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Design and Development of a Light Hybrid e-Choop-Choup

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A B S T R A C T

Silence is bliss. The paradigm is a holistic design feature for moving products like transportation systems which mandate freedom from noise (opposite of vibration), interference, side effects of friction -abrasion due to rubbing, component heating and so on. The present work presents the experiences as applied to the design of a hybrid tricycle, which is run using a mix of both manual and electrical power. The former is usable for charging the batteries which may empower the latter to put the wheels in continuous motion. It is endeavoured that such a vehicle could serve the needs of commuters (driver and co-driver) holistically with a twin objective of savings (fuel, money) and simultaneously facilitate provision of exercising opportunities.

Through this paper we explores the operation of the 4DM tool for the design, development, deployment of the choop-choup (silent) tri- wheeler, after its requirements were defined duly respecting the boundaries as mandated by SAE for the design competition. Thus the initial Define phase was used for an alignment and honing of design inputs from SAE further. Such objectives were realised by supporting a team of motivated students who were behaviourally and technically aligned to solve the design and development challenges and problems for a holistic success which included efficiency, environment and cost effectiveness.

Keywords: Team Alignment Using AUM Model, THE (Cheaper Transportation System for Better Health and Environment), 4 DM (Define, Design, Develop, Deploy and Manage)

Introduction

While Public transportation is indicated as a key player to ensure sustainable, affordable and high-quality mobility in urban areas1, 1 the need becomes more complex for transport requirements for smaller distances, or in smaller cities. Historically, the road conditions in smaller cities are rather bad and thus the need of a cheaper intracity transport in smaller cities is of poor significance. To render it economical it is usually served by either a rickshaw and/ or additionally through a Tuk- Tuk - also known in India as an 'auto'/ or auto rikhshaw. The complimentary problems have though been a volatility in fuel prices as well as the high rise in energy demand which raises prices. In the present time the shortage of time with most of commuters, also severed due to increasing distances and poor value assigned to cyclists/ riders of Rickshaws have almost caused their disappearance from the roads.

To define, a Rickshaw or Jinrikisha,[2] is a light, pulled cart

consisting of a doorless, main body dominated by chair(s), mounted on springs, provision of a collapsible hood and two shafts. In its two-wheeled version, it is manually drawn by a single rickshaw runner, while the mechanized version has an appendage of a cycle thereby culminating into a peddled tricycle. In arduous circumstances or terrains it takes the form of an atrocity, as if a slave or servant is 'put into service', transporting the passengers and that calls for putting an end into this social menace. Additionally, the problems relate to economic levels of people due to health effects, because of their reducing resistance as a result of lack of physical work indulgence, as aggravated by the increasing pollution levels in nearness of the riders of polluting vehicles which are generated CO/ CO_2/ NO_x, SPM (suspended particulate matter etc) from the fossil fuels used therein. The governments are propagating the development of electric vehicles, while upgrading the standards of efficiency of fuel combustion etc to BS VI standards in newer vehicles, though lawfully, all vehicles from BS I to BS VI standards continue to ply on the roads unabated.[3]

In the interim the promotion of design competences among the youth are attempted for enhancement as is the awareness requirements regarding aforementioned imperatives. In line with the former objective, an option of modification of above system as a Hybrid Human pulled-Electric cycle was already endeavored by Society of Automotive Engineers (SAE) who annually hold a national level intercollege design competition for undergraduate students with a view to simulate real world engineering design projects and their related challenges. It is because the use of a Combined human and electric motorized vehicle could be a superior example of such variety of alternative solution that can have multiple base for soluions in future for small distance transportation.

Since the boundary of the design competition, which forms the subject of this paper, was duly mandated by organizers to limit the weight of the vehicle below 160 kgs, keep as the primary condition, we endeavoured a project to design a zero emission ultra-light human assisted vehicle, calling this an e- rickshaw. Arguably, this substitute of which is much lower on the inhumane scale of service-conditions.

