND PROLINE CONTENT IN SHADE AND SUN PLANTS K.H. BATANOUNY, A.H. HASSAN (Faculty of Science, Cairo University, Egypt)Y.M. ABU SITTA (Faculty of Science, Girls Branch, Al-Azhar university)]
- Temperature within the cabin is 20 − 30 deg C degrees higher than the temperature outside the car (at 40 − 45◦ C) in the middle of the day (a staggering maximum of 70◦C is reached) [Source: TEMPERATURE VARIATIONS IN A PARKED CAR I.R. Dadour (A Centre for Forensic Science, School of Mathematics and Statistics, University of Western Australia, 3 Crawley WA 6009, Australia I. Almanjahie, N.D.Fowkes, G.Keady, K.Vijayan (School of Mathematics and Statistics, University of Western Australia, Crawley WA 6009 Australia)]
- Every time you switch on your AC after your car have been parked in sun for 2 hours .7 L of standard petrol is invested in powering the AC unit to cool the car from T2 to T1 (T2 : Car temperature with windows closed while T1 is atmospheric temperature) [Source: IMPACT OF VEHICLE AIR-ECONOMY, TAILPIPE EMISSIONS, AND ELECTRIC VEHICLE RANGE R. Farrington and J. Rugh,(National Renewable Energy Laboratory (NREL) 1617 Cole Blvd. Golden, CO 80401)]

Bimetallic Strip

A bimetallic strip is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals which expand at different rates as they are heated, usually steel and copper, or in some cases brass instead of copper. The strips are joined together throughout their length by riveting, brazing or welding. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its initial temperature. The metal with the higher coefficient of thermal expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled. The sideways displacement of the strip is much larger than the small lengthways expansion in either of the two metals. This effect is used in a range of mechanical and electrical devices. In some applications the bimetal strip is used in the flat form. In others, it is wrapped into a coil for compactness. The greater length of the coiled version gives improved sensitivity.



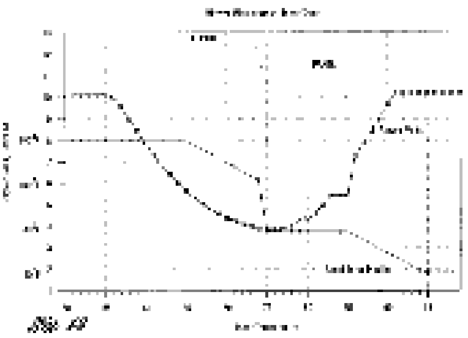
Bimetallic Strips [Source: http://en.wikipedia.org/wiki /Bimetallic_strip]

Automobile growth in India

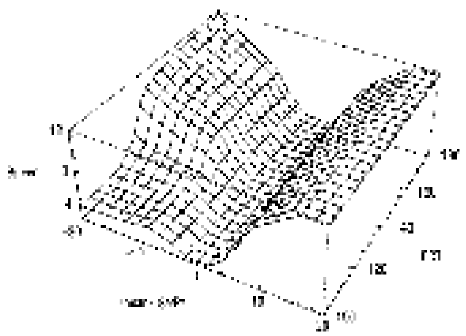
Year	Car Production	% Change	Commercial Vehicles	% Change
2009	2,166,238	17.34	466,456	-4.08
2008	1,846,051	7.74	486,277	-9.99
2007	1,713,479	16.33	540,250	-1.20
2006	1,473,000	16.53	546,808	50.74
2005	1,264,000	7.27	362, 755	9.00
2004	1,178,354	29.78	332,803	31.25
2003	907,968	28.98	253,555	32.86
2002	703,948	7.55	190,848	19.24
2001	654,557	26.37	160,054	-43.52
2000	517,957	-2.85	283,403	-0.58
1999	533,149		285,044	

[Source: http://en.wikipedia.org/wiki/Automotive_ industry_in_India]

Climate Control



How the fan speed and expelled temperature varies for a demanded temp of 75F

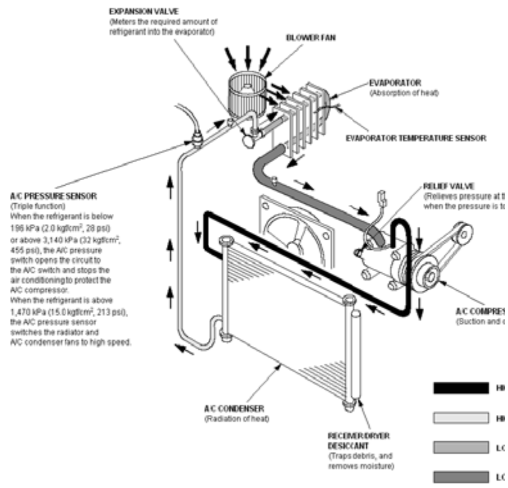


How the fan speed varies with coolant temperature

General Description

All cars other than the never-seen "S" specification (not Type S) have Climate Control (CC) which includes Air Conditioning (AC). This system should attempt to maintain a cabin temperature (set on a dial) by blowing hot or cold air and varying the fan speed and air direction to maintain the cabin temperature. The system will also try to cool the effect of radiated heat from the sun, by blowing colder when sunlight is detected by a sensor on the dash. The GPS sun direction from the Accord is fitted, but not implemented. If the air vents are aimed at your face, then you will feel some "odd" temperatures, since the system will vary the output temperature in order to maintain the cabin temperature.

Schematic View



Puddle of water under the car

This comes up all the time! The aircon has 2 functions - to cool the air and to remove the water. The water removal is why you should leave the aircon on in the winter, to stop the inside of the windows from misting up. The water that is removed from the air is discharged through a little pipe to the underside of the car. Sometimes when you park the car, a small puddle of water is left from this tube on the ground, and is quite normal.

Recirc comes on when Auto selected

If conditions are warm, Auto will engage the recirc function. That way the air conditioner will be cooling down already-cooled interior air, rather than warm exterior air, thus providing colder output air. After a while, when the interior temperature is under control the Auto function will switch off recirc and will draw in and cool external air.

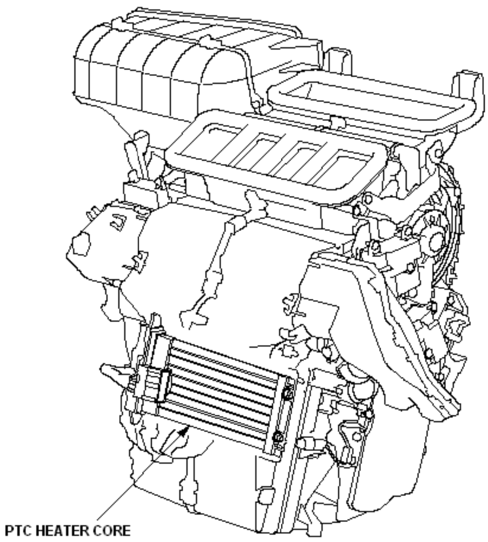
Suggested Usage

In "Auto" all functions are controlled by the ECU. The air conditioning compressor will be on, though it is always going to cycle on and off every few seconds to save fuel. You can turn individual functions to "manual", for example turning off the AC or reducing the fan speed, and the remaining systems will do their best to maintain temperature, albeit with reduced effectiveness. For those worried about increased fuel use from having the air conditioning compressor on, the increase is so small that it has yet to be measured by anyone. It is not wise to turn the AC function off, since this will increase misting, and reduce the life of the AC system. Suggested usage is:

1. Make sure all vents are open.
2. Make sure all vents are not blowing air directly on to you.
3. Set 21C.
4. Press Auto.
5. Let it do its thing.

