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USAID

CENTER FOR ENVIRONMENT
OFFICE OF ENERGY, ENVIRONMENT, AND TECHNOLOGY

BAJAJ AUTORIKSHA RE HEV AND EV CONVERSION FEASIBILITY STUDY

February 1997

Prepared by: Energy Technology Innovation Project
Contract No. DHR-5741-Q-00-1062-00
Delivery Order No. 8
Prime Contractor: Bechtel Corporation
Subcontractor: Unique Mobility, Inc.

1. Introduction

Bajaj Auto, Ltd. (Bajaj) requested Unique Mobility, Inc. (Unique) to conduct a study and develop a plan for the conversion of the Rear Engine (RE) Autoriksha three wheel vehicle to an electric vehicle (EV) and a hybrid electric vehicle (HEV) configuration. The conversion plan is to include: 1) characterization of the existing vehicle, 2) development of a simulation model, 3) recommendation of appropriate EV and HEV drive and support system components and 4) development of a detailed design for the implementation of the conversions.

This program is funded by United States Agency for International Development, Office of Energy, Environment and Technology (USAID). The program is managed by Bechtel Corp. (Bechtel) for USAID. Unique's contract is with Bechtel and the following report is fulfillment of the contract. Unique will continue to work on the program after the submission of this report and provide regular progress updates to Bajaj and USAID with the program concluding in a final report submitted to both parties detailing the program results.

The program is divided into two logical phases, **Phase I, Vehicle Specification** this phase will include:

1. Instrumenting and testing the existing vehicle to determine the vehicle characteristics i.e., performance and specifications.
2. Development of a simulation model that represents the Autoriksha.
3. Through the simulation model determination of the appropriate drive and support system components.
4. Submission of the Phase I Final Report detailing the findings, recommendations and approach for the completion of Phase II.

and **Phase II, Vehicle Conversions** this phase will include:

1. Conducting a study and providing recommendations for the packaging of the EV and HEV drive and support components and sub- systems.
2. Identification and detailed description of vehicle modifications necessary for the conversion to EV and HEV.
3. Development of a detailed design for the conversions including; installation plan, mounting and bracket designs and other related work specific to the EV and HEV conversions.
4. Submission of the Phase II Final Report detailing the conversion plan, detailed designs and recommended procedures.

The results discussed in the following report are based on limited work and are not to be considered final.

2. Characterization of Vehicle

Characterization of the stock Bajaj Autoriksha has consisted of three major components. First, the vehicle was instrumented, measured, and weighed. Next, the performance of the existing vehicle was evaluated. Finally, vehicle specifications were generated. The results of each step of the vehicle characterization follows.

2.1 Description of Instrumentation

A Daytronic DataPac was used for data collection during the vehicle characterization. This system recorded vehicle speed and time while testing acceleration, top speed and speedometer calibration. Vehicle speed was measured using a magnetic pickup, mounted to the trailing arm of the suspension. This magnetic pickup was mounted to sense vehicle speed using the lug bolts for excitation. Time is recorded from the computer clock. The data acquisition system can be seen installed on the vehicle in figure 1.

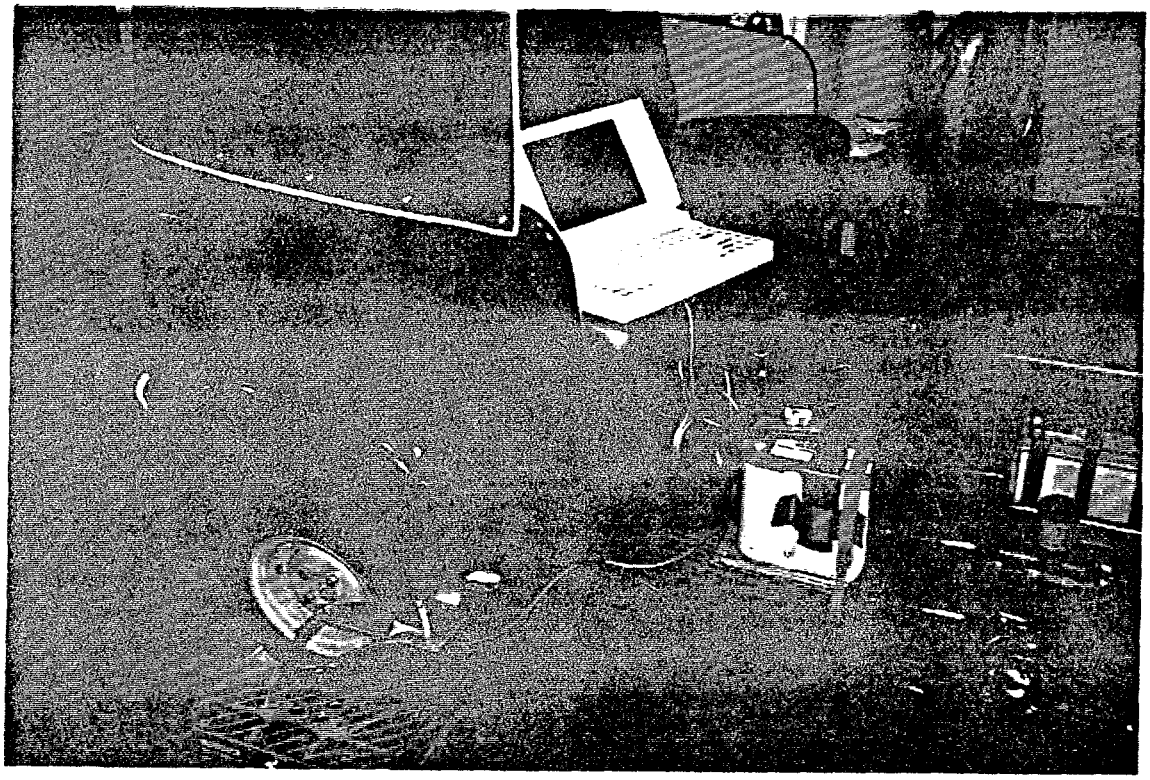

Figure 1, Data Acquisition System Installed on Vehicle.

A set of Longacre Automotive Products model 72588 vehicle scales were used to determine the total weight of the vehicle in both stock and as tested loading configurations. These scales were also used to determine the location of the center of gravity in the stock vehicle. Figure 2 shows the test vehicle being weighed in the as-tested condition.

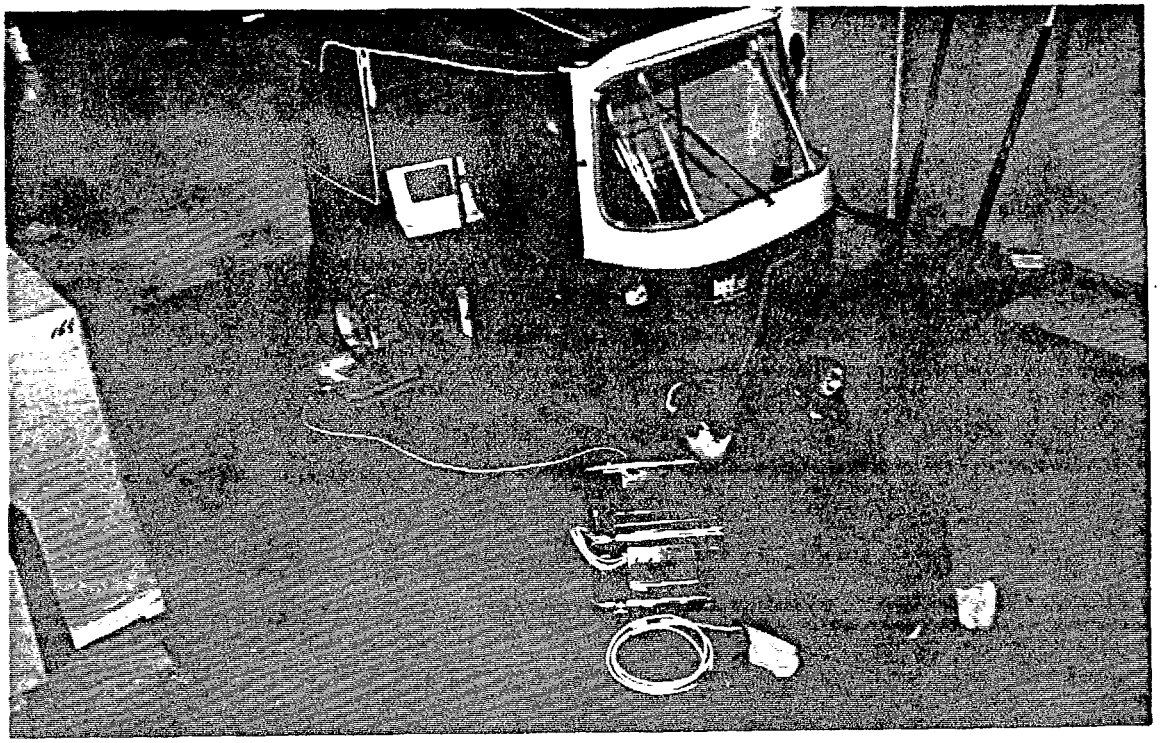

Figure 2, Weighing of Test Vehicle.

The tire rolling radius was determined by marking the tire of the vehicle, and then rolling the vehicle for 3 tire revolutions. The distance traveled for the 3 tire revolutions was measured. With this information the distance traveled in one revolution was calculated. Using the distance traveled in one revolution, the effective rolling radius was calculated. This testing can be seen in figure 3.