In this project/ paper the authors attempt to build all the necessary data, which is important to fabricate this vehicle. With the objective to cater to Health, Environment and Cheaper Transportation (call it THE), we design THE transport as a zero emission ultra-light human assisted vehicle. Beyond the objectives, we cater to stability and safety as a part of the vehicle attributes. We use a tadpole design, in which the front end exhibit less acceleration than rear such that any turning allows us to negotiate turns with greater speed and stability. Rear wheel driving system, double coil suspension, Westwood tyros, Ackerman steering, disc brakes with manual & automatic power transmission system is installed. We challenged our designing functional objectives to keep weight low, albeit the intended limits of ' below 160 kgs' allowed, for which we provided a light weight chassis of steel (AISI-1018) and optimize structural designing for cost effectiveness, easy workability, strength and safety to drivers. Conceptually "Optimisation is [deemed as] the order of today @ low access to materials, [while] the demands are all time high and growing-because of materialism.,, [to meet such challenges] We require mean people to answer the provision of wherewithal for such requisites".[4]

Objectives

Short objective and problem statement - Since the current challenge was to keep the weight of the vehicle below 160kgs, the list of objectives were charted, beginning by a behavioural Change, technical competencies, Invoking creativity for designing, building design competencies, manufacturing and safe driving habits.

Problem Description

The realization of objectives was targeted by training a Team of highly motivated individuals christened as Choop - Choup (a silent machine which should aim at a behavioural disruption in the concept of short distance transportation). They were strategically aligned and oriented to recklessly work towards the realization of this goal, using the tenets of Thareja's AUM model. The domain to training included THE imperatives enriched through trough design and development with the goals in mind, was formulated.

A project is begun when someone conceives a business/ innovation idea like THE, executes the needed formalities to set up a TEAM (so as to formalize the paradigm - Together Everyone Achieves More) and mentors the members to achieve the team's objectives. So, the imperative of analysing team's holistic investments in the project can be an effective strategy for identifying right design imperatives.[5] Teams that have better behavioural alignment and technical competencies, witness a gradual increase in their learnability are expected to have assured success[6,7] Behavioural alignment and learnability are essential pursuits and vital for achievement of stated objectives. Since " Environmental preservation is about individual's culture. It is though a necessity to preserve our globe, but generally people attempt to guise it by using a suitable end of pipe solution. This is easy to implement rather than conceptually attempting to take suitable preventative action bused on cultural change (s)."[8]

The paradigm Together Everyone Achieves More allows better levels of strategic planning which is necessary for a high Quality and consequently success.[6] Thus establishment

of development teams of capable people is the key to successful organizations.[6] Thus choosing to work on this project was a plan for satisfaction of two motives. That is the educational challenge and the competitive spirit.

Towards the latter objective, various specifications all for rendering Light weight wheels, seats and steering were planned. In initial trials problems at rear wheel suspension shaft shuffling etc were encountered, which called for mass improvements for use of a monocoque frame design was selected so to keep weight to low.

The objective thus was set up to design an ecofriendly, safe to peddle, but capable of supporting with powered transmission in times of need, manually pulled vehicle for affording a comfortable and untiring ergonomic ride. Evidently riding a bicycle is recommended both for exercising and costfreedom in regard to the operational part of travelling.[9]

The brief Objective was finally listed as:

Team 'Choop-Choup' aimed to design a cost effective, stable, comfortable and ergonomically suitable tricycle (rickshaw) that meets the need of the market.

Project Planning and Consummation

The need for development technology, for the glocal (global + local) use, that is of meeting low cost, ease of fabrication and quality and safety necessary has been amply reinforced by Thareja[10,11] and several others.[12-19] The complimentary requirements in future state vehicles have been discussed in another two part papers.[20] Consequently, they have now re-adapted to serve the needs of local street -tricycle/ rickshaw pullers.

Each journey is conceptually guided by some paradigm. Similarly this project was guided by the 4 DM model as developed by Mannu Thareja,[21] which specifies 5 steps namely Define, Design, Develop, Deploy and Manage the journey of development.