PTC Heater

Diesel cars have an additional electric heater to add warmth to the cabin air when the coolant temperature is low and the outside air temperature is low. The heater is of the ceramic type (Positive Temperature Coefficient)



Possible Faults

After a period of driving, the system suddenly decides to blow an unusual amount of cold air. This may be caused by air from the driver's footwell vent rising up to the interior air sensor and fooling it into the fact that the cabin is hotter than it is, or possibly a software glitch that occurs after a certain period of time. There is no known fix at the moment.

Recently one dealer has suggested it may be a faulty spring in the vent mechanisms.

The temperature sensor in the cabin has cabin air sucked over it. It has been known for the pipe behind the grill to become disconnected - you can test this by turning the fan to full and placing a small bit of paper over the grill. The paper should be sucked into position, and should only fall off as you reduce the fan speed (see video - the fan speed is in the top right corner of the nav display, and the bit of paper is at the very bottom right of the video).

Diagnostic Tests

To see what the ECU considers to be the interior temperature, simply turn the temperature up and down until the fan speed is at a minimum.
The diagnostic tests are as follows:

1. Ignition OFF Press and hold down the A/C system's Auto and Mode buttons.
2. Start the engine
3. Release the buttons

On the A/C - Radio display you'll see the sensor number and the value for that sensor. To advance to the next sensor just press the mirror/rear window defogger button.

1st sensor: Cabin temperature C

2nd sensor: Exterior temperature C

3rd sensor: Solar radiation sensor value (Dark=00, Flashlight=04, Cloudy=10, Sunny=65)

4th sensor: Temperature of the air exiting the air conditioning evaporator C

5th sensor: Drivers air mix opening (low value indicates cooler air distribution, higher value indicates warmer air distribution) % open

6th sensor: Passenger air mix opening (low value indicates cooler air distribution, higher value indicates warmer air distribution) % open

7th sensor: Mode positioning % open

8th sensor: recirc flap % open.

9th sensor: vent output air temperature C

Other test:

Ignition OFF

Press and hold down the Auto and Recirculation buttons

Ignition into II position

Release the buttons

You'll see the "88" at the A/C temperature. If you see any letter from A to P then it means an error message. The messages can be read out only from the HDS system at the service.

Climate control experiment

This was an experiment done by an owner to: Work out if the system maintains a constant cabin temperature.

- Get a picture of how it distributes air.
- Find out if the cabin sensor is aspirated enough at low fan speeds.
- Find out if the footwell vent influences the cabin sensor.

The measurements were taken on a 2 hour journey. The conditions were:

- 22C set.
- Auto mode.
- All vents open.
- Night time.
- No dual zone.
- Two people in the car.
- All A roads.
- 10C outside.

The measurements taken were:

- Foot vent.
- Face vent (one of the side ones, since the centres only come on for cooling and dual zone).
- Inside the cabin sensor cavity.
- Two points in the cabin, averaged out.
- Several parameters reported by the car, including cabin temp and vent output temp.

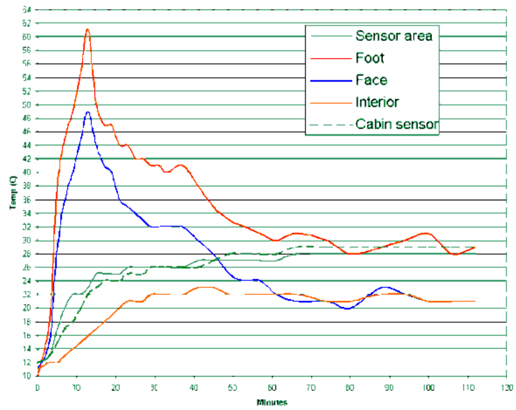
I used electronic thermometers, which I calibrated to each other (though there wasn't much difference between them).

Initial findings were:

- The CC's own cabin sensor (dotted green line) is reading temperature correctly (solid green line is the temperature measured by my probe inside the sensor area).
- The system responds to the cabin sensor and warms the cabin to the set temperature, and then maintains it to +/- 1C.
- There is always a tenancy to send warmer air to your feet, and cooler air to your face.
- The system works fine at low fan settings
- After about an hour stability is attained, with the control system cycling nicely and responding with warming and cooling air.
- The cabin sensor reads about 7C too high, but appears to be compensated.

Important observation

Between 30 minutes and 60 minutes, the output air temperature gradually falls in order to maintain the cabin temperature (as the interior structure of the car warms up). This may be perceived as a fall in cabin temperature, although it can clearly be seen that it isn't - and I wonder if this is what some people are detecting and complaining about.



I then tried 4 variations by manually selecting certain parts of the system (have a look at the four sections of the graph below):

1. Turn the fan up to full; to see if the extra flow past the sensor made it read closer to actual cabin temperature. It didn't. If anything the extra blow from the foot area warmed the sensor up a bit.

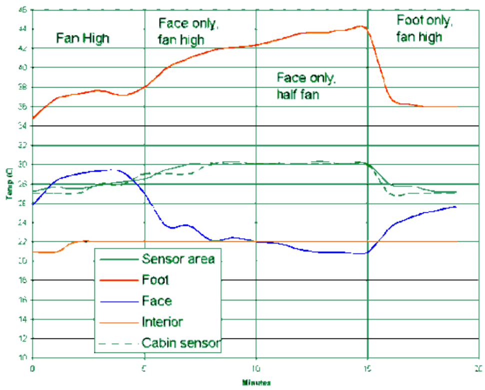
2. Then I sent air to the face only, still on full fan. The face vent temperature dropped to demanded temperature, and a small amount of hot air from the footwell warmed the sensor yet further.

3. Next a reduction in fan speed to half (still face only) made very little difference.

4. Finally, sending all the air to the feet with the fan on full caused the foot temperature to return to 36, but the cabin sensor dropped by 5 degrees! Is the cabin sensor aspiration powered by a venturi in the footwell air system? It looks like it might be, but it still reads too high, so the sensor is still clearly influenced by the temperature of the footwell air.

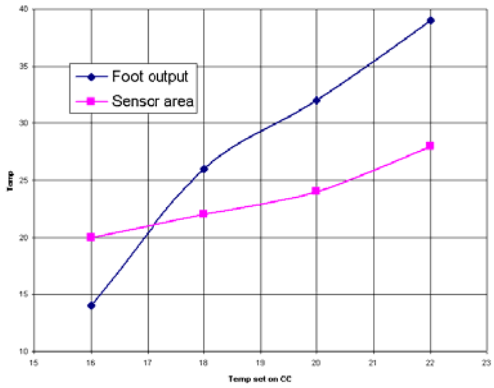
It appears that the sensor is reading a mixture of cabin and footwell air, the system knows the temperature of the footwell air and is compensating to arrive back at a cabin temperature. Very odd (and amazing that it works at all)!

So I then decided to see the effect of footwell air on the cabin sensor reading.



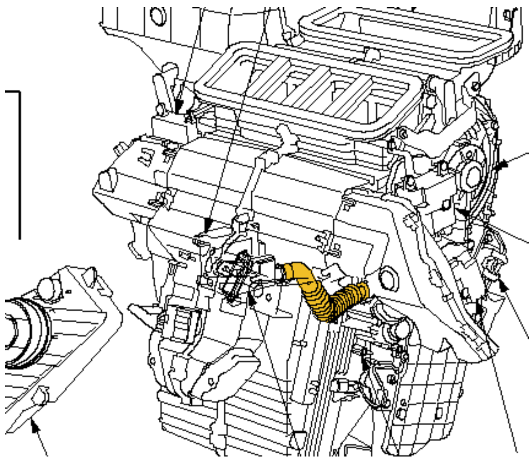
At the bottom of the graph is the demanded temperature (as set on the CC temperature control). The fan is on full and the air is directed to feet only.

You can see that as the demanded temperature is increased, the foot output temperature increases and so does the sensor. These measurements were taken pretty quickly and the cabin remained at 22C the whole time. I can only assume that this increase is what's subtracted by the programmer to get to the cabin temperature.