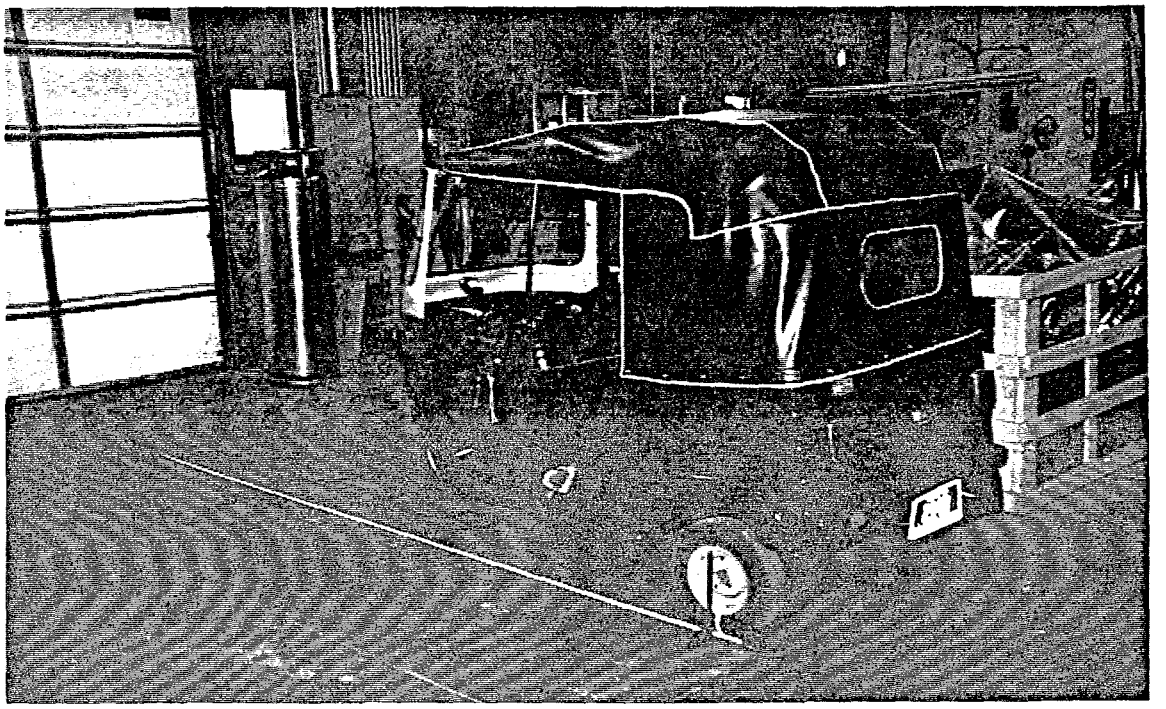

Figure 3, Measurement of Tire Rolling Radius.

Vehicle coast down testing was performed on the Autoriksha to determine the coefficient of aerodynamic drag and the rolling resistance coefficient. These tests were performed from 2 vehicle speeds. These tests were performed in both directions on a nearly level surface to average the effects of the grade. Equations from the Bosch Automotive Handbook, 3rd ed. were used.

The vehicle frontal area was determined using an estimate of the projected frontal area. This estimate is included in the vehicle specification section.

An estimate of the rotating inertia was made based on previous experience with vehicles of this size along with estimates for the components available without disassembly of the vehicle.

2.2 Existing Vehicle Performance

After the vehicle was instrumented several acceleration runs were directed. The test was conducted on a mild, constant grade making an equal number of runs in each direction at full throttle. The average of the data collected in each direction allowed us to eliminate the grade variable from the equation and simulate a level grade.

First, the data collected in each uphill test was analyzed and converted into equation form. The equations were averaged and the results yielded the curve shown in figure 4. The average top speed in this direction was 46.96 kph.

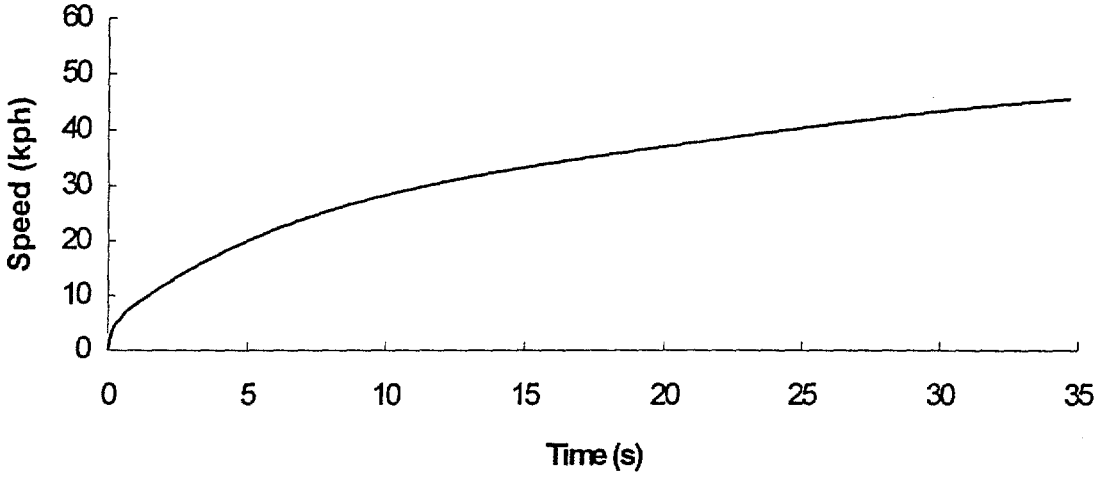

Figure 4, Uphill Acceleration Profile

Next, the data representing acceleration in the downhill direction was analyzed and processed similar to the uphill data. The average top speed at this approach was found to be 53.67 kph. Figure 5 shows the average downhill acceleration.

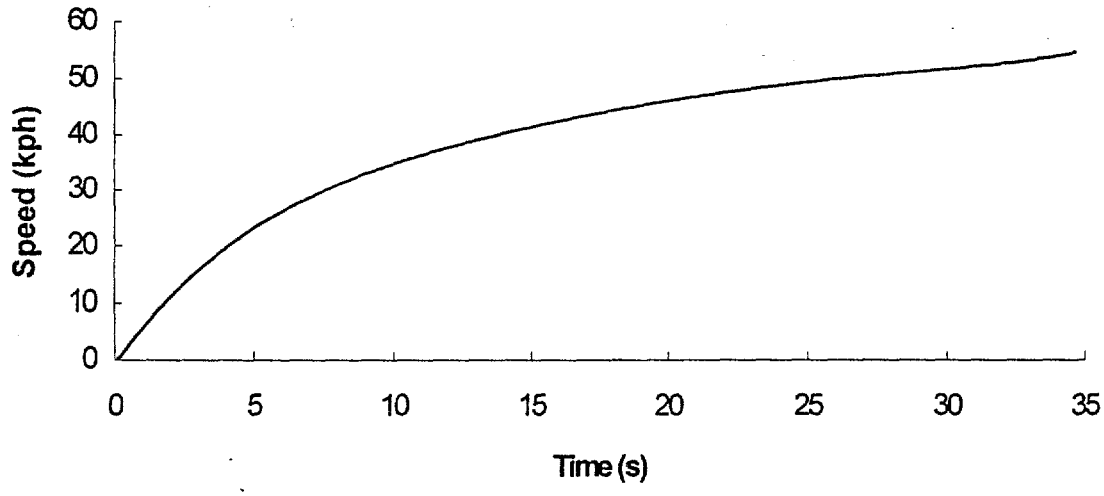

Figure 5, Downhill Acceleration Profile

After an average was generated in each direction, a composite equation could be calculated. This curve would represent the absolute acceleration of the vehicle as tested, simulating the performance of the vehicle on a perfectly level grade. The top speed of the vehicle on level ground was determined to be 50.32 kph. The composite acceleration profile is provided in figure 6.

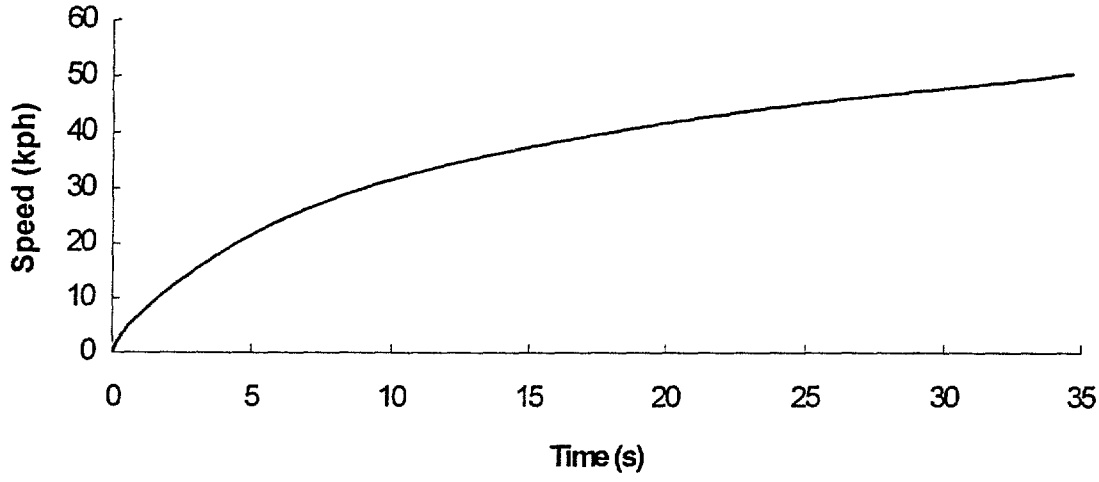

Figure 6, Composite Acceleration Profile

The vehicle's speedometer was verified using a stopwatch to measure the time to cover a known distance at two different vehicle speeds. Four trials were performed at each speed in an effort to reduce error. A 200 foot distance was used. As the vehicle was driven through the test course the speed of the vehicle was maintained at the desired verification speed. The time was recorded and averaged for the four trails. The speedometer correlation was found to be 9% faster than actual vehicle speed. This means that the speedometer on the test vehicle registered a speed faster than the true vehicle speed.

2.3 Vehicle Specifications

Based on data collected during testing and information from the vehicle's operator, service and parts manuals the following specifications were determined.

Table 1, Vehicle Specifications.

Stock Vehicle Weight (empty)	
Total	268.5 kg (592 lb)
Front Distribution	29 %
Rear Distribution	71 %
Stock Vehicle Center of Gravity Location (empty)	
Distance ahead of rear axle centerline	581.7 mm (22.9 in)
Distance above ground	328.2 mm (12.9 in)
As Tested Vehicle Weight (Data Acquisition, 1 Driver, and 1 Passenger)	
Total	464.5 kg (1024 lb)
Front Distribution	34 %
Rear Distribution	66 %
Speedometer Correlation	109% of actual speed
Effective Rolling Radius	197.9 mm (7.8 in)
Coefficient of Aerodynamic Drag	1.46
Coefficient of Rolling Resistance	.020
Projected Frontal Area	2.05 m^2 (22.1 ft^2)
Rotating Inertia	.764 kg-m^2 (.75 lb-ft-sec^2)
Gear Ratios (Overall)	
First Gear	25.12:1
Second Gear	16.49:1
Third Gear	11.30:1
Fourth Gear	7.48:1

3. Vehicle Conversion Architecture

The EV and HEV systems consist of a number of subsystems and components that are integrated to form a complete drive system. The EV and HEV system architectures will be similar except the HEV will incorporate a power generation unit (PGU). The PGU will be sized to fulfill the constant power requirements and an appropriately sized battery pack will be used to supplement the PGU power during acceleration and climbing a grade. Based on the initial results Unique has determined a first draft for the major components of the EV and HEV drive systems. The components and the method of integration into the vehicle are described below.

3.1 Electric Traction Drive System

The motor will be interfaced to the existing transmission. The use of the existing transmission and differential minimizes the components that must be developed and the multi-gear transmission will provide the necessary ratios to achieve the desired vehicle performance.