Define Phase

The first phase of the 4DM journey -the Define phase involves securing a clarity within the boundaries of scope, vis the definition of a rickshaw in the beginning, averse to a vehicle. Viz. while Cambridge English Dictionary[22] defines vehicle as a machine, usually with wheels and an engine, used for transporting people or goods on land, especially on road, our instrument of transport though functions as a machine is not yet powered because of the absence of the engine. This aspect and its conformance w.r.t the provisions of SAE was earnestly debated in the design phase.

The define phase continued listing the ambitions and the mapping of solutions.

Having defined the objectives, the definition phase also included deliberations on the name of this project to be. The objectives had involved a humanistic ferver to conscientiously recycle the manual exhaustion through storage of energy in the batteries. Thus this hybrid venture would be free from the knocking emanating of a petrol engine. The conventional that powered Auto-Rickshaws are popularly known as 'tuk-tuk' a Thai name based upon the linguistic principle called Onomatopoeia -as it mimicks the sound of a small (often two-cycle) engine.[23] On the contrary the present concept has been engineered to produce a hybrid electric tricycle powered from the rear and make no noise. Because of this feature of silence and guided by Onomatopoeia the proposed tricyle will be named Choup-Choup (silent - silent).

Table 1.Conceptual Specifications

Concept	Ideation	Significance
Thematic	A Hybrid human powered and electric motorized vehicle	Higher Flexibility, lower cost and willing adaptation
Main Structural Element	A Monocoque and light weight chassis of steel (AISI-1018)	vehicle stability and structural reliability
Negotiated turning @ greater speed and stability	tadpole design the front end exhibit less acceleration than rear while turning	vehicle.stability and reliability during turning
Needing to trace out circles of different radii	Providing Ackerman steering	Providing lower skidding during turning
Power Train	Rear wheel driving system	Easier pulling efficiency/ power development and higher loading
Lower skidding during	disc brakes	Least skidding while stopping
Driving Comfort and Flexibility	Motorised & Battery provision	Augmenting automatic power transmission & manual system
Vibration, Shocks and Riding Comfort	double coil suspension	Shock absorption

Design Phase

Thus, fully guided by technological advancements and current technological revolution the ultimate vehicle characteristic were defined and chosen. Consequently the specifications were narrowed down in line with the objectives. These are shown as in Table 1.

Designing and Development of Structural Elements

To render a light body, it was endeavoured to provide for a monocoque body. Such is a structure that integrates body and chassis together so as to form a composite structure is characterized by providing better stiffness and lower weight as well. The absence of chasis however calls for pursuing excellence in designing such that the safety requirements are sustained. Since the components of the monocoque body are used for performance and hence the net final weight is lower. It ultimately creates better value in the product.

It is vital to reiterate that engineers are not only The Builders of both society and the nation, but are also vehicles to the safety and well being of society. Thus a excellence in education may induct a transformational exuberance in the student, by bringing Value to educational products in good stance, through selects from individual elements interfaced with proportions of significance, that can change design or production propensity in a jiffy.[24]

In step one we proposed a working structure consisting of the three wheels and a loading component which supports the two seats (for pilot and the passenger/ trainee (call it co pilot), Battery and other components that may be necessary (Motors, transmission and auxiliaries -e.g. lubricating mechanism etc).

The selected option is schematically shown in figure 1.

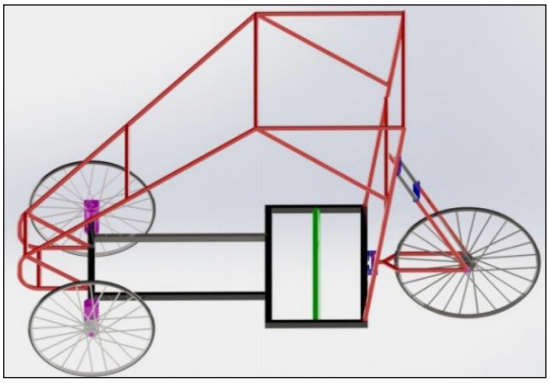

Figure 1. The Stipulated Monocoque Frame as Project Proposed for Validation by ANSYS

It was endeavoured that the tricycle could be driven jointly by the occupants and thus we could dispense the puller from being put into service. For this objective of power and stability it was decided to resort to Rear Wheel Driving (RWD).