- In this test, the system worked well. Of course, this is only for one set of circumstances (10 C outside, 22 C demanded inside).
- The system is very odd, in so much that the cabin sensor is hugely affected by footwell air temperature and speed, but these effects have been programmed out by the system software.
- There is no simple fault and workround to be found, so if you are getting a bit chilly, turn the temperature up a bit.

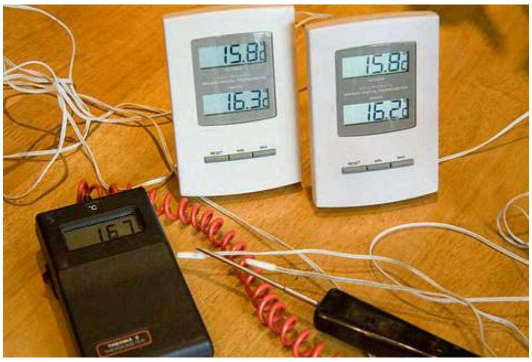
Here's a reminder of the cabin sensor aspiration pipe location:



Here are some pics of the experiment:

Calibration

Car dimension



TECHNICAL SPECIFICATIONS OF HYUNDAI SANTRO		
		Santro Xing eRLX
DIMENSIONS	Overall Length (mm)	3565
	Overall Width (mm)	1525
	Overall Height (mm)	1590
	Wheelbase (mm)	2380
	Min Turning Radius (m)	4.4
	Kerb Weight (Kg)	854(M/T) 868(A/T)
	Fuel Tank Capacity (L)	35
ENGINE	No. of Cylinders	4
	No. of valves	12
	Valvetrain (type)	SOHC
	Displacement (cc)	1086
	Maximum Power (ps/rpm)	63@5500
	Max. Torque (kgm/rpm)	9.8 @ 3000
SUSPENSION	Front Suspension	McPherson Strut with Stabilizer Bar
	Rear Suspension	Torsional Beam Axle , 3 Link Offset Coil Spring & Hydraulic Damper
	Rear Shock Absorbers	Hydraulic
BRAKES	Front	Ventilated Discs
	Rear	Drums
TYRE	Size	155/70R13

Source : http://www.hyundai.co.in

Misconception

During the research phase we came across an interesting fact that we would like to touch upon here.

Have you ever wondered which is more fuel efficient among a car running on AC with windows closed or AC switched off with windows down?

You will be surprised to know that the first process is more fuel efficient because in the first case the main energy goes in taking car to a particular fixed temperature and after that the AC does not consume much energy while in the latter case there is a continuous air drag, resulting in more fuel consumption thus making it fuel inefficient in comparison with first case. [Source: HOW STUFF WORKS, A Discovery Company]

[Source:http://auto.indiamart.com/cars/santro/#tech]

General practices to keep the car cool

1. Leaving a small fraction of window open so that air could flow, which hardly makes a 2-3 degree temperature difference.
2. Keeping the AC on which is a great wastage of so valuable resources (in terms of fuel and money).
3. Wait 4-5 minutes outside the car after opening the doors so that the temperature could return to its normal state, adding more woes to the users.
4. Toyota HVAC designers have suggested the installation of Solar Powered Ventilation System which uses an electric fan to draw outside air into, through AND out of the cabin once the inside temperature reaches 68°Fahrenheit. This will lower the cabin temperature to near the outside ambient temperature to help make the cabin more comfortable when re-entering the vehicle. It must be turned on prior to leaving the vehicle and cannot perform cooling such as with an air conditioner.
   [Source: Study on the Thermal Accumulation and Distribution Inside a Parked Car Cabin Hussain H. Al-Kayiem, M. Firdaus Bin M. Sidik and Yuganthira R.A.L Munusammy Department of Mechanical Engineering, University Technology PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia]

System and Interface

So how does the system actually work?

As discussed earlier the environment in/around the car are basically divided into three broad zones.

T1 zone above the car (is the same as environment temperature)

T2 zone inside the car (under the effect of green house effect)

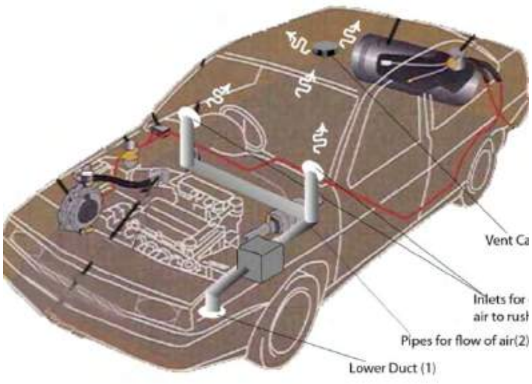
T3 zone under the car (created by the shade of the car parked in the sun)

Where T2>T1>T3,

On a hot summer day temperature levels in the cabin of a car parked in the sun can be more than 20 deg C above that outside the car [black car is typically 5 deg C higher than that inside a white car].T2-T1>20 deg C. [Temperature within the cabin is 20 – 30 deg C degrees higher than the temperature outside the car (at 40 – 45deg C) in the middle of the day (a staggering maximum of 70deg C is reached).] [The inside car temperature (T2) is dependent on the amount of sunlight and time the car is left in the sun. Lowering the driver's window of the car by 2.5 cms typically reduces cabin temperatures by about 3 deg C; which is not sufficient.]

The temperature difference between normal environment and shaded region under the car: T1-T3>6 deg Centigrade [2].Thus, T2-T3>30 (+/- 2) deg Centigrade.

From Ideal gas equation PV=nRT, whenever there is a temperature difference there is a creation of pressure variation between the two points (T2 (low pressure) and T3 (High pressure)).Using this pressure, a suction and air blower mechanism is automatically created without any external power source using a temperature sensitive materials/membranes. The sensitive material can be placed between the vent cap and the base material such that, whenever the temperature inside is increasing, it will in turn expand the sensitive material and thus increasing the gap between the vent cap and the base material thus facilitating the flow of air (cross ventilation modes).These vents will be placed at proper locations on the car for maximum flushing out of the hot air and input of cold air. The actual air vent caps will be placed, one beside the standard AC vent hole[reaching out to the bottom of the car],one each at each bottom corner of the cabin and the other on top of the car[output of Hot air]. And just like how we get monsoon, air will be directed from colder points to the hotter using its own pressure thus pushing hot air out of the car and replacing it with cold air from beneath. This cold air being blown from under chassis. This system would save .7 L of standard petrol [3] invested in powering the AC unit to cool the car from T2 to T1. If we could save this much of petrol in just one car, you can just imagine the panoramic view of how much resources are getting conserved in the process(multiply the effect 150 million times). And this, we are talking every time this phenomenon happens for a stationary parked time of approximately 2 hours and only in cars. Taking the general usage of cars, we can only imagine how much fuel can be saved monthly. Moving further to implement this idea in all vehicles would be a huge favor to mother earth. Apart from just saving fuel, it also increases the lifespan of the AC unit and decreases air pollution without use of any extra material. Such similar systems can also be implemented in larger Buses with suitable modifications. Implementation would be prioritized for the car first; following its success would be implemented even in the buses.



Schematic diagram of car,in which our basic mechanism is shown. Basically there 3 different temp zones, henceforth 3 different pressure zones which is the main driving force for the mechanism we have proposed. Cold air rushes from 1 and through the pipe to replace the hot air, which gets flushed from vent, which opens itself due to the temperature sensitivity of bimetalic strip. Thus creating a natural car cooling mechanism.

Acknowledgements

Our work was supported by Prof. PRADEEP YAMMIYAVAR, Dept of Design & Centre for Environment & SAE members, IITG.

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Intelligent Transport System in GIS Environment.