The drive system initially being investigated for the conversion of the Autoriksha is a modified UQM® SR180 motor. This motor is expected to be designed to become an integral part of the transaxle, replacing the engine. It will also be modified to operate at a nominal 96 V. This SR180 motor will likely be controlled by a modified UQM® CD05-100. This component combines inverter, controller, DC/DC converter and charger into a compact and integrated unit.

3.2 Power Generation Unit

A substitute for a portion of the battery pack in the hybrid will be the PGU, consisting of a small internal combustion engine driving a Unique PM generator and a power inverter unit. A modified UQM® SR121 motor is proposed for use as the alternator in the PGU. The engine for the PGU is not yet defined, but a 4-stroke gasoline and diesel types are under investigation. It is also proposed that rectification of the motor's three phase output be done with a bridge rectifier to provide a smaller package size and decreased cost compared to the typical inverter/controller unit.

3.3 Batteries

The battery requirements for the EV and HEV are different based upon their intended usage. Therefore, Unique has conducted separate studies to determine the appropriate battery and quantity for the EV and HEV applications. For the determination of the desired battery pack, battery modules from several manufactures were investigated to determine how each would meet the desired performance and range specifications of the vehicle in both the EV and HEV configurations.

The range specification provided for the EV configuration was 80 km. A nominal speed of 20 kph was used to calculate the required energy of the battery pack. The average energy required was 4.39 kW-h. However, this energy level varied due to the different battery weight. The number of total modules required to meet or exceed the specified range was found for each battery type considered. After this information was acquired, the specific and available capacity, actual range, and total pack weight was found and compiled into the following chart along with estimated cost and availability. Table 2 shows the comparison of the battery models investigated.

Table 2, EV Battery Comparison

Battery Pack Description	Required Capacity (kW-h)	Available Capacity (kW-h)	Range @ 20kph (km)	Total Pack Weight (kg)	Total Modules	Estimated Pack Cost ($)	Availability
Optima 6V	4.67	5.00	85.7	201.8	64	>10,000	N
Optima 12V	4.48	5.20	92.4	162.9	8	1,064	Y
Hawker (G12V12Ah10EP)	4.46	4.80	86.2	159.6	32	2,000	Y
Hawker (G12V26Ah10EP)	4.49	5.20	92.6	166.9	16	1,500	Y
Horizon 24V	4.20	4.20	79.9	136.0	10	>30,000	N
Ovonic 48V	4.02	4.50	89.6	71.2	2	>100,000	N

For the EV configuration Unique recommends the Optima 12V modules. This recommendation is based on the high energy capacity to weight ratio, cost and availability of these batteries.

The range specification for the HEV configuration was to be dependent upon the fuel on board the vehicle. For this specification the vehicle must be able to operate at a low depth of discharge of the battery pack. As indicated in section 3.2 the PGU will be used as the main power source and the battery pack will provide surge power. In this case, the energy capacity of the pack is not a primary concern. The pack size was chosen based on the minimum number of modules needed to meet the instantaneous power requirements and the 100V nominal system voltage. This allowed considerable reduction in pack size. For the HEV configuration the recommended battery is the Hawker (G12V12Ah10EP) unit. This conclusion is based on the low pack weight, cost, and availability of these batteries. A comparison of the investigated batteries for the HEV configuration is shown below in table 3.

Table 3, HEV Battery Pack Comparison

Battery Pack Description	Required Capacity (kW-h)	Available Capacity (kW-h)	Range @ 20kph (km)	Total Pack Weight (kg)	Total Modules	Estimated Pack Cost ($)	Availability
Optima 6 V	N/A	1.25	N/A	50.7	16	>10,000	N
Optima 12 V	N/A	5.20	N/A	162.9	8	1,064	Y
Hawker (G12V12Ah10EP)	N/A	1.20	N/A	39.9	8	500	Y
Hawker (G12V26Ah10EP)	N/A	2.60	N/A	83.5	8	725	Y
Horizon 24 V	N/A	2.10	N/A	54.4	4	>30,000	N
Ovonic 48 V	N/A	4.50	N/A	71.2	2	>100,000	N

3.4 Vehicle Accessory Power

The Autoriksha vehicle has a 12V accessory system for head lights and tail lights, turn signals and horn. This system must be maintained for safety reasons, therefore, Unique plans to use a DC to DC voltage converter to fulfill this requirement.

A DC to DC converter was sized for this application based on the continuous loads expected on the vehicle. This estimate was made primarily with the use of the service manual for the vehicle and the ratings of the major components expected to be operated on the vehicle. The initial estimate of DC to

DC converter requirement was found to be 50 W. This power level can be met with the DC to DC converter included in the UQM® CD05-100 inverter/controller unit described in section 3.1.

3.5 Suspension Modifications

In order to safely support the increased weight of the vehicle due to the EV and HEV conversion, the rear suspension should be strengthened for safety. Reinforcing the crossmember connecting the trailing arm pivots is advised. It is also suggested that the shock mounting connections on the trailing arms be gusseted to distribute the increased load evenly into the trailing arm. Connecting the top shock mounting locations to help to maintain rear suspension geometry and integrity is also suggested. It may also be necessary to increase the rear spring rate to better control the movement of the body and suspension.

3.6 EV and HEV Conversion Layout

Based on the components selected and the existing design of the Autoriksha vehicle Unique has defined an initial packaging layout of the EV and HEV drive and support systems as installaed in the vehicle. Figures 4 and 5 show the basic layout of the major components for the EV and HEV conversions respectivily.

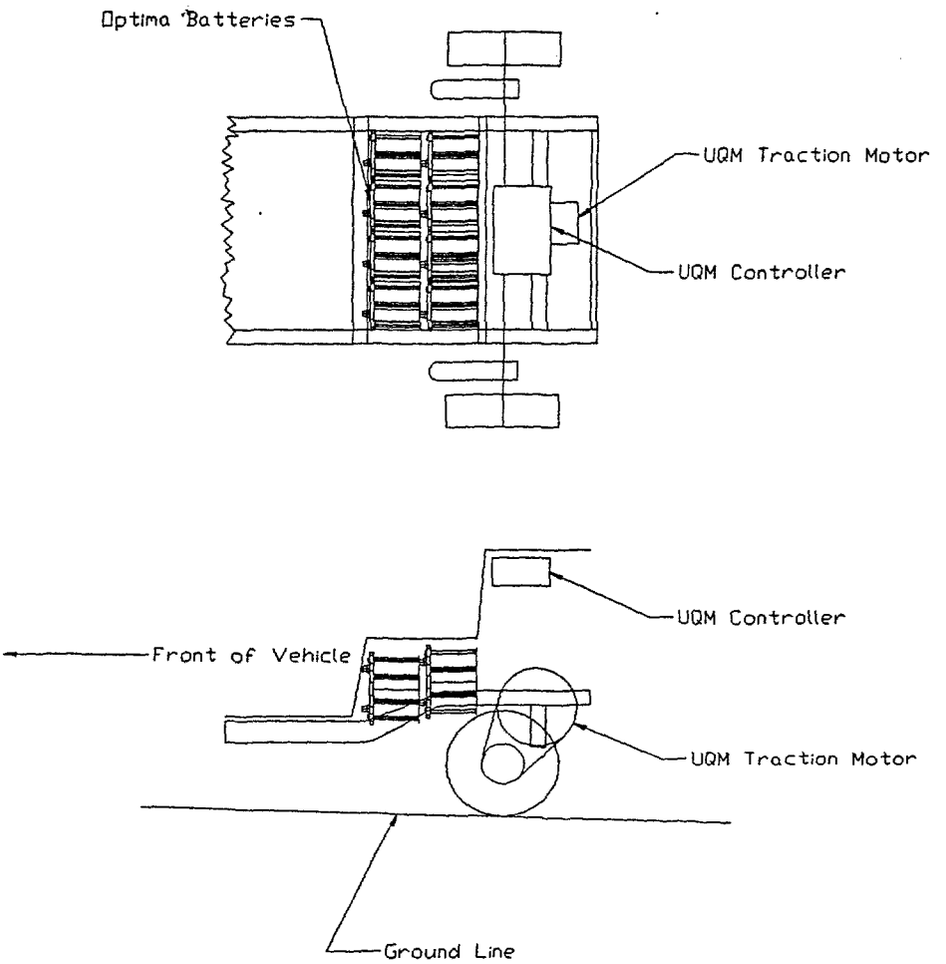

Figure 4, Basic EV Conversion Package Layout.

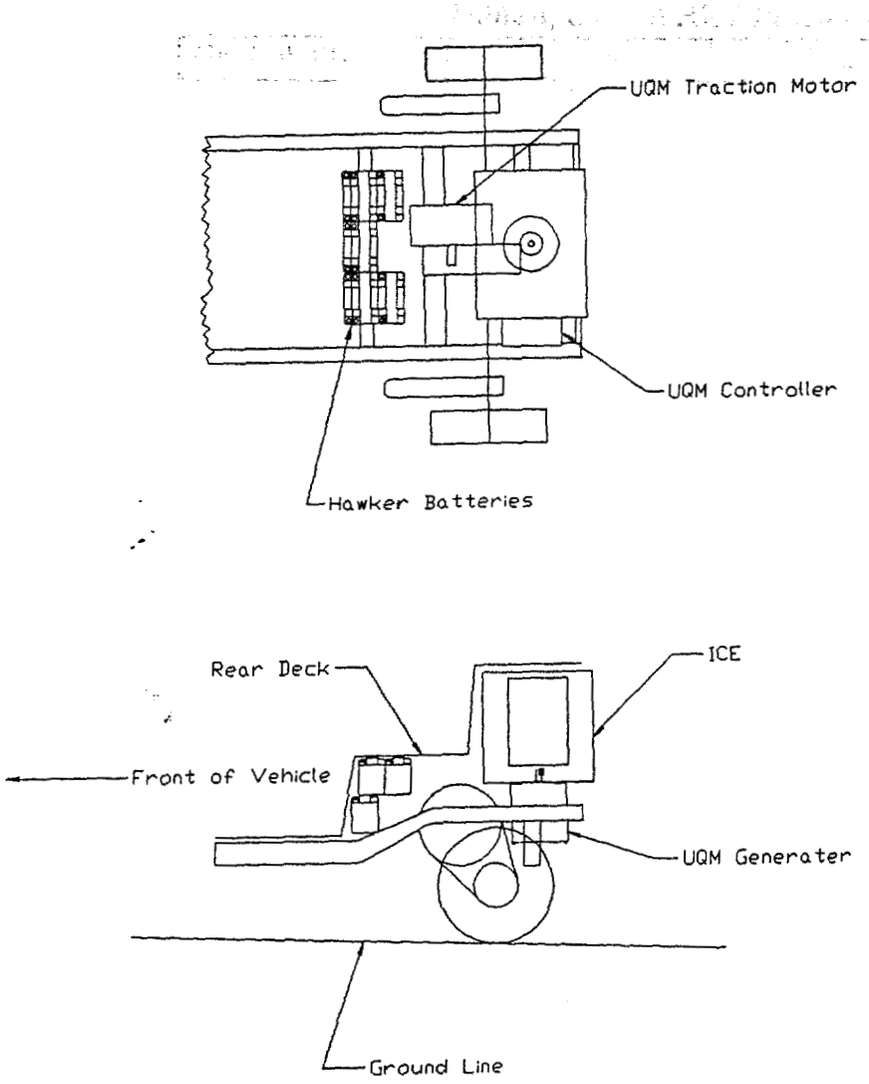

Figure 5, Basic HEV Conversion Package Layout.