Validation of Structure

We needed to be different, while being better in contrast to the traditional body-on-frame construction which relies on the frame to provide structural integrity. However to decide on monocoque body the systematic Structural Design was attempted for stress analysis using ANSYS. But before that a CAD file was to be prepared and analysed in ANSYS 14.0. The ANSYS output for static structural analysis for total deformation is shown in figure 2.

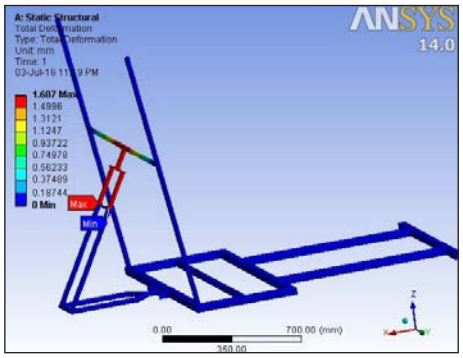

Figure 2. The screen shop of stress analysis using ANSYS 14

Thus, post validation we formulated a draft Design Specification Sheet, in which we optimized the dimensions and stipulated expected weight considering steel as the primary structural element.

Deployment

In the 4DM paradigm of Define, Design, Develop, Deploy and Manage, deployment calls for the implementation of improvement solutions, develop the processes incorporating conceived Change from erstwhile practices. In case of this project after the tricycle was developed we needed to give it a necessary shape and execute the detailed schema for execution.

Deployment of Design Solution

The next step involved development of the final concept. The proposed product was envisaged to be nearly conforming to the planned requirements and would look as close to the one which was (to be) finally developed, as is shown in figure 3. It involved equipping the valid chasis with the other functional requirements of the choop- choup. The fabrication quality had to be good so that both vibration and friction between moving parts were kept under control. The purpose of such activities is to add value to achieve targeted objectives, which do not preclude society's overall interests',[25] which have been identified as in the objectives of this paper. The development of design solution there fore must be synchronized with the material attributes for realsing the objectives in toto.

The draft Design Specification Sheet developed as a part of development process is shown as in table 1.

Figure 3.The proposal and final shaping of envisaged solution for choop-choup

Table 1.Chup choup Efficycle 2016 Design Specification Sheet

Team ID	**Team Name**			
xxx	Chup choup			
1. Dimensions				
Overall Length (with Bumpers etc)	2688.74	mm	105.86	inch
Overall Width (with Projected Parts)	1384.41	mm	54.5	inch
Overall Height	1719.74	mm	67.71	inch
Wheelbase	1940.27	mm	76.38	inch
Trackwidth	1260.27	mm	49.62	inch
Ground Clearance (rigid parts)	304.39	mm	11.98	inch
Ground Clearance (moving parts)	219.54	mm	8.64	inch
2. Weight	**Front**		**Rear**	
Kerb Weight (w/o driver & payload)	33.3	kg	79.7	kg
Total Weight	243			kg
Weight distribution over axles	30	%	70	%
Weigth with 75 kg drivers on each seat + 20kg payload	87	kg	203	kg
Weight distribution over axles	36	%	64	%

Role of Materials

Materials are the backbone of any society or its components. Governed by the same paradigm the materials for this choop- choup had to be designed to keep the weight limitations, as also the stipulated loading and ease of fabrication.

For the present work and stipulated chasis the required two types of sections included circular (tubular) and square sections. Hollow sections are better than the solid sections (of the same weight basis) as determined w.r.t strength to weight ratio. Thus we also endeavoured to deploy hollow materials for both section types.

The various set of properties as endeavoured in chosen materials are shown in the table 2.