Thiyam Tamphasana Devi, Department of Civil Engineering, IITG;
Email- d.thiyam@iitg.ernet.in

Abstract

The application of Geographic Information System (GIS) in Intelligent Transport System (ITS) was conceptualized in this paper. ITS is introduced to improve the quality of life by providing safety, quality environment and economic productivity to the user. Advanced Traveler Information System (ATIS) is kind of ITS developed in this paper as main objective. ATIS is based on GIS software, network analyst and software development (programming). The integrated approach of ATIS is user friendly point to click graphical user interface (GUI) which allows user to find shortest path, closest facility and searches for intercity bus, train and air services.

Key Words

GIS, ATIS, shortest path, closest facility

1. Introduction

Transportation is the movement of people and goods from one location to another. For transportation we require infrastructure, vehicle and its operational system. Costs and efforts needed to built infrastructure, to buy vehicle and for its operation. As the world become more developed day by day and people do not have time to spend while travelling from one place to another place so we start looking for such type of system that requires minimum cost to construct infrastructure such as roads, rail tracks, stations, stopping, airports, energy consumption and also require less efforts (congestions, casualties) to drive the vehicle as well as we want no impact on environment. The management and policies of transportation system should be done in such a way that it should be socially, economically and environmentally efficient. So, sustainable transportation system came into picture. By less costs with less effort and without any impact on environment within less time we want to reach our destination and such type of whole system is called sustainable transportation system. And to achieve, an intelligent transport system (ITS) is introduced with the help of advanced technologies.

Intelligent Transport System (ITS) is a name given to the application of computer and communications technologies to transport problem (Praveen K. et al. 2003). By using these advanced technologies we can map, plan and generate information regarding the transportation system of a particular city or region such as its shortest distance between two destinations, closest route of required facilities like college, hospitals, market, parks etc. And even the timings of buses, rails, flights with their frequencies can be inter-associated. These technologies give efficient result in less time. The benefits given by ITS by introducing it, are improved safety, improved traffic efficiency, reduced congestion, improve environmental quality & energy efficiency and improved economic productivity (Praveen K. et al. 2003).

The developed countries like Japan and United States has started the work on ITS in 1980s and 1970s. Countries like Canada, Australia, U.K and Germany are spending lots of money for adopting these technologies and also successfully has implemented. But in India, still it is not initializing such type of technologies. Although we can not say that we are very far away from such technologies. We have the ability to implement these technologies as India is a fast growing developing country in every field.

2. Purpose of Study

The present paper aims to develop concept on an Advanced Traveler Information System (ATIS) in Geographic Information System (GIS) environment. ATIS is the decision support system of the user to plan their travel route and to estimate their travel time. It gives fast and accurate information to the user such as reduction in travel time, reduction in stress, avoidance of congestion and avoidance of unsafe driving conditions. Once the ATIS has developed, the management and policies of transport can be easily planned, generalized and implemented in a very feasible way. So, it will be very helpful to enhance the knowledge of planning and management of roads by the concerned authorities and to the road users. This paper targeted to show the significance of GIS in developing the most efficient route for transportation with effective cost within less time.

This objective can be attained by carrying out the following activities:

- By finding out the shortest path and closest facility of the travel route.
- Location wise information like bus, train & airways timings and intercity bus route number has been attributed to each node using GIS software.
- By performing Network Analysis in GIS software.
- Programming in GIS software

3. Methods and Tools used

3.1 Concepts

3.1.1 Decision Support System

To develop the concept of Advanced Traveler Information System (ATIS) in GIS environment from literature review in the main objective of this paper. In this mechanism the information like shortest path, closest facility, location wise intercity bus routes, trains and airways timings can be considered. Further detail is given in the following sub section.

3.1.2 Shortest Path

Shortest path is the optimal route segment of a journey. A route planning is the way that a driver can plan a route prior or during a journey. A variety of Route optimization criteria or planning route may be used in route planning. The effectiveness of a route depends upon its travel distance, travel time, number of turn and travel speed. And it is the cost of travel. There are two choices of shortest path based on travel distance and another on travel time. The route selection process can be performed through selectable user interface. In the optimization of travel distance, route planning algorithm was done by using road segment length. In the travel time, road segment length and speed limit on that road was stored in digital data and travel time is calculated as distance by speed limit. And it is taken as the travel cost of the path and was used in path optimization.

3.1.3 Closest Facility

The different closest facilities can be taken as like market place, hospitals, bus stops, parks, institutional places etc. In the closest facility, travel distance and travel time can be considered as travel cost. All the routes from selected origin to facilities were calculated using closest facility algorithm based on travel cost. Travel costs of these routes were compared and give one optimal route as output.

3.1.4 Bus Routes

The numbers of city buses were stored and search algorithm was performed to find out the bus service number from selected point to point.
The typical flowchart of concept used is given in figure 1.

3.2 Source Program

The source program for this concept can be presented in macro language which is available in GIS software (ArcGIS Desktop, ArcView etc). Any kind of programming language can be used as per the convenient of the user who is going to write that program. In this tools, customization of any concepts can be done like adding of toolbars, editing, deleting and even the running of program which we have written.

3.3 Software Development

In the software development the following three tools can be considered.

- GIS software
- Network analysis
- Programming

3.3.1 GIS Software

There are varieties of GIS software available in the market, we can use any kind of software which allows us to digitize, store data, analyze data, querying etc. These are advanced technologies which can be beneficially and efficiently adaptable to standardized human lifestyle in many ways.

3.3.2 Network analysis

Network analysis is an extension tool specially designed to solve the problems in networks efficiently. In the license version of the most of the GIS software, this tool is available but in some cases it may not work, so we should ensure about the licensing of any GIS product.

3.3.3 Programming

Programming language is in the form of macros which is in built in GIS software. It is use for customization of toolbars according to the user’s choice.

3.4 Geo-Referencing

The scanned image obtained from concerned department or satellite image is not geographically correct. So, to correct its co-ordinates of rows and column, this raster image is projected. The projection system should be selected as per the location of the study area. Such projection system is available in GIS software itself. The projected image is again rectified using known co-ordinates (x.y) of another image taking as reference. Then, such type of rectified image is geometrically correct and ready to use.

3.5 Digitization

Digitization is a process of encoding geographic features in digital form as x, y coordinates. Digitization is done to find out the different spatial information from satellite image or any other image document. Different type of spatial covers can be digitized in lines, points, polygons. Road network is digitized in line and water bodies are digitized by polygons. Bus and train station, market place, institutional buildings, hospitals etc. are drawn in points. The schematic diagram of the whole methodology used in this paper is given in figure (2).

3.6 Required Data

1. Topological map
2. Speed limits on roads
3. Road names
4. Information on One way road
5. Bus route
6. Time table of bus, train and air services

Road names, speed limits, information on one way, city bus route and intercity bus, train and air services were attributed to the respective themes.

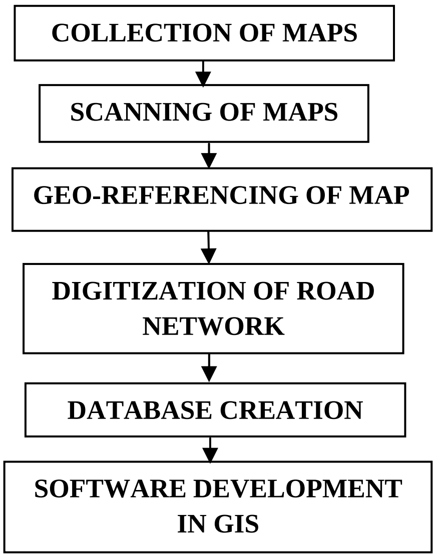

Figure2. Schematic diagram of whole methodology used.

3.7 Attributes of Themes and Fields

There are some themes and fields given with their descriptions (table 1). We can add more themes and fields as per the availability of data or our requirements.

Table1. Attributes of Themes and Fields.