3.7 Predicted EV and HEV Performance

Based on the vehicle specifications and the above detailed drive systems the predicted performance for the EV and HEV conversions is listed in Table 4.

Table 4, EV and HEV Predicted Performance.

Gradeability	Target	EV Prediction	HEV Predication
10 kph	16	33 %	39 %
20 kph	--	20 %	23 %
30 kph	--	11 %	13 %
40 kph	--	4 %	5 %
50 kph	--	2 %	3 %
Acceleration			
0-10 kph	--	0.70 sec	0.62 sec
0-20 kph	6	1.72 sec	1.50 sec
0-30 kph	11	3.62 sec	3.14 sec
0-40 kph	16	7.53 sec	6.45 sec
0-50 kph	21	15.33 sec	12.82 sec
Range			
20 kph (EV) 20 kph (HEV)	80 km determined by fuel	92.4 km N/A	N/A 216 km w/ 6.5 l fuel

Details of the complete simulation models, EV and HEV, are included as Attachments A and B respectively.

4. Program Completion Plan

As indicated the preceding is an interim report that is to be used to fulfill a specific requirement and the recommendations discussed within are based on initial testing and evaluation efforts and are not considered final at this time. Unique is on contract to complete the program as proposed and expects to perform the work in full over the period of the program. Table 5 shows the schedule for completion of the program.

Table 5, Program Schedule.

	Months							
Task	1/97	2/97	3/97	4/97	5/97	6/97	7/97	8/97
Receive Autoriksha	*							
Assemble Vehicle	*							
Phase I Vehicle Specification	S----------C							
Vehicle Characterization	S----------C							
Systems Analysis			S---------C					
Phase I Report				S--C				
Program Management	S----------C							
Phase II Vehicle Conversion				S----------C				
Component Packaging Study				S---C				
Identify Vehicle Modifications				S----------C				
Detailed Engineering Design				S----------C				
Prepare Phase II Report							S------C	
Submit Phase II Report								*
Program Management				S---------- C				

During the System Analysis efforts it is expected that Bajaj will have representative(s) present to view the ongoing work and provide input.

Attachment A

EV Performance Prediction

Autorik1.xls

VEHICLE SPECIFICATION AND PERFORMANCE REQUIREMENTS:

Motor/Controller System : Modified SR180/CR10-200

VEHICLE DESCRIPTION: Bajaj Autorikshaw 2/11/97

VEHICLE WEIGHT;			
Curb Weight =	600.00	lb	(input variable)
Hybrid Generator	0.00	lb	(input variable)
Battery Weight	360.00	lb	(input variable)
Payload =	432.00	lb	(input variable)
Vehicle Test Weight =	1392.00	lb	(calculated value)
VEHICLE CHARACTERISTICS;			
Rolling Resistance Coefficient	0.02		(input variable)
Tire Rolling Radius =	7.8	inch	(input variable)
Tire rev/mile =	1294.5		(calculated value)
Cd = Vehicle Drag Coeff =	1.46		(input variable)
Vehicle Frontal Area =	22.14	ft^2	(input variable)
Air density =	0.00233	lbm/ft^3	(input variable)
Drivetrain efficiency =	91	%	(input variable)
First Gear Overall Reduction	25.12	: 1	(input variable)
Top Speed in First Gear	9.96	mph	(calculated value)
Second Gear Overall Reduction	16.49	: 1	(input variable)
Top Speed in Second Gear	15.18	mph	(calculated value)
Third Gear Overall Reduction	11.30	: 1	(input variable)
Top Speed in Third Gear	22.15	mph	(calculated value)
Fourth Gear Overall Reduction	7.48	: 1	(input variable)
Top Speed in Fourth Gear	33.46	mph	(calculated value)
Shift Time	0.75	sec	(input variable)
Total Inertia at Wheel Speed =	0.75	lbf-ft-sec^2	(input variable)
Number of Drive Motors =	1		(input variable)
Continuous Torque Rating	13.60	lb-ft	(input variable)
Contituous Power Rating	12.95	hp	(input variable)
Intermittent Torque Rating	13.60	lb-ft	(input variable)
Intermittent Power Rating	12.95	hp	(input variable)
Intermittent Power Rating Duty Cycle	25	%	(input variable)
Motor Base Speed	5000	rpm	(input variable)
Maximum Motor Speed =	5400	rpm	(input variable)
Vehicle Accessory Power Requirement	10	W	(input variable)
Drive System Maximum Auxiliary load	5	W	(input variable)
Grade During and Acceleration	0	%	(input variable)
Nominal Battery Pack Voltage	48	V	(input variable)
Location of Center of Gravity ahead of Rear	22.88	in	(input variable)
Location of Center of gravity behind front axe	55.86	in	(Calculated Value)
Location of Center of Gravity above Ground	20.71	in	(input variable)
Wheelbase	78.74	in	(input variable)

Performance Summary: 2/11/97

Test Weight 1392 lb

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RESULTS

Predicted Acceleration from a stop to

5	kph	0.32 sec
10	kph	0.70 sec
15	kph	1.11 sec
20	kph	1.72 sec
25	kph	2.49 sec
30	kph	3.62 sec
35	kph	4.85 sec
40	kph	7.53 sec
45	kph	10.84 sec
50	kph	15.33 sec
55	kph	30.21 sec

Predicted Continuous gradeability

5	kph	34.17 %
10	kph	33.95 %
15	kph	33.19 %
20	kph	20.01 %
25	kph	12.08 %
30	kph	11.44 %
35	kph	9.78 %
40	kph	4.53 %
45	kph	3.56 %
50	kph	2.44 %
55	kph	0.32 %

Maximum Gradeability due to traction

Dry road	1.38
.2 mm of Water on roa	1.04

2/11/97

Table 1

Constant speed requirements and maximum gradeability based on continuous motor rating