Table 2.Material Consideration of Structural Component: Frame

Material-1 grade		
Cross Section Type	Circular	
Size (ID*OD*Wall Thickness) or similar specification	ID=21.4mm, OD=25.4mm, Thickness=2mm	
Yeild Strength	370	Mpa
Ultimate Strength	440	Mpa
% Elongation at Break (50mm length)	15	%
% Reduction in area	40	%
Density	7870	kg/m^3
Bending Strength	295.322	N-m
Bending Stiffness	2078031.7	$N\text{-}mm^2$
Material-2 grade		
Cross Section Type	Square	
Size (ID*OD*Wall Thickness) or similar specification	Sides=25.4mm, Thickness=2mm	
Yeild Strength	370	Mpa
Ultimate Strength	440	Mpa
% Elongation at Break (50mm length)	15	%
% Reduction in area	40	%
Density	7870	kg/m^3
Bending Strength	501.355	N-m
Bending Stiffness	3527777.76	$N\text{-}mm^2$

The ergonomics considerations are vital points in terms of driving comfort and safety and relevant input considerations were narrowed form study at How Stuff Works.[26] The various points considered were facilitating the flexibility to raise or lower the level of seat to ensure the driver has maximum vision of the road while ensuring the Knees are not bent to a level which strains the driver over exceeding sitting time. Additionally driver should sit comfortably so as to operate the accelerator/ clutch and break Lower Limb Position. The chosen seat parameters are summed up in table 3(a), whereas ergonomics considerations in table 3(b)0.

Table 3(a).The structural feature continued (Incorporating Seats)

Seating Configuration	Adjacent			
Driver Seat				
Facing	Forward			
Adjustments provided in seat	NA			
Seat Height (measured at Point-A)	304.8	mm	12	inch
Sitting Space Height	914.4	mm	36	inch
Seat Back angle (minimum)	105			deg
Seatback Angle (maximum)	107			deg
Slider total travel	NA	mm	NA	inch
Head Rest Type	Fixed to Seat			
Overhead protection type	Close Hoop			
Distance of Bend from Driver's head	516	mm	20.3	inch
Materials used in seat construction	Steel			
Co-Driver Seat				
Facing	Forward			
Adjustments provided in seat	NA			
Seat Height (measured at Point-A)	304.8	mm	12	inch
Sitting Space Height	914.4	mm	36	inch
Seat Back angle (minimum)	105			deg
Seatback Angle (maximum)	107			deg
Slider total travel	NA	mm	NA	inch
Head Rest Type	Fixed to Seat			
Overhead protection type	Close Hoop			
Distance of Bend from Driver's head	516	mm	20.3	inch
Materials used in seat construction	Steel			

Graduating the vehicle to a Hybrid one for increasing Capatence: For a continual availability of vehicle within constraints of freedom from driving stress or for driving comfort good capatence (capacity+competence) is mandated. This capatence requirement is a collaborative tenet of total drivers empowerment, implying that one can switch on into a powered mode from manual mode at will. The system was so designed such that a motor got charged when the pedals were moved. Such a power train is the u.s.p of the hybrid vehicle. Thus the Choop-Choup is prefixed by an "E" meaning 'Electric' try cycle.

The parameters of power train are tabled as in table 4.

Table 3 (b).Additional Requirements of Seats as Part of Structural feautures (optional)

Ergomonic Features in the vehicle	Seat ventilation system
Body panel material & Mounting Method	Composite fiber sheet & clamping method
Driver Assisting Devices (instrumentation or communication device etc)	

Table 4.Power Train

Human Power Drive Type (Driver)				
Type	Chain			
Operated by (Hands/ Foot/others)	Foot/ Hands			
Drive	Rear Wheel			
No of Gears	8			
Crank Length	1200	mm	47.2	inch
Distance between sprocket centres supporting chain till intermediate shaft	700.87	mm	27.59	inch
Number of Idler Gears	Not provided			
Human Power Drive Type (Co-driver)				
Type	Chain			
Operated by (Hands/ Foot/others)	Foot/Hands			
Drive	Rear Wheel			
No of Gears	8			
Crank Length	1200	mm	47.2	inch
Distance between sprocket centres supporting chain till intermediate shaft	700.87	mm	27.59	inch
Number of Idler Gears	Not provided			
4.1 Overall Human Power Drive Specificiation				
Intermediate Shaft	Yes			