Theme	Field	Attribute
Road network	Name	Name of the road
	One way	Information on one way
	Speed limit	Speed limit on road segment
	Drive time	Drive time based on speed limit and
	Length	Length of road
Educa-tional institutes	Name	Name of institute
	Label	Label of institute
	Type	Type of education
Transport	Name	Name of the bus, rail stations and airports
	Label	Label of the bus, rail stations and airports
Tourist site	Name Label	Name and label of tourist places

3.8 Examples of Application of Concept

The customization of toolbars can be done as given in the table 2. In the Main Menu there is FILE, VIEW, PATH etc. and under FILE there is Sub Menu as CLOSE, PRINT, PRINT SETUP, EXIT etc. and again under CLOSE there is Closes view etc. Likewise we can create new toolbars of our choices.

Table 2. Description of menus and sub-menus

Menu name	Sub menu	Function
File	Close	Closes view
	Print	Prints view
	Print setup	Edits the printer and the printing options
	Exit	Exits from the application
View	By location	Displays location wise details
	Full	Displays full view
	Search	Searches for different features
Path	Shortest path	Gives shortest path
	Closest facility	Gives closest facility path
	Site tour	Gives optimum path for site tour and so on…

4. Conclusions

This paper only gives the concepts on how to generate decision support system of an intelligent transport system. It is purely based on the literature available and its application into specific areas was not performed, it just aims to show the generalized roles of GIS in the planning of transportation.

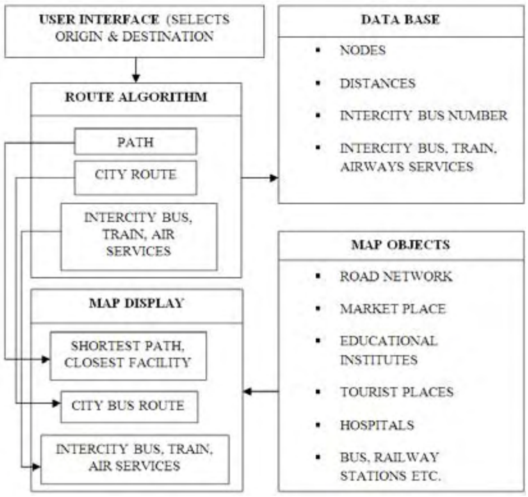

Figure 1. Typical flowchart of concepts used (Praveen K. et al 2003)

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Modifying Traffic circles to Reduce Fuel Consumption.

Gaurav Abnesh Kulshrestha, Department of Design, IITG;
Email- g.kulshrestha@iitg.ac.in
Kshitij Bhardwaj, Department of Design, IITG;
Email- b.kshitij@iitg.ac.in
Pradeep Yammiyavar, Department of Design, IITG;
Email- pradeep@iitg.ac.in

1. Abstract

A traffic circle or rotary is a type of circular intersection in which traffic must travel in one direction around a central island. In India left is the free turn and hence vehicles commute in clockwise direction around the circle.

Common characteristics include large diameters (over 100 m or 300 ft) and minimal horizontal deflection so as to facilitate speeds of 50 km/h (30 mph) or more.

1.1 Existing scenario

In the current system major traffic zone circles are designed in such a way that if a person has to go right, he has to initially take a left and cover 3/4th circle in clockwise direction to take right.

1.2 Proposed solution

To have two opposite directional concentric circle monitored by traffic lights, so that the person can take shortest path and save both fuel and time.

2. Detailed solution

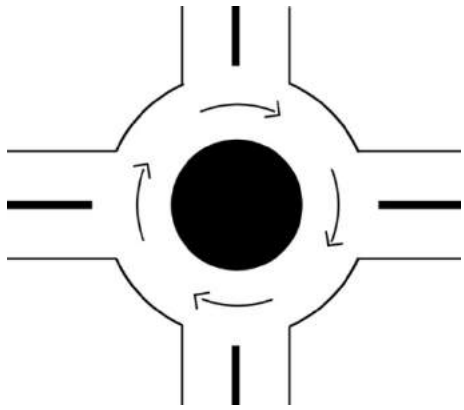
"Our concept is based for traffic circles that are very busy and have high traffic volume passing by."

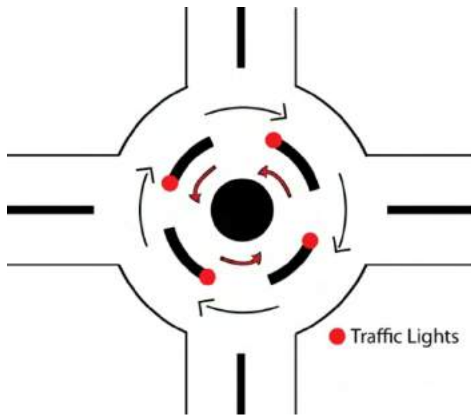
Consider an example of time interval T seconds where T is the time for which commuters have to wait at traffic lights. (Assuming equal traffic density from each direction)

In the existing system, two lights are turned green for T seconds at a time. Mostly these lights being just opposite. This is because of less traffic congestion at these points as people taking right turn at a time are very few. This system is more vulnerable for traffic jams as it is based on the assumption that at all times number of people taking right turn is small. But there are times when there are many vehicles going in right direction.

Collectively these people contribute to wastage of considerable amount of fuel. To take a right turn, they have to travel 3/4th circle which contribute to fractional loss of fuel if considered individually, but considering the whole lot of cars going in that direction, it leads to unconscious wastage of considerable amount of fuel.

Our proposed system concept deals with the situation of traffic jams and fuel wastage. This system saves fuel unknowingly which would have been wasted.





2.1 System

This system has another inner circle in addition to the existing circle. To build this circle, it is not required to increase the radius of the existing one; the new circle is introduced inside the outer circle. Big circles that qualify for this system have min radius of 50m. So the inner circle has to radius of 25m as there will be single lane road in inner circle.
Commuters will be going in anticlockwise direction to reach the nearest exit i.e. There required direction. This way, people won't have to travel 3/4th of the outer circle and instead they will be taking 1/4th round of the inner circle.

Thus quantifiable amount of fuel is saved at the end of day at a circle. The introduction of inner circle makes this system very less vulnerable to traffic jams as compare to existing system.

2.2 Working

There will be traffic light for 2 directions at every stop. There will be no restrictions other than general traffic rules on traffic going in left direction. 1st light controlling the regular traffic flow i.e. commuters going straight. The second light will be controlling the vehicles entering the inner circle. So overall there will be traffic lights controlling traffic in 8 directions.

These lights are synchronized in such a way that at a time 3 lights are turned green hence 3 directions are open for commuters. These 3 lights being:

- One traffic post allowing people to go straight and to go in inner circle simultaneously.
- Another adjacent traffic post in the clockwise direction allowing people to go only straight.

Time intervals for which they will be turned green: The light that is allowing people to go in both directions will continue to do so till T/2 seconds and for the next T/2 seconds it will allow traffic only in straight direction. Light for inner circle is kept red in this interval so that traffic will be cleared for the next adjacent (in anticlockwise clockwise direction) stop which turned both of its lights green at the moment at which light for inner circle (of the light that was earlier allowing people to go in both the directions) turned red.

3. Analysis
3.1 Existing model

Minimum diameter of major traffic circle = 50m

Circumference = 167m (approx.)

Minimum distance traveled for a right turn (circular + linear motion) = (125 + X) m

3.2 Proposed model

Maximum diameter of inner traffic circle = 25m

Circumference = 84m (approx.)

Maximum distance traveled for a right turn (circular + linear motion) = {21 + (X + 25)} = (46 + X) m

3.3 Minimum distance saved for a right turn

Minimum of existing model – maximum of proposed model = (125 + X) – (46 + X) = 79 m

3.4 Fuel saved

Maximum mileage of average cars = 16 Km per liter approx.

Average cost of petrol in India in October = Rs. 55.69

Cost per meter = 55.69/16000 = 0.35 P approx.