Speed (kph)	Speed (mph)	Wheel (rpm)	Rolling Res't (W)	Aero Drag. (W)	Wheel Power (W)	Wheel Torque (lb-ft)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (W)	Mtr/Cntr Effic'y (%)	Availiabile Motor Power (W)	Motor Torque (ft-lb)	Continuou Grade (%)	Road Energy (kWh/km)
0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.00	75.7	0.00	13.6	36.64	0.000
1	0.62	13.4	34.5	0.0	34.50	18.1	336.8	0.79	37.91	75.7	650.55	13.6	34.25	0.050
2	1.24	26.8	69.0	0.3	69.33	18.2	673.5	0.80	76.19	75.7	1301.11	13.6	34.23	0.050
3	1.86	40.2	103.7	1.0	104.73	18.3	1010.3	0.80	115.09	75.7	1951.66	13.6	34.22	0.051
4	2.49	53.6	138.5	2.5	140.93	18.5	1347.0	0.81	154.87	75.7	2602.21	13.6	34.20	0.051
5	3.11	67.0	173.3	4.8	178.16	18.7	1683.8	0.82	195.78	85.3	3252.77	13.6	34.17	0.046
6	3.73	80.4	208.3	8.4	216.65	19.0	2020.5	0.83	238.08	85.3	3903.32	13.6	34.14	0.047
7	4.35	93.8	243.4	13.3	256.65	19.3	2357.3	0.84	282.03	85.3	4553.87	13.6	34.10	0.047
8	4.97	107.2	278.5	19.8	298.36	19.6	2694.1	0.86	327.87	89.1	5204.42	13.6	34.05	0.046
9	5.59	120.7	313.8	28.2	342.04	20.0	3030.8	0.87	375.87	89.1	5854.98	13.6	34.01	0.047
10	6.21	134.1	349.2	38.7	387.92	20.4	3367.6	0.89	426.28	89.1	6505.53	13.6	33.95	0.048
11	6.84	147.5	384.7	51.5	436.22	20.8	3704.3	0.91	479.36	91.0	7156.08	13.6	33.89	0.048
12	7.46	160.9	420.3	66.9	487.17	21.3	4041.1	0.93	535.35	91.0	7806.64	13.6	33.83	0.049
13	8.08	174.3	456.0	85.0	541.02	21.9	4377.8	0.96	594.52	91.0	8457.19	13.6	33.76	0.050
14	8.70	187.7	491.8	106.2	597.98	22.4	4714.6	0.98	657.13	117.1	9107.74	13.6	33.68	0.040
15	9.32	201.1	527.7	130.6	658.31	23.0	5051.4	1.01	723.41	115.4	9659.09	13.5	33.19	0.042
16	9.94	214.5	563.7	158.6	722.22	23.7	5388.1	1.04	793.64	106.2	9659.09	12.6	30.65	0.047
17	10.56	227.9	599.8	190.2	789.94	24.4	3758.1	1.63	866.07	91.0	7259.93	13.6	20.29	0.056
18	11.18	241.3	636.0	225.8	861.72	25.1	3979.1	1.68	946.95	91.0	7686.99	13.6	20.20	0.058
19	11.81	254.7	672.3	265.5	937.78	25.9	4200.2	1.73	1030.53	91.0	8114.04	13.6	20.11	0.060
20	12.43	268.1	708.7	309.7	1018.36	26.7	4421.3	1.78	1119.08	91.0	8541.10	13.6	20.01	0.062
21	13.05	281.5	745.2	358.5	1103.69	27.6	4642.3	1.84	1212.64	117.1	8988.15	13.6	19.91	0.049
22	13.67	294.9	781.8	412.2	1193.99	28.5	4863.4	1.90	1312.08	117.1	9395.21	13.6	19.81	0.051
23	14.29	308.3	818.5	471.0	1289.51	29.4	5084.5	1.96	1417.04	114.3	9659.09	13.4	19.30	0.054
24	14.91	321.7	855.3	535.1	1390.47	30.4	5305.5	2.03	1527.99	108.1	9659.09	12.8	18.21	0.059
25	15.53	335.1	892.3	604.9	1497.11	31.4	3787.2	3.06	1645.16	91.0	7316.13	13.6	12.08	0.072
26	16.16	348.6	929.3	680.4	1609.66	32.5	3938.7	3.16	1768.86	91.0	7608.78	13.6	11.96	0.075
27	16.78	362.0	966.4	761.9	1728.35	33.6	4090.1	3.27	1899.28	91.0	7901.42	13.6	11.84	0.077
28	17.40	375.4	1003.6	849.8	1853.41	34.8	4241.6	3.38	2036.72	91.0	8194.07	13.6	11.71	0.080
29	18.02	388.8	1041.0	944.1	1985.08	35.9	4393.1	3.50	2181.41	91.0	8486.71	13.6	11.57	0.083
30	18.64	402.2	1078.4	1045.2	2123.59	37.2	4544.6	3.61	2333.62	117.1	8779.36	13.6	11.44	0.066
31	19.26	415.6	1115.9	1153.2	2269.17	38.4	4696.1	3.74	2493.59	117.1	9072.00	13.6	11.29	0.069
32	19.88	429.0	1153.6	1268.5	2422.05	39.7	4847.6	3.87	2661.59	117.1	9364.65	13.6	11.15	0.071
33	20.51	442.4	1191.3	1391.1	2582.47	41.1	4999.1	4.00	2837.88	117.1	9657.30	13.6	10.99	0.073
34	21.13	455.8	1229.2	1521.5	2750.65	42.5	5150.6	4.13	3022.69	112.3	9659.09	13.2	10.38	0.079
35	21.75	469.2	1267.1	1659.7	2926.83	43.9	5302.0	4.27	3216.30	108.2	9659.09	12.8	9.78	0.085
36	22.37	482.6	1305.2	1806.1	3111.25	45.4	3809.9	6.67	3418.95	91.0	6973.76	13.6	5.23	0.104
37	22.99	496.0	1343.3	1960.8	3304.13	46.9	3710.2	6.89	3630.91	91.0	7167.48	13.6	5.06	0.108
38	23.61	509.4	1381.6	2124.1	3505.70	48.4	3810.5	7.12	3852.42	91.0	7361.19	13.6	4.89	0.111
39	24.23	522.8	1419.9	2296.3	3716.21	50.0	3910.8	7.35	4083.74	91.0	7554.91	13.6	4.71	0.115
40	24.85	536.2	1458.4	2477.5	3935.87	51.7	4011.1	7.59	4325.13	91.0	7748.63	13.6	4.53	0.119
41	25.48	549.6	1497.0	2668.0	4164.93	53.3	4111.3	7.84	4576.85	91.0	7942.34	13.6	4.35	0.123
42	26.10	563.0	1535.6	2868.0	4403.61	55.1	4211.6	8.09	4839.13	91.0	8136.06	13.6	4.15	0.127
43	26.72	576.5	1574.4	3077.8	4652.15	56.8	4311.9	8.35	5112.26	91.0	8329.77	13.6	3.96	0.131
44	27.34	589.9	1613.3	3297.5	4910.78	58.6	4412.2	8.61	5396.47	91.0	8523.49	13.6	3.76	0.135
45	27.96	603.3	1652.2	3527.5	5179.74	60.4	4512.4	8.88	5692.02	117.1	8717.20	13.6	3.56	0.108
46	28.58	616.7	1691.3	3767.9	5459.25	62.3	4612.7	9.16	5999.17	117.1	8910.92	13.6	3.35	0.111
47	29.20	630.1	1730.5	4019.0	5749.54	64.2	4713.0	9.44	6318.18	117.1	9104.64	13.6	3.14	0.115
48	29.83	643.5	1769.8	4281.1	6050.85	66.2	4813.3	9.73	6649.29	117.1	9298.35	13.6	2.92	0.118
49	30.45	656.9	1809.2	4554.2	6363.42	68.2	4913.5	10.02	6992.77	117.1	9492.07	13.6	2.70	0.122
50	31.07	670.3	1848.7	4838.8	6687.47	70.2	5013.8	10.32	7348.86	116.6	9659.09	13.6	2.44	0.126
51	31.69	683.7	1888.2	5135.0	7023.23	72.3	5114.1	10.62	7717.83	113.4	9659.09	13.3	2.01	0.133
52	32.31	697.1	1927.9	5443.0	7370.94	74.4	5214.4	10.94	8099.94	110.5	9659.09	13.0	1.59	0.141
53	32.93	710.5	1967.7	5763.1	7730.83	76.6	5314.6	11.25	8495.42	107.9	9659.09	12.8	1.16	0.149
54	33.55	723.9	2007.6	6095.5	8103.14	78.8	5414.9	11.58	8904.55	105.6	9659.09	12.6	0.74	0.156
55	34.18	737.3	2047.6	6440.5	8488.09	81.0	5515.2	11.91	9327.57	50.1	9659.09	12.3	0.32	0.338

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Table 2

Vehicle acceleration based on intermittent motor torque — Bajaj Autorikshaw — 2/11/97

Performed on a 0 % Grade

Accel Time (S)	Speed (kph)	Speed (mph)	Distance (ft)	Wheel (rpm)	Rolling Res't (W)	Aero Drag. (W)	Grade Resistance (W)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (kW)	Availiabile Motor Torque (lb-ft)	Motor Power (kW)	Power for Accel (kW)	Energy Required for Accel (kW-h)
0.0	0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.40	0.00	13.6	0.00	0.00	0.0000
0.0	1	0.6	0.0	13.4	17.2	0.0	0	336.8	0.40	0.02	13.6	0.65	0.63	0.0000
0.1	2	1.2	0.1	26.8	51.8	0.2	0	673.5	0.60	0.06	13.6	1.30	1.24	0.0000
0.2	3	1.9	0.3	40.2	86.4	0.9	0	1010.3	0.67	0.10	13.6	1.95	1.86	0.0000
0.2	4	2.5	0.5	53.6	121.1	2.2	0	1347.0	0.71	0.14	13.6	2.60	2.47	0.0000
0.3	5	3.1	0.8	67.0	156.0	4.4	0	1683.8	0.74	0.18	13.6	3.25	3.08	0.0001
0.4	6	3.7	1.2	80.4	190.9	7.7	0	2020.5	0.76	0.22	13.6	3.90	3.69	0.0001
0.5	7	4.3	1.6	93.8	226.0	12.3	0	2357.3	0.78	0.26	13.6	4.55	4.29	0.0001
0.5	8	5.0	2.2	107.2	261.1	18.6	0	2694.1	0.80	0.31	13.6	5.20	4.90	0.0001
0.6	9	5.6	2.8	120.7	296.4	26.7	0	3030.8	0.82	0.35	13.6	5.85	5.50	0.0001
0.7	10	6.2	3.4	134.1	331.7	36.8	0	3367.6	0.85	0.40	13.6	6.51	6.10	0.0001
0.8	11	6.8	4.2	147.5	367.2	49.2	0	3704.3	0.87	0.46	13.6	7.16	6.70	0.0002
0.9	12	7.5	5.0	160.9	402.8	64.1	0	4041.1	0.89	0.51	13.6	7.81	7.29	0.0002
0.9	13	8.1	6.0	174.3	438.4	81.8	0	4377.8	0.92	0.57	13.6	8.46	7.89	0.0002
1.0	14	8.7	7.0	187.7	474.2	102.4	0	4714.6	0.95	0.63	13.6	9.11	8.47	0.0002
1.1	15	9.3	8.0	201.1	510.1	126.3	0	5051.4	0.97	0.70	13.5	9.66	8.96	0.0002
1.2	16	9.9	9.3	214.5	546.0	153.6	0	5388.1	1.00	0.77	12.6	9.66	8.89	0.0002
1.3	17	10.6	11.2	227.9	582.1	184.6	0	3758.1	1.58	0.84	13.6	7.28	6.42	0.0003
1.5	18	11.2	13.3	241.3	618.3	219.5	0	3979.1	1.63	0.92	13.6	7.69	6.77	0.0003
1.6	19	11.8	15.6	254.7	654.6	258.5	0	4200.2	1.68	1.00	13.6	8.11	7.11	0.0003
1.7	20	12.4	17.9	268.1	691.0	301.9	0	4421.3	1.74	1.09	13.6	8.54	7.45	0.0003
1.9	21	13.0	20.4	281.5	727.4	350.0	0	4642.3	1.80	1.18	13.6	8.97	7.78	0.0003
2.0	22	13.7	23.0	294.9	764.0	402.8	0	4863.4	1.86	1.28	13.6	9.40	8.11	0.0003
2.1	23	14.3	25.9	308.3	800.7	460.8	0	5084.5	1.92	1.39	13.4	9.66	8.27	0.0004
2.3	24	14.9	29.0	321.7	837.5	524.0	0	5305.5	1.99	1.50	12.8	9.66	8.16	0.0004
2.5	25	15.5	33.9	335.1	874.4	592.8	0	3787.2	3.00	1.61	13.6	7.32	5.70	0.0005
2.7	26	16.2	39.0	348.6	911.4	667.3	0	3938.7	3.10	1.73	13.6	7.61	5.87	0.0005
2.9	27	16.8	44.3	362.0	948.5	747.8	0	4090.1	3.21	1.86	13.6	7.90	6.04	0.0005
3.2	28	17.4	50.0	375.4	985.7	834.6	0	4241.6	3.32	2.00	13.6	8.19	6.19	0.0005
3.4	29	18.0	55.9	388.8	1023.0	927.8	0	4393.1	3.44	2.14	13.6	8.49	6.34	0.0005
3.6	30	18.6	62.1	402.2	1060.4	1027.8	0	4544.6	3.55	2.29	13.6	8.78	6.48	0.0006
3.8	31	19.3	68.6	415.6	1097.9	1134.6	0	4696.1	3.68	2.45	13.6	9.07	6.62	0.0006
4.1	32	19.9	75.4	429.0	1135.6	1248.6	0	4847.6	3.80	2.62	13.6	9.36	6.74	0.0006
4.3	33	20.5	82.5	442.4	1173.3	1370.1	0	4999.1	3.94	2.79	13.6	9.66	6.86	0.0006
4.6	34	21.1	90.3	455.8	1211.1	1499.1	0	5150.6	4.07	2.98	13.2	9.66	6.68	0.0007
4.8	35	21.7	98.7	469.2	1249.0	1636.0	0	5302.0	4.21	3.17	12.8	9.66	6.49	0.0007
5.3	36	22.4	114.9	482.6	1287.0	1781.0	0	3609.9	6.57	3.37	13.6	6.97	3.60	0.0012
5.9	37	23.0	132.1	496.0	1325.2	1934.3	0	3710.2	6.80	3.58	13.6	7.17	3.59	0.0010
6.4	38	23.6	150.3	509.4	1363.4	2096.2	0	3810.5	7.02	3.80	13.6	7.36	3.56	0.0011
7.0	39	24.2	169.7	522.8	1401.7	2266.8	0	3910.8	7.26	4.03	13.6	7.55	3.52	0.0011
7.5	40	24.9	190.5	536.2	1440.2	2446.5	0	4011.1	7.50	4.27	13.6	7.75	3.48	0.0012
8.1	41	25.5	212.6	549.6	1478.7	2635.4	0	4111.3	7.74	4.52	13.6	7.94	3.42	0.0013
8.8	42	26.1	236.3	563.0	1517.4	2833.8	0	4211.6	7.99	4.78	13.6	8.14	3.35	0.0014
9.4	43	26.7	261.8	576.5	1556.1	3042.0	0	4311.9	8.25	5.05	13.6	8.33	3.28	0.0015
10.1	44	27.3	289.2	589.9	1594.9	3260.0	0	4412.2	8.51	5.34	13.6	8.52	3.19	0.0016
10.8	45	28.0	318.8	603.3	1633.9	3488.3	0	4512.4	8.78	5.63	13.6	8.72	3.09	0.0017
11.6	46	28.6	351.0	616.7	1672.9	3727.0	0	4612.7	9.06	5.93	13.6	8.91	2.98	0.0019
12.4	47	29.2	386.0	630.1	1712.1	3976.3	0	4713.0	9.34	6.25	13.6	9.10	2.85	0.0021
13.3	48	29.8	424.3	643.5	1751.4	4236.5	0	4813.3	9.62	6.58	13.6	9.30	2.72	0.0023
14.3	49	30.4	466.6	656.9	1790.7	4507.8	0	4913.5	9.92	6.92	13.6	9.49	2.57	0.0025
15.3	50	31.1	514.1	670.3	1830.2	4790.4	0	5013.8	10.22	7.28	13.6	9.66	2.38	0.0028
16.6	51	31.7	572.5	683.7	1869.7	5084.6	0	5114.1	10.52	7.64	13.3	9.66	2.02	0.0034
18.2	52	32.3	647.3	697.1	1909.4	5390.7	0	5214.4	10.83	8.02	13.0	9.66	1.64	0.0043
20.3	53	32.9	749.7	710.5	1949.2	5708.7	0	5314.6	11.15	8.42	12.8	9.66	1.24	0.0057
23.6	54	33.6	907.7	723.9	1989.0	6039.1	0	5414.9	11.47	8.82	12.6	9.66	0.84	0.0087
30.2	55	34.2	1237.3	737.3	2029.0	6381.9	0	5515.2	11.80	9.24	12.3	9.66	0.42	0.0178
														0.07533 kW-hr