Intermediate Shaft Size & Material	Diameter - 38.1 mm & AISI 1018			
Final Drive Gear Ratio	4:01			
Maximum Speed (km/h)	15	km/h	4.16	m/s
Maximum Acceleration	0.2			m/s^2
Gradeability	5	deg	8.74	%
Reaches 0-100 meters in	31.6			sec
4.2 Electric Drive Specificiation				
Motor Make	Abbron			
Type of Motor	PMDC			
Motor Power Output	0.5			HP
Maximum RPM	1500			
Input Voltage	48			Volt
Current Rating	8			Amps
Motor Efficiency	0.8			%
Battery Make	Amcell			
Type of Battery	Lithium-Ion			
Number of Batteries	1			
Individual Battery Voltage Rating	48			V
Individual Battery Capacity	35			Ah
Battery Pack Voltage Rating	48			V
Battery Pack Capacity	35			Ah
Battery Pack full charging time	3			hrs
Description of Transmission System, (write specs below where applicable)	Chain mechanism with one intermediate shaft			
No of Gears	3			
Distance between sprocket centres supporting chain at motor & Final Drive	778.92	mm	30.67	inch
Number of Idler Gears	0			
Controller Make	DC Drive			
Description of Controlling Mechanism	Open loop system			

Final Drive Gear Ratio	4:01			
Maximum Speed (km/h)	30	km/h	8.33	m/s
Maximum Acceleration	0.8			m/s^2
Gradeability	5	deg	8.74	%
Reaches 0-100 meters in	15.81			sec
4.3 Hybrid Drive Performance Specificiation				
Maximum Speed (km/h)	35	km/h	9.72	m/s
Maximum Acceleration	1.1			m/s^2
Gradeability	5	deg	8.74	%
Reaches 0-100 meters in	13.48			sec

Figure 4. The Execution of Hybridization in the Envisaged Solution for Electric choop-choup

Manage

Last Phase in 4 DM, i.e. Manage helps the quality improvements secured in the project sustain for necessary periods without any relapse or downgradation. The quality culture duly imbibed in the T.E.A.M come handy during this phase and all activities that help promote such requirements or competencies are pursued. Following set of tools, that may support the Quality Manage are suitably pursued:

Preventive Maintenance

Experience has it that it is simpler to design and develop a solution than managing it. Primarily because any 'Managing' requires a discipline. The vitality is therefore seen in the paradigm of 4DM, which integrates a post manufacturing management function. This Management function, in the 4DM paradigm, pertains essentially to the continual improvement function. However in this project the boundary

of 'Managing' must encompass a preventive maintenance policy or system as an integrated part of programme.

The maintenance rigour was defined herein around a set of three predefined preventive maintenance actions guided by fixed time-based intervals for each of the subsystems and especially the braking system.[27] A robust Preventive Maintenance programme can sure reduce number of short stoppages while additionally maintaining efficiency and productivity standards at the full scale operational levels.[28] The execution of an optimal preventive maintenance policy for a light and silent vehicle as in this project is essential to maintain system in fully operational effectiveness (availability) and also in terms of reliability.

The integration of Maintenance function with that of the Quality function as a part of 4DM is seen closer to being Autonomous. The goals of such Program are:[28]

- To prevent equipment deterioration through correct operation and daily checks.
- Establish the basic conditions needed to keep equipment well maintained.
- Bring equipment to its ideal state through restoration and proper management.
- Use the Autonomous Maintenance function as a process for inculcating in operators a new way of thinking and working.