Minimum cost saved per person per round = 27.5 P

Minimum number of cars taking right turn over a busy circle in a day = 10000

Amount of petrol saved per circle per day = 50 liters approx.

Cost saved per circle in a day = Rs. 2750 approx.

4. ACKNOWLEDGMENTS

A special Thanks to Prof Pradeep Yammiyawar and Metadesign (Design student community)

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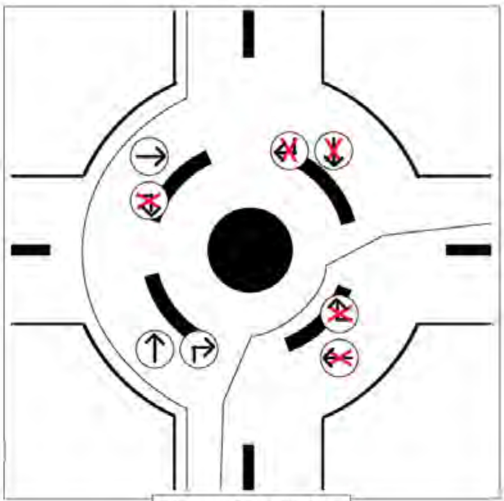

Figure1: 0 to T/2 Sec

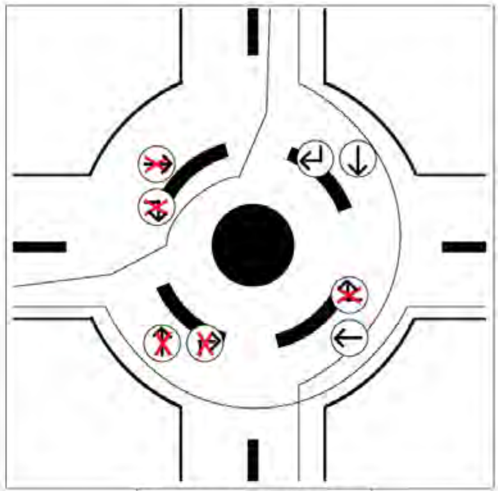

Figure3: T to (T+T/2) Sec

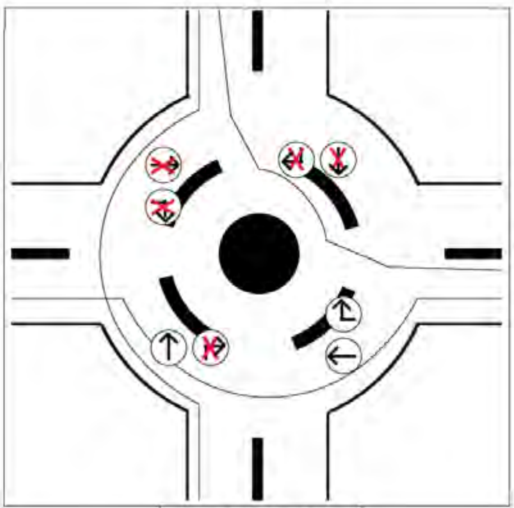

Figure2: T/2 to T Sec

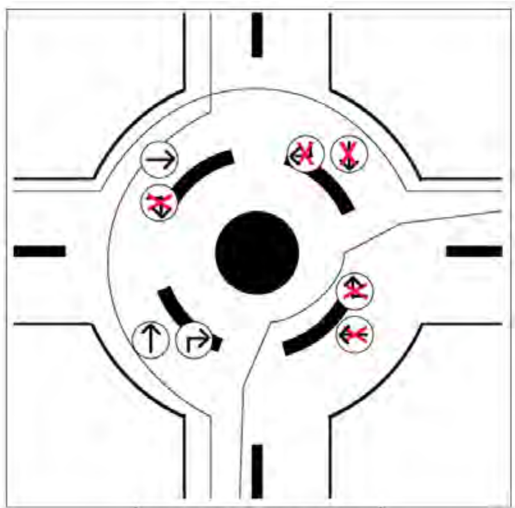

Figure5: 2T or 0 to T/2 Sec

Systems Approach to a Sustainable Transportation System - An Overview.

Vikash Kumar, Department of Design, IITG; *Email- vikash.k@iitg.ac.in*
Prof. Pradeep Y., Department of Design, IITG; *Email- pradeep@iitg.ac.in*

Abstract

Transportation, in today's world has become one of the basic needs of human society. This paper examines the concept of sustainability and the different approaches taken in literature to understand and implement it in the context of transportation system. The paper argues that to achieve transportation sustainability the planners should approach it at a system level and calls for new designing methodologies in place of the ineffective old ones.

1. Introduction

The concept of Sustainable Development as reported by Brundtland Commission, 1987 is defined as 'development that meets the needs of present generations without compromising the ability of future generations to meet their own needs' [1]. John Elkinton, in 1998 [2] proposed the Triple Bottom Line (TBL) principle of approaching sustainability which propagates with economic (profit), environment (planet), and social welfare (people) objectives as shown in figure-1.

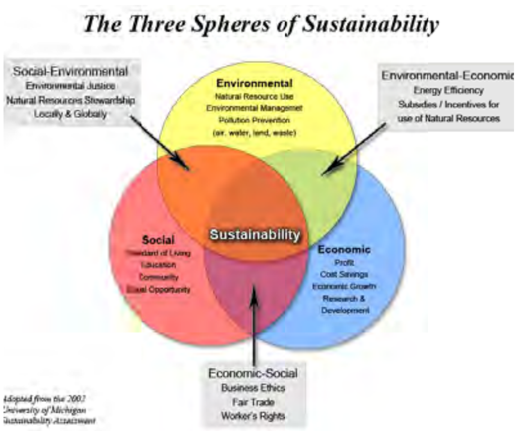

Figure-1: Three pillars of sustainability
Source: Adopted from the 2002 University of Michigen, Sustainability Assignment

Although this concept has become a new mantra for many development policies, still its understanding varies throughout literature [3]. The paper tries to examine this concept in transportation system context and suggests researchers that the complex system like transportation cannot be solved until approached comprehensively.

2. Sustainability and development

The basic understanding of sustainability comes from the fact that there is a limit to growth of human population which can be supported by the earth. The nature has its own mechanism of regulating the delicate balance of population growth through various ways like competition for food resources; disease etc., but humans have overcome these mechanisms to a certain extent. This has resulted in an uncontrolled growth, putting a lot of stress on the limited resources, which may lead to catastrophic consequences. One way of avoiding this is controlling our development to a limit which is within the earth's carrying capacity. The second way may be creation of new resources with efficient use of existing resources avoiding any negative impact on ecology.

The first way of attaining sustainability also known as zero growth advocated by scholars like Forrester, Meadows, Alcamo [4-6], met with intense criticism in both developed and developing countries. The second approach of sustainable development looks far more attractive to scholars than the previous approach and was advocated by the Brundtland Commission [1].

In literature, some scholars believe that the concept is very simple: a sustainable system is one that survives and persists [7]. Others argue that concept involves trade-offs among social, ecological and economic objectives to sustain the overall integrity of the system [8]. There is also confusion between the term ‘sustainability, and ‘sustainable development’ so a distinction in made here for clarity.

‘Sustainability’ is considered as a dynamic balance among three mutually interdependent elements:

1. protection and enhancement of natural ecosystems and resources;
2. economic productivity; and
3. Provision of social infrastructure such as jobs, housing, education, medical care and cultural opportunities” [9].

Whereas ‘Sustainable development’ means “process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations” [1].

These concepts are further extended in the following section in the context of Transportation System termed as Sustainable Transportation (ST).

3. Transportation Sustainability

Transportation is considered to be one of the basic needs for development. The concerns about the sustainability of conventional fossil fuel, highway-oriented transportation system began to emerge around 1970s and was taken seriously after the first energy crisis, alerting us to the dangers of relying on non-renewable fuels for our existence [3]. The Brundtland Report fueled a lively discussion in achieving Sustainable Transportation (ST) and many literatures were published in an effort to describe or define it.