Actual Time (sec)	Actual Speed (mph)	Calculation Use Only Time (sec)	Calculation Use Only Speed (mph)	Vehicle cceleratio (mph/s)	Wheel Speed (rpm)	Calculation Use Only Distance (ft)	Actual Distance (ft)	Power Due to Grade (W)
0.00	0	0.00	0	0.00	0.00	0.00		
0.04	1	0.04	1	24.92	21.57	0.03		
0.10	2	0.10	2	16.36	43.15	0.16		
0.17	3	0.17	3	14.64	64.72	0.41		
0.24	4	0.24	4	13.90	86.30	0.78		
0.32	5	0.32	5	13.49	107.87	1.27		
0.39	6	0.39	6	13.22	129.45	1.88		
0.47	7	0.47	7	13.03	151.02	2.62		
0.55	8	0.55	8	12.88	172.60	3.47		
0.62	9	0.62	9	12.76	194.17	4.45		
0.70	10	0.70	10	12.67	215.75	5.55		
0.78	11	0.78	11	12.59	237.32	6.77		
0.86	12	0.86	12	12.51	258.90	8.12		
0.94	13	0.94	13	12.44	280.47	9.59		
1.02	14	1.02	14	12.38	302.05	11.19		
2.02	15	2.02	15	1.00	323.62	32.46		
3.02	15	3.02	15	0.00	323.62	54.46		
4.02	15	4.02	15	0.00	323.62	76.46		
5.02	15	5.02	15	0.00	323.62	98.46		
6.02	15	6.02	15	0.00	323.62	120.46		
7.02	15	7.02	15	0.00	323.62	142.46		
8.02	15	8.02	15	0.00	323.62	164.46		
9.02	15	9.02	15	0.00	323.62	186.46		
10.02	15	10.02	15	0.00	323.62	208.46		
11.02	15	11.02	15	0.00	323.62	230.46		
12.02	15	12.02	15	0.00	323.62	252.46		
11.57	14	13.02	15	2.20	302.05	274.46		
11.11	13	14.02	15	2.20	280.47	296.46		
10.66	12	15.02	15	2.20	258.90	318.46		
10.20	11	16.02	15	2.20	237.32	340.46		
9.75	10	17.02	15	2.20	215.75	362.46		
9.29	9	18.02	15	2.20	194.17	384.46		
8.84	8	19.02	15	2.20	172.60	406.46		
8.38	7	20.02	15	2.20	151.02	428.46		
7.93	6	21.02	15	2.20	129.45	450.46		
7.47	5	22.02	15	2.20	107.87	472.46		
7.02	4	23.02	15	2.20	86.30	494.46		
6.56	3	24.02	15	2.20	64.72	516.46		

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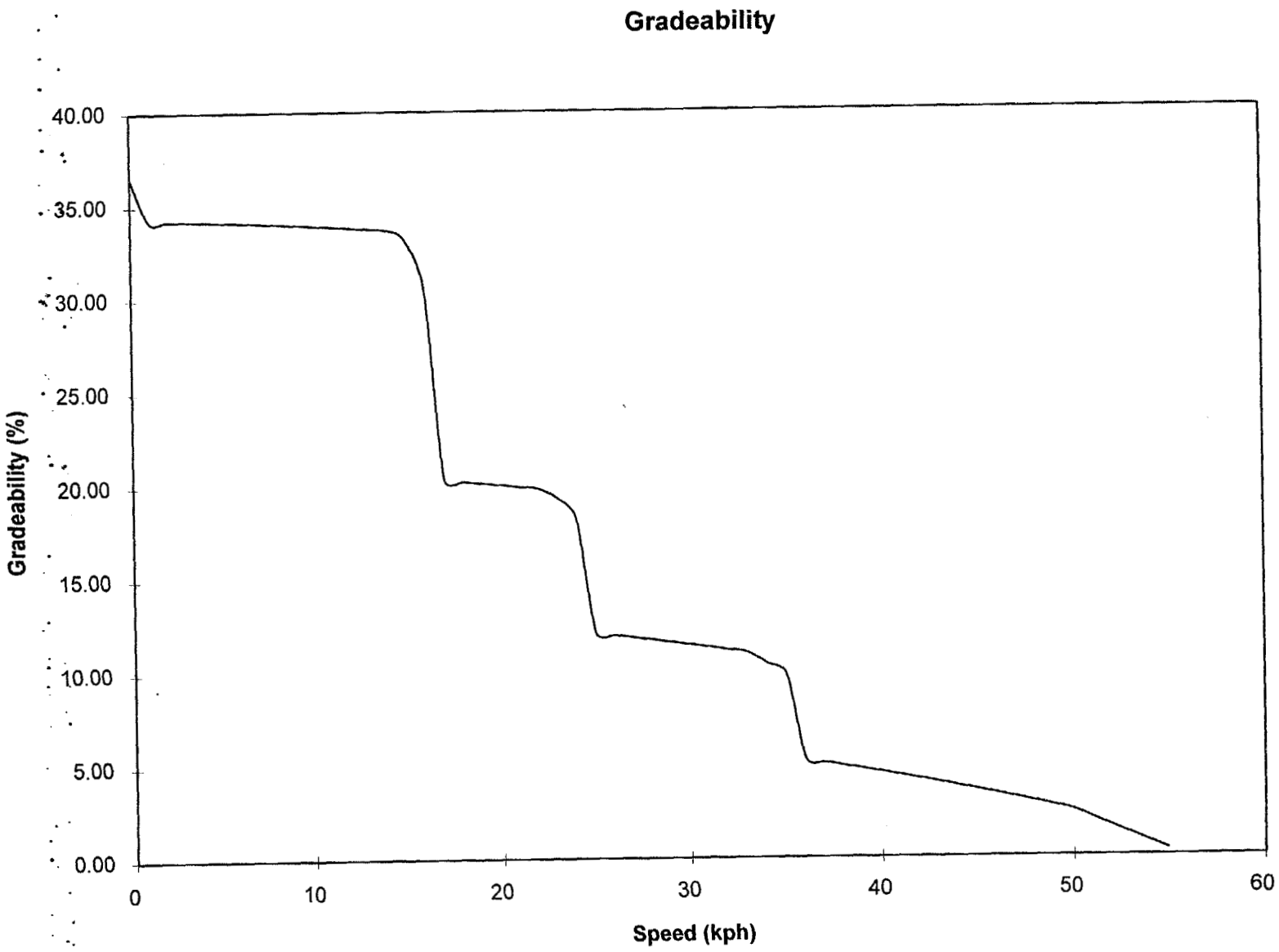
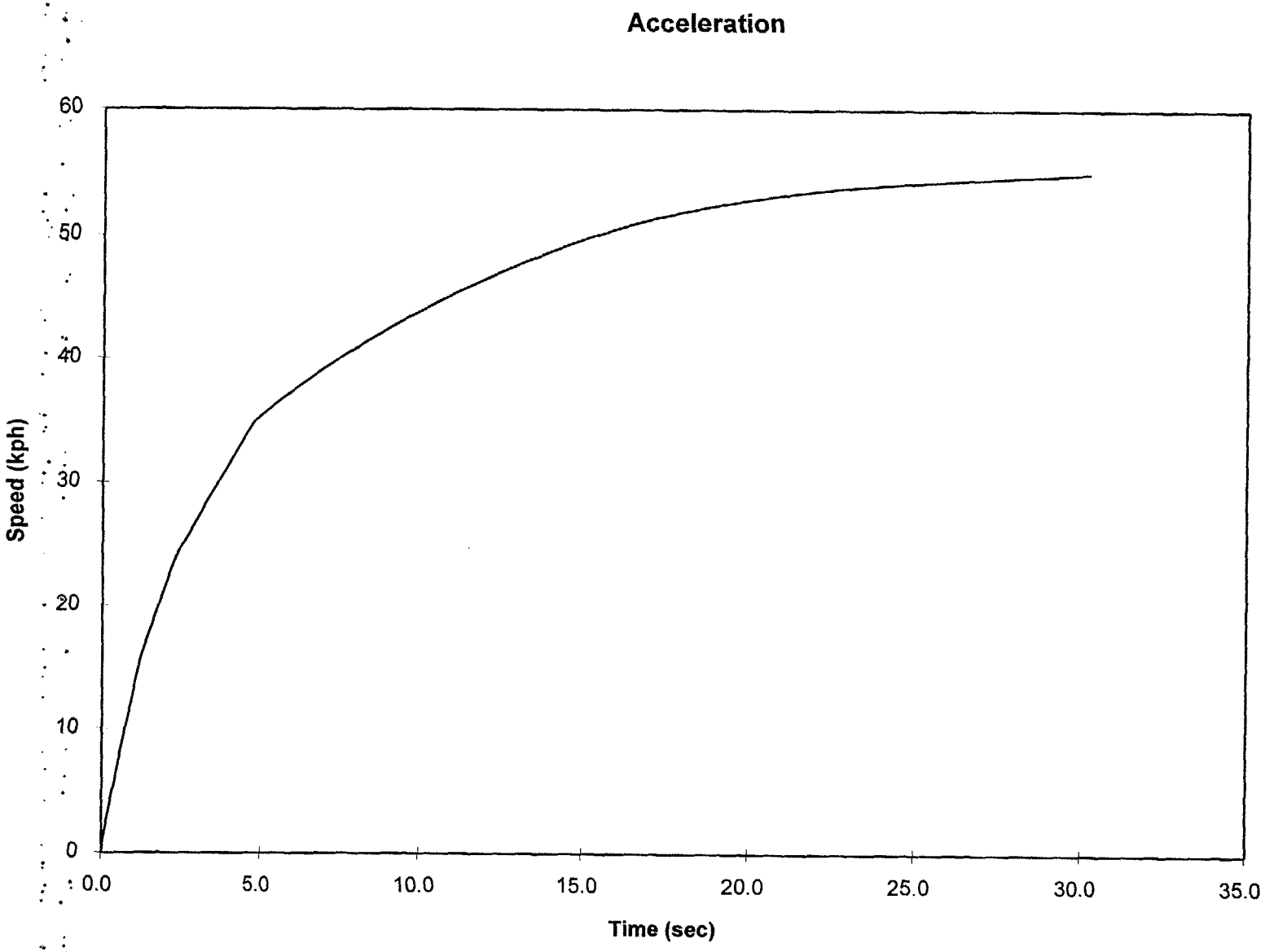
Table 1