Continual Improvement & Kaizens

In view of the demand for higher Quality in both products and services, a new stimulus of building a continual support system is mandated. The stimulus of higher quality is additionally important to the modem organization and becomes more critical for ultimate survival within demanding consumer markets. The awareness of Quality imperatives and the competitive environments are now getting global. To answer such requirements this project accented for beginning a training programme for building the concepts of Continual improvement & Kaizens in THE T.E.A.M. The initiatives was in line with the Quality Guru W E Deming's thinking, who in his Point 6 of the 14 point list recommends instituting training on the job. Training on the job is a double-edged practice applied in the context of corporate cultural practices,[29] which helps reinforce theory with practice.

Lean Thinking

Efficiently Managing the Utility of Manufacturing Facilities is vital, which can conceptually be set up through Lean thinking.[30] A Right and focused thinking sets in the impetus of higher productivity at lowest costs among The TEAM[1] As Gilbert and Gilbert echo the 'Accomplishments are what remain when the behavior has passed into history'.[31] The Lean thinking stimulus would help the TEAM ground with the imperatives of their improvement of engineering competence sustainably.

Total Productive Maintenance

Total Productive Maintenance (TPM) is a cooperator of the process of implementation of continuous improvement towards the total quality management. The Quality philosophy suggests it is necessary to identify the real causes behind any minor stop in execution and/ or generation of any quality defects any time[32] so that it is speedily corrected and desired progress maintained. This required a thorough understanding of the concept so that we can maintain any part of function/ equipment continuously at the desired performance level. For this is necessary that a detailed analysis for all the TPM components of the process equipment are carried out.[33] As stressed earlier about the lack of data on productivity of design and development of THE Choop- Choup and also in view of the cost constraints, the need for continual iteration was felt, which could be facilitation by TPM oriented thinking. Given, it is about the continuous improvement of equipment and consequently makes extensive use of standardization and/or workplace organization,[34] it was a potent tool for speedier execution of project and effectiveness of 4DM.

Conclusion

The Efficient Choop-Choup was designed for the benefit of the humanity. It is an eco friendly human powered vehicle with an augmented electric drive power system. The focus was laid on deriving high performance and easy maintenance. The stated objectives were targeted applying a holistic design solution. This was achieved while assuring simplicity of design and safety, including design comfort and quality of fabrication. All such requirements were pursued using the concepts of frugal product designing, maintain lower costs at all stages pursuing reasonable prices with high value/ performance projections. The project planning was govered by the author's paradigm that "The modulation of requirements of quality management makes a case that the total quality improvement process accents on the various core activities associated with the knowledge transfer to students through an environment which sustains the proliferation of 'quality culture' and plethoric use of quality, its management, through the optimal use of the quality management standard".[24]

It was endeavoured that the project serves the commuters between rural and urban settings and thus served as a hybrid empowerment for putting wheels in motion. The objective was sustained around reducing the efforts of driver & at the same time allow a more reliable control of the vehicle. It implies safety first, the education of which is built in during training of the T.E.A.M.[35] The design steps and validation of project details are being reported in a separate paper.[36]

What is there in a name is a popular parable and without any

argument this project served to provide more than necessary gains to the practitioners, apart from contributing a silent vehicle which may have wide potential in sub-city transport sector. It was a good challenge for understanding customer (socital) requirements and undertake manufacturing of many components. The gains have been reiteration of the concepts as indicated by one of the authors:

Technically, the tricycle was chosen to be a rear wheel driven one after having considered the pros and cons of front wheel driven and rear wheel driven vehicles as discussed by Peters.[37] The choice was supported by the consideration of design objectives iteratively, so as to ensure robustness. To support this the position of motors was controlled with respect to speed by DC drive which in turn controls the position of gear shifter. Thus it was endeavoured to make the vehicle increasingly efficient.

As mandated both in design provisions and expectations, this vehicle successfully met the necessary specifications as laid down by SAE India. The imperatives like Break Test, Endurance Strength of vehicle (as validated later during Technical Inspection by the team of SAE experts), were checked and found to our design expectations and thus fully served to continue the furtherance of 4DM motivation unabated. Thus, the journey that Human powered hybrid vehicle is a potent promise to further achieving higher milestone in the realm of "Green Technology" is seen to be true.

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