Most of those efforts were fraught with difficulty mainly because of the following two reasons:

1. Its complex nature involving social, ecological, and economic issues.

2. The derived nature of demand from human socio-economic activity.

The University of Winnipeg’s Centre for Sustainable Transportation defined ST system as one that [10]:

1. Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and which equity within and between generations;

2. Is affordable, operates efficiently, offers choices of transport mode and support vibrant economy;

3. Limits emissions and waste within the planets ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuse and recycles its components and minimizes the use of land and the production of noise.

The difference between the conventional approach of planning, (also known as BAU) and the new definition of Sustainable Transportation are shown in table 1.

Business as usual (BAU)	Sustainable Transportation (ST)
Emphasizes mobility and quantity (more, faster)	Emphasizes accessibility and quality (closer, better)
Emphasizes one module (uni-modality, automobile)	Emphasizes plurality (multi-modality)
Often lacks good connections between modes	Emphasizes interconnections (inter-modality)
Accommodates and accepts trends	Seeks to interrupt and remove harmful trends
Plans and builds based on forecasts of likely demand (predict and provide)	Work backwards from a preferred vision to planning and provision (deliberate and decide)
Expands roads to respond to travel demand	Manages transportation or mobility demand
Ignores many social and environmental costs	Incorporates full costs within planning and provision
Transportation planning is often ‘silos’ disconnected from environment, social and other planning areas	Emphasizes integrated planning combining transportation with other relevant areas.

Table 1: Comparison between BAU and ST
Source: Preston L. Schiller [10].

Since transportation is a derived demand of humans various socio-economic activities, the following section discusses how ancient walking cities evolved into existing transit based cities.

4. Evolution of Transit Cities

Thousand of year ago when the dominant means of transport was walking or animal driven, the cities then were very dense, small, with highly mixed land use and all the destinations remain accessible within few kilometers. The transit or public transport cities began to emerge with the advent of motorized means of transport. These technologies made it possible for people to travel faster and thus the city size began to expand. This expansion created the need of infrastructure development and thus expanded the cities further which led to the existing transportation system. The whole land use pattern changed from mixed land use to zonal way of planning.

Thus transportation system plays a central role in structuring and shaping a city ultimately establishing its sustainability. So, we need to look at the systematic model of understanding the transportation system. A vast amount literature is published in this direction but; most of them lack a comprehensive system's approach of understanding, evaluating and implementing. Automobiles were the main focus of such studies often pushing the planning decision making processes [11].

The following section presents an overview of such approaches taken by different authors.

5. Approaching Sustainable Transport

Meeting the needs of present without sacrificing the ability of future generations to meet the same was the ultimate aim articulated by the Brundtland report. These 'needs' were interpreted differently by different authors, is now a widely accepted goal for any transportation project. All those projects might have taken varied direction, but tend to fall in two broad categories as indicated by Todd Goldman [12].

1. The group which avoids attempting to define a particular outcome that would mark the attainment of sustainability. This approach is propagated by a 'more sustainable' situation than the present conditions, evaluated by a set of indicators.

2. The other group attempted to come up with a definition or vision of what a sustainable system might look like. They also depend on indicators for in the service of vision.

These approaches have their own advantages and disadvantages for example the former approach is easy to understand and conceptualize but focuses only on mobility. The latter approach takes into considerations social and economic aspects but is difficult to understand and implement due to lack of guidance on how to mediate or balance among competing objectives.

Both the approaches are partially successful due to the porous nature of transport system. It is not a closed, self-contained system; rather it is interdependent on other systems. So, in order to fully understand the different variables affecting the system one has to come out of system that they are evaluating. However, the indicators and assessment tools may be used with the new set of variables. The following section presents methodology for analyzing the effect of transportation system on environment, society and economy.

6. System Approach for ST

As discussed in section-3 that transportation is a highly complex system involving social, ecological and economic issues at the same time transportation needs are derived demand of human socio-cultural activities. Section-4 discusses how transportation modified the ancient walking cities into existing transit cities. Thus, in order to understand this complex relationship one need to have a problem structuring model. This model should give an overview of the system from outside the system and provide us with necessary vision of how the system is intertwined with other systems. Füsun Ülengin [13] proposed such a framework which could be used for the purpose as shown in figure 3.

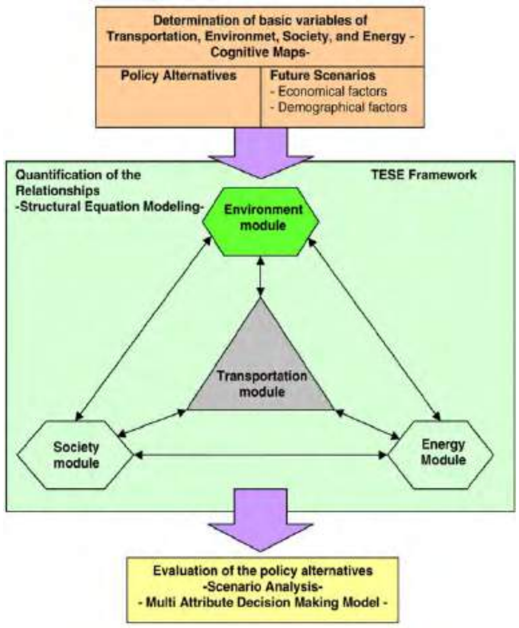

Figure-2: Framework for analyzing relationship between different modules of sustainability
Source: Füsun Ülengin A [13]

Identification of the basic variables that affect or are affected by transportation system from different perspective namely environment, society, Economic and Technology is the first step to the framework. In a complex environment such as transportation the number of variables are many; few affect the system directly few indirectly. A thorough study of those variables and their affect on the system should be understood especially for the purpose of evolving a Design Methodology that integrates Sustainability within itself. The following section attempts to identify the first level variables in the category of Environment, Society, Economy and Technology.

7. Identifying variables affecting sustainability in a transportation system

Using the triple bottom line as a base, variables which affect transportation systems sustainability are identified by brainstorming and then grouped under four headings namely:

1. Environmental,
2. Social,
3. Economical, and
4. Technology related

The variables shown in figure 2 are not an exhaustive list. These are gross level variables which have significant effect in establishing the sustainability of transportation system as a whole.

The total number of variables identified at first level sums to (8+10+6+11) = 43.

Assuming that each of these 43 variables effect each other at least once in a system the total number of combinations work out to be:

43 x 43 = 1849 interrelationships.

This is already a large number to be considered by any designer trying to analyze a system for sustainability.