Constant speed requirements and maximum gradeability based on continuous motor rating

Speed (kph)	Speed (mph)	Wheel (rpm)	Rolling Res't (W)	Aero Drag. (W)	Wheel Power (W)	Wheel Torque (lb-ft)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (W)	Mtr/Cntr Effic'y (%)	Availiable Motor Power (W)	Motor Torque (ft-lb)	Continuou Grade (%)	Road Energy (kWh/km)
0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.00	75.7	0.00	13.6	36.64	0.000
1	0.62	13.4	34.5	0.0	34.50	18.1	336.8	0.79	37.91	75.7	650.55	13.6	34.25	0.050
2	1.24	26.8	69.0	0.3	69.33	18.2	673.5	0.80	76.19	75.7	1301.11	13.6	34.23	0.050
3	1.86	40.2	103.7	1.0	104.73	18.3	1010.3	0.80	115.09	75.7	1951.66	13.6	34.22	0.051
4	2.49	53.6	138.5	2.5	140.93	18.5	1347.0	0.81	154.87	75.7	2602.21	13.6	34.20	0.051
5	3.11	67.0	173.3	4.8	178.16	18.7	1683.8	0.82	195.78	85.3	3252.77	13.6	34.17	0.046
6	3.73	80.4	208.3	8.4	216.65	19.0	2020.5	0.83	238.08	85.3	3903.32	13.6	34.14	0.047
7	4.35	93.8	243.4	13.3	256.65	19.3	2357.3	0.84	282.03	85.3	4553.87	13.6	34.10	0.047
8	4.97	107.2	278.5	19.8	298.36	19.6	2694.1	0.86	327.87	89.1	5204.42	13.6	34.05	0.046
9	5.59	120.7	313.8	28.2	342.04	20.0	3030.8	0.87	375.87	89.1	5854.98	13.6	34.01	0.047
10	6.21	134.1	349.2	38.7	387.92	20.4	3367.6	0.89	426.28	89.1	6505.53	13.6	33.95	0.048
11	6.84	147.5	384.7	51.5	436.22	20.8	3704.3	0.91	479.36	91.0	7156.08	13.6	33.89	0.048

12	7.46	160.9	420.3	66.9	487.17	21.3	4041.1	0.93	535.35	91.0	7806.64	13.6	33.83	0.049
13	8.08	174.3	456.0	85.0	541.02	21.9	4377.8	0.96	594.52	91.0	8457.19	13.6	33.76	0.050
14	8.70	187.7	491.8	106.2	597.98	22.4	4714.6	0.98	657.13	117.1	9107.74	13.6	33.68	0.040
15	9.32	201.1	527.7	130.6	658.31	23.0	5051.4	1.01	723.41	115.4	9659.09	13.5	33.19	0.042
16	9.94	214.5	563.7	158.6	722.22	23.7	5388.1	1.04	793.64	106.2	9659.09	12.6	30.65	0.047
17	10.56	227.9	599.8	190.2	789.94	24.4	3758.1	1.63	868.07	91.0	7259.93	13.6	20.29	0.056
18	11.18	241.3	636.0	225.8	861.72	25.1	3979.1	1.68	946.95	91.0	7686.99	13.6	20.20	0.058
19	11.81	254.7	672.3	265.5	937.78	25.9	4200.2	1.73	1030.53	91.0	8114.04	13.6	20.11	0.060
20	12.43	268.1	708.7	309.7	1018.36	26.7	4421.3	1.78	1119.08	91.0	8541.10	13.6	20.01	0.062
21	13.05	281.5	745.2	358.5	1103.69	27.6	4642.3	1.84	1212.84	117.1	8968.15	13.6	19.91	0.049
22	13.67	294.9	781.8	412.2	1193.99	28.5	4863.4	1.90	1312.08	117.1	9395.21	13.6	19.81	0.051
23	14.29	308.3	818.5	471.0	1289.51	29.4	5084.5	1.96	1417.04	114.3	9659.09	13.4	19.30	0.054
24	14.91	321.7	855.3	535.1	1390.47	30.4	5305.5	2.03	1527.99	108.1	9659.09	12.8	18.21	0.059
25	15.53	335.1	892.3	604.9	1497.11	31.4	3787.2	3.06	1645.18	91.0	7316.13	13.6	12.08	0.072
26	16.16	348.6	929.3	680.4	1609.66	32.5	3938.7	3.16	1768.86	91.0	7608.78	13.6	11.96	0.075
27	16.78	362.0	966.4	761.9	1728.35	33.6	4090.1	3.27	1899.28	91.0	7901.42	13.6	11.84	0.077
28	17.40	375.4	1003.6	849.8	1853.41	34.8	4241.6	3.38	2036.72	91.0	8194.07	13.6	11.71	0.080
29	18.02	388.8	1041.0	944.1	1985.08	35.9	4393.1	3.50	2181.41	91.0	8486.71	13.6	11.57	0.083
30	18.64	402.2	1078.4	1045.2	2123.59	37.2	4544.6	3.61	2333.62	117.1	8779.36	13.6	11.44	0.066
31	19.26	415.6	1115.9	1153.2	2269.17	38.4	4696.1	3.74	2493.59	117.1	9072.00	13.6	11.29	0.069
32	19.88	429.0	1153.6	1268.5	2422.05	39.7	4847.6	3.87	2661.59	117.1	9364.65	13.6	11.15	0.071
33	20.51	442.4	1191.3	1391.1	2582.47	41.1	4999.1	4.00	2837.88	117.1	9657.30	13.6	10.99	0.073
34	21.13	455.8	1229.2	1521.5	2750.65	42.5	5150.6	4.13	3022.69	112.3	9659.09	13.2	10.38	0.079
35	21.75	469.2	1267.1	1659.7	2926.83	43.9	5302.0	4.27	3216.30	108.2	9659.09	12.8	9.78	0.085
36	22.37	482.6	1305.2	1806.1	3111.25	45.4	3609.9	6.67	3418.95	91.0	6973.76	13.6	5.23	0.104
37	22.99	496.0	1343.3	1960.8	3304.13	46.9	3710.2	6.89	3630.91	91.0	7167.48	13.6	5.06	0.108
38	23.61	509.4	1381.6	2124.1	3505.70	48.4	3810.5	7.12	3852.42	91.0	7361.19	13.6	4.89	0.111
39	24.23	522.8	1419.9	2296.3	3716.21	50.0	3910.8	7.35	4083.74	91.0	7554.91	13.6	4.71	0.115
40	24.85	536.2	1458.4	2477.5	3935.87	51.7	4011.1	7.59	4325.13	91.0	7748.63	13.6	4.53	0.119
41	25.48	549.6	1497.0	2668.0	4164.93	53.3	4111.3	7.84	4576.85	91.0	7942.34	13.6	4.35	0.123
42	26.10	563.0	1535.6	2868.0	4403.61	55.1	4211.6	8.09	4839.13	91.0	8136.06	13.6	4.15	0.127
43	26.72	576.5	1574.4	3077.8	4652.15	56.8	4311.9	8.35	5112.26	91.0	8329.77	13.6	3.96	0.131
44	27.34	589.9	1613.3	3297.5	4910.78	58.6	4412.2	8.61	5396.47	91.0	8523.49	13.6	3.76	0.135
45	27.96	603.3	1652.2	3527.5	5179.74	60.4	4512.4	8.88	5692.02	117.1	8717.20	13.6	3.56	0.108
46	28.58	616.7	1691.3	3767.9	5459.25	62.3	4612.7	9.16	5999.17	117.1	8910.92	13.6	3.35	0.111
47	29.20	630.1	1730.5	4019.0	5749.54	64.2	4713.0	9.44	6318.18	117.1	9104.64	13.6	3.14	0.115
48	29.83	643.5	1769.8	4281.1	6050.85	66.2	4813.3	9.73	6649.29	117.1	9298.35	13.6	2.92	0.118
49	30.45	656.9	1809.2	4554.2	6363.42	68.2	4913.5	10.02	6992.77	117.1	9492.07	13.6	2.70	0.122
50	31.07	670.3	1848.7	4838.8	6687.47	70.2	5013.8	10.32	7348.86	116.6	9659.09	13.6	2.44	0.126
51	31.69	683.7	1888.2	5135.0	7023.23	72.3	5114.1	10.62	7717.83	113.4	9659.09	13.3	2.01	0.133
52	32.31	697.1	1927.9	5443.0	7370.94	74.4	5214.4	10.94	8099.94	110.5	9659.09	13.0	1.59	0.141
53	32.93	710.5	1967.7	5763.1	7730.83	76.6	5314.6	11.25	8495.42	107.9	9659.09	12.8	1.16	0.149
54	33.55	723.9	2007.6	6095.5	8103.14	78.8	5414.9	11.58	8904.55	105.6	9659.09	12.6	0.74	0.156
55	34.18	737.3	2047.6	6440.5	8488.09	81.0	5515.2	11.91	9327.57	50.1	9659.09	12.3	0.32	0.338