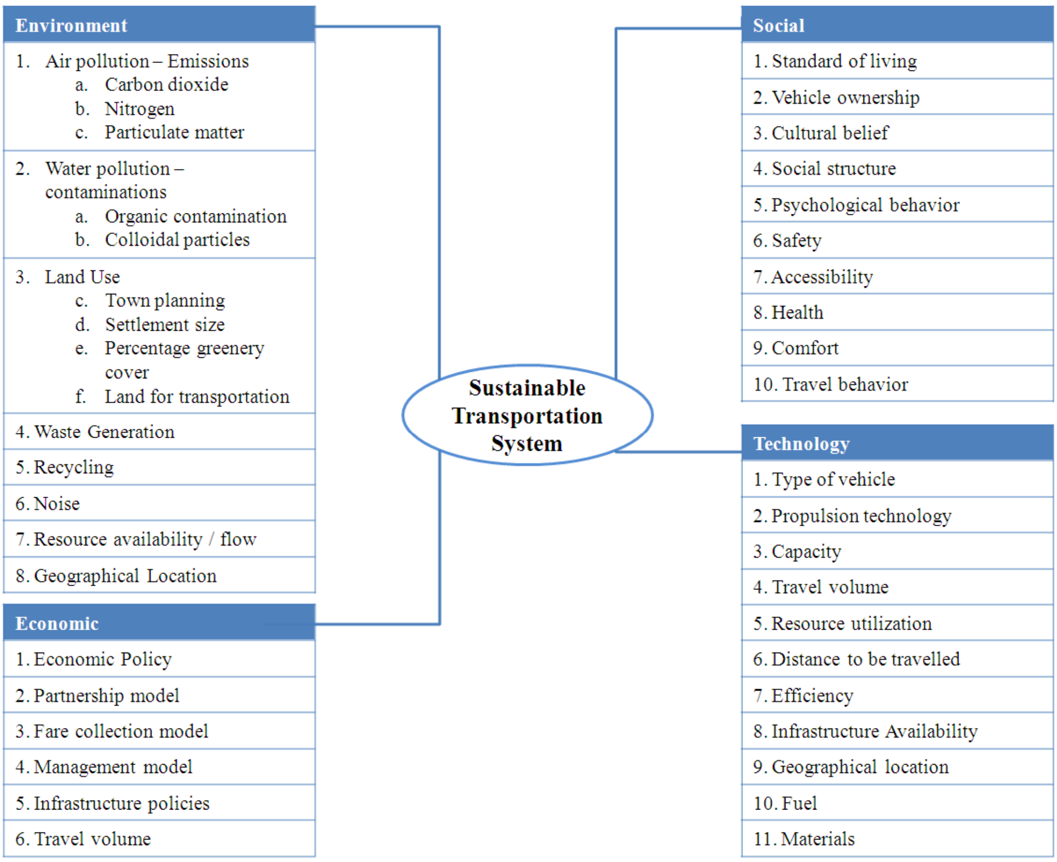

Figure 3- Variable for Sustainable Transportation.

If the deeper levels of variables considered the number of combinations increases geometrically making it a very complex problem to analyze or resolve at the system level. A change in one variable may affect many other variables. A combination of two variables will result in a birth of a new variable with multiple cascading effects on the system as a whole.

Such large numbers of variables and their interdependence makes transportation systems complex, difficult to understand and design from one or two perspectives alone such as say for example Civil engineering or Environmental Sciences or Development policy – Town planning. A holistic view of system's approach is needed in establishing a Sustainable Transportation metrics especially for designing purposes.

Designing methodologies that Designers have been following (For example: Figure-4) need to be redesigned if the designers have now to also consider Sustainability as a design input.

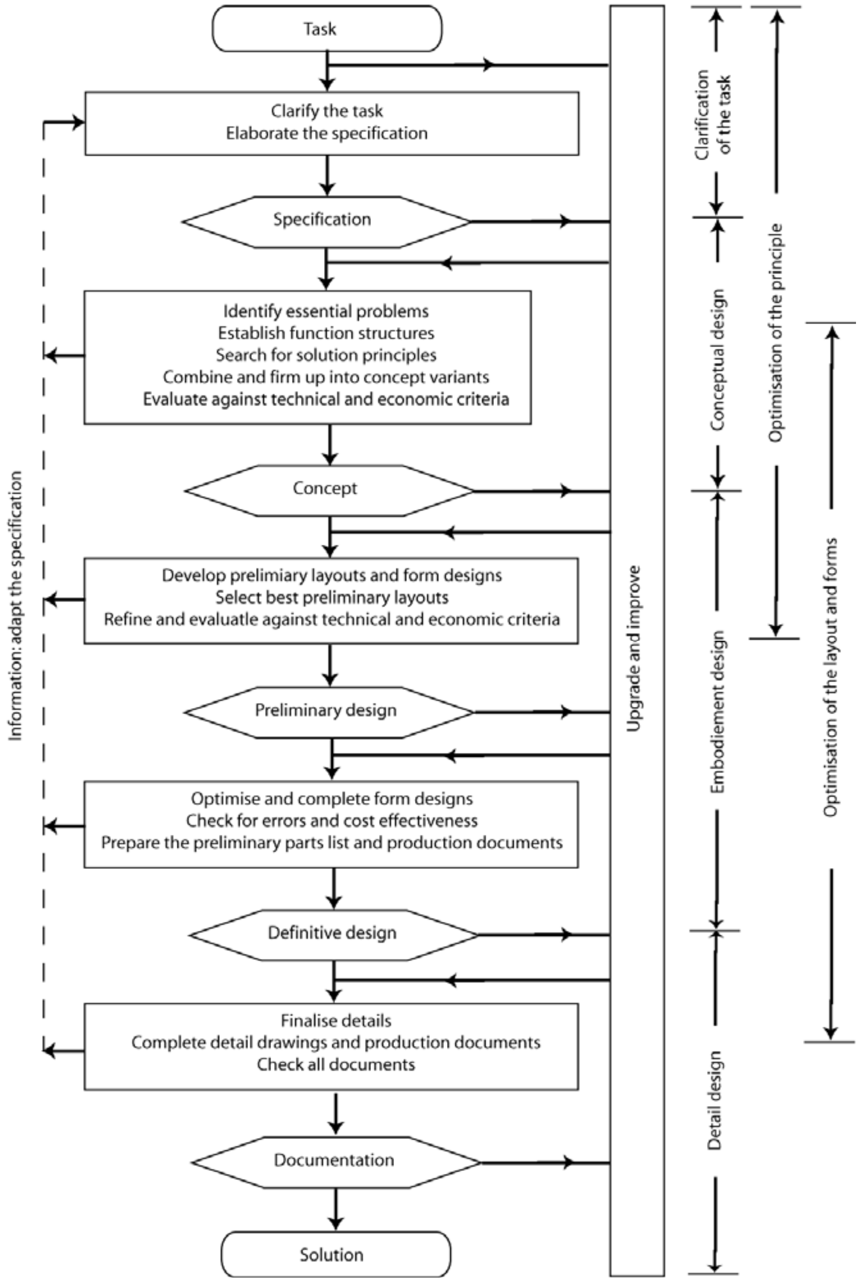

Figure-4: Paul and Beitz Model 1984 for engineering design methodology
Source: G. Pahl and W. Beitz, "Engineering design", Design Council London.

8. Conclusion

This paper initially discusses about the concept of sustainability in general and then moved to possibilities of application in the field of transportation systems. Discussion on the evolution of cities reveled that transportation has played a major role in structuring any city in terms of its layout and geography. Literature in Sustainable transportation reflected that the approaches many scholars have been taking is limited and is insufficient in application to a complex system like a city. The extent of complexity of a transportation system itself was estimated through listing of variables at a gross level. The number of variable which is affecting transportation sustainability is many and it's difficult for any one discipline to approach it from one perspective only.

Thus a comprehensive approach to sustainability in the transport sector is suggested for further investigation. Not only new modes of internal transport (such as an electric Bus or Light rail) but also a new approach to designing transportation supporting infrastructure such as terminals, passenger information systems etc are the need of the hour. Existing known physical components of transportation Infrastructure may not be ideal for new upcoming urban demarcated zones such as Townships/ satellite towns and Educational campuses. New designs of supporting components and sub components that take into considerations the energy and environmental sustainability issues as well as commuter behavioral characteristics need to be conceptualized designed and developed. This calls for new designing methodologies in place of the ineffective old ones.

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Author Index

Solar Charging station for Electric Vehicles, DoD, IITG, Shyam Prajapati & Pradeep Y

About IIT Guwahati

Indian Institute of Technology Guwahati, the sixth member of the IIT fraternity, was established in 1994.

At present the Institute has eleven departments covering all the major engineering and science disciplines, offering B. Tech., B. Des., M. Tech., Ph.D. and M.Sc. programmes. Within a short period of time, IIT Guwahati has been able to build up the necessary infrastructure for carrying out advanced research and has been equipped with state-of-the-art scientific and engineering instrument. It is involved in many national and International R&D projects.

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