Gradeability
Gradeability (%)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
10
20
30
40
50
60
Speed (kph)


Acceleration
Speed (kph)
60
50
40
30
20
10
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Time (sec)

Attachment B

HEV Performance Prediction

Autorik1.xls

VEHICLE SPECIFICATION AND PERFORMANCE REQUIREMENTS:

Motor/Controller System : Modified SR180/CR10-200

VEHICLE DESCRIPTION: Bajaj Autorikshaw 2/11/97

VEHICLE WEIGHT;			
Curb Weight =	600.00	lb	(input variable)
Hybrid Generator	100.00	lb	(input variable)
Battery Weight	88.00	lb	(input variable)
Payload =	432.00	lb	(input variable)
Vehicle Test Weight =	1220.00	lb	(calculated value)
VEHICLE CHARACTERISTICS;			
Rolling Resistance Coefficient	0.02		(input variable)
Tire Rolling Radius =	7.8	inch	(input variable)
Tire rev/mile =	1294.5		(calculated value)
Cd = Vehicle Drag Coeff =	1.46		(input variable)
Vehicle Frontal Area =	22.14	ft^2	(input variable)
Air density =	0.00233	lbm/ft^3	(input variable)
Drivetrain efficiency =	91	%	(input variable)
First Gear Overall Reduction	25.12	: 1	(input variable)
Top Speed in First Gear	9.96	mph	(calculated value)
Second Gear Overall Reduction	16.49	: 1	(input variable)
Top Speed in Second Gear	15.18	mph	(calculated value)
Third Gear Overall Reduction	11.30	: 1	(input variable)
Top Speed in Third Gear	22.15	mph	(calculated value)
Fourth Gear Overall Reduction	7.48	: 1	(input variable)
Top Speed in Fourth Gear	33.46	mph	(calculated value)
Shift Time	0.75	sec	(input variable)
Total Inertia at Wheel Speed =	0.75	lbf-ft-sec^2	(input variable)
Number of Drive Motors =	1		(input variable)
Continuous Torque Rating	13.60	lb-ft	(input variable)
Contituous Power Rating	12.95	hp	(input variable)
Intermittent Torque Rating	13.60	lb-ft	(input variable)
Intermittent Power Rating	12.95	hp	(input variable)
Intermittent Power Rating Duty Cycle	25	%	(input variable)
Motor Base Speed	5000	rpm	(input variable)
Maximum Motor Speed =	5400	rpm	(input variable)
Vehicle Accessory Power Requirement	10	W	(input variable)
Drive System Maximum Auxiliary load	5	W	(input variable)
Grade During and Acceleration	0	%	(input variable)
Nominal Battery Pack Voltage	48	V	(input variable)
Location of Center of Gravity ahead of Rear	22.88	in	(input variable)
Location of Center of gravity behind front axe	55.86	in	(Calculated Value)
Location of Center of Gravity above Ground	20.71	in	(input variable)
Wheelbase	78.74	in	(input variable)

Performance Summary: 2/11/97
Test Weight 1220 lb

UNIQ
RESULTS

Predicted Acceleration from a stop to

5	kph	0.28 sec
10	kph	0.62 sec
15	kph	0.97 sec
20	kph	1.50 sec
25	kph	2.17 sec
30	kph	3.14 sec
35	kph	4.20 sec
40	kph	6.45 sec
45	kph	9.18 sec
50	kph	12.82 sec
55	kph	22.26 sec

Predicted Continuous gradeability

5	kph	40.05 %
10	kph	39.79 %
15	kph	38.87 %
20	kph	23.29 %
25	kph	14.12 %
30	kph	13.38 %
35	kph	11.48 %
40	kph	5.47 %
45	kph	4.36 %
50	kph	3.09 %
55	kph	0.67 %

Maximum Gradeability due to traction

Dry road	1.38
.2 mm of Water on roa	1.04

25

2/11/97

Table 1

Constant speed requirements and maximum gradeability based on continuous motor rating

Speed (kph)	Speed (mph)	Wheel (rpm)	Rolling Res't (W)	Aero Drag (W)	Wheel Power (W)	Wheel Torque (lb-ft)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (W)	Mtr/Cntr Effic'y (%)	Availiabile Motor Power (W)	Motor Torque (ft-lb)	Continuou Grade (%)	Road Energy (kWh/km)
0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.00	75.7	0.00	13.6	42.68	0.000
1	0.62	13.4	30.2	0.0	30.24	15.9	336.8	0.69	33.23	75.7	650.55	13.6	40.14	0.044
2	1.24	26.8	60.5	0.3	60.80	16.0	673.5	0.70	66.82	75.7	1301.11	13.6	40.12	0.044
3	1.86	40.2	90.9	1.0	91.92	16.1	1010.3	0.70	101.01	75.7	1951.66	13.6	40.10	0.044
4	2.49	53.6	121.3	2.5	123.82	16.3	1347.0	0.71	136.07	75.7	2602.21	13.6	40.08	0.045
5	3.11	67.0	151.9	4.8	156.74	16.5	1683.8	0.72	172.25	85.3	3252.77	13.6	40.05	0.040
6	3.73	80.4	182.6	8.4	190.92	16.7	2020.5	0.73	209.80	85.3	3903.32	13.6	40.01	0.041
7	4.35	93.8	213.3	13.3	226.57	17.0	2357.3	0.74	248.98	85.3	4553.87	13.6	39.96	0.042
8	4.97	107.2	244.1	19.8	263.95	17.3	2694.1	0.76	290.05	89.1	5204.42	13.6	39.91	0.041
9	5.59	120.7	275.0	28.2	303.27	17.7	3030.8	0.77	333.26	89.1	5854.98	13.6	39.85	0.042
10	6.21	134.1	306.1	38.7	344.77	18.1	3367.6	0.79	378.67	89.1	6505.53	13.6	39.79	0.043
11	6.84	147.5	337.2	51.5	388.68	18.6	3704.3	0.81	427.12	91.0	7156.08	13.6	39.72	0.043
12	7.46	160.9	368.3	66.9	435.24	19.0	4041.1	0.83	478.29	91.0	7806.64	13.6	39.64	0.044
13	8.08	174.3	399.6	85.0	484.68	19.6	4377.8	0.86	532.61	91.0	8457.19	13.6	39.55	0.045
14	8.70	187.7	431.0	106.2	537.22	20.2	4714.6	0.88	590.35	117.1	9107.74	13.6	39.46	0.036
15	9.32	201.1	462.5	130.6	593.11	20.8	5051.4	0.91	651.77	115.4	9659.09	13.5	38.87	0.038
16	9.94	214.5	494.0	158.6	652.57	21.4	5388.1	0.94	717.11	106.2	9659.09	12.6	35.82	0.042
17	10.56	227.9	525.7	190.2	715.83	22.1	3758.1	1.47	786.63	91.0	7259.93	13.6	23.61	0.051
18	11.18	241.3	557.4	225.8	783.14	22.8	3979.1	1.52	860.59	91.0	7686.99	13.6	23.51	0.053
19	11.81	254.7	589.2	265.5	854.72	23.6	4200.2	1.57	939.25	91.0	8114.04	13.6	23.40	0.054
20	12.43	268.1	621.1	309.7	930.79	24.4	4421.3	1.63	1022.85	91.0	8541.10	13.6	23.29	0.056
21	13.05	281.5	653.1	358.5	1011.61	25.3	4642.3	1.69	1111.66	117.1	8968.15	13.6	23.17	0.045
22	13.67	294.9	685.2	412.2	1097.39	26.2	4863.4	1.75	1205.92	117.1	9395.21	13.6	23.05	0.047
23	14.29	308.3	717.4	471.0	1188.37	27.1	5084.5	1.81	1305.90	114.3	9659.09	13.4	22.46	0.050
24	14.91	321.7	749.6	535.1	1284.78	28.1	5305.5	1.87	1411.85	108.1	9659.09	12.8	21.20	0.054
25	15.53	335.1	782.0	604.9	1386.86	29.1	3787.2	2.83	1524.02	91.0	7316.13	13.6	14.12	0.067
26	16.16	348.6	814.5	680.4	1494.83	30.2	3938.7	2.94	1642.67	91.0	7608.78	13.6	13.98	0.069
27	16.78	362.0	847.0	761.9	1608.94	31.3	4090.1	3.04	1768.06	91.0	7901.42	13.6	13.84	0.072
28	17.40	375.4	879.6	849.8	1729.40	32.4	4241.6	3.15	1900.44	91.0	8194.07	13.6	13.69	0.075
29	18.02	388.8	912.3	944.1	1856.46	33.6	4393.1	3.27	2040.06	91.0	8486.71	13.6	13.54	0.077
30	18.64	402.2	945.2	1045.2	1990.34	34.8	4544.6	3.39	2187.19	117.1	8779.36	13.6	13.38	0.062
31	19.26	415.6	978.1	1153.2	2131.28	36.1	4696.1	3.51	2342.07	117.1	9072.00	13.6	13.21	0.065
32	19.88	429.0	1011.0	1268.5	2279.51	37.4	4847.6	3.64	2504.96	117.1	9364.65	13.6	13.04	0.067
33	20.51	442.4	1044.1	1391.1	2435.26	38.8	4999.1	3.77	2676.11	117.1	9657.30	13.6	12.87	0.069
34	21.13	455.8	1077.3	1521.5	2598.77	40.1	5150.6	3.90	2855.79	112.3	9659.09	13.2	12.16	0.075
35	21.75	469.2	1110.6	1659.7	2770.26	41.6	5302.0	4.04	3044.25	108.2	9659.09	12.8	11.48	0.080
36	22.37	482.6	1143.9	1806.1	2949.98	43.0	3609.9	6.32	3241.73	91.0	6973.76	13.6	6.27	0.099
37	22.99	496.0	1177.3	1960.8	3138.14	44.5	3710.2	6.54	3448.51	91.0	7167.48	13.6	6.08	0.102
38	23.61	509.4	1210.9	2124.1	3334.99	46.1	3810.5	6.77	3664.82	91.0	7361.19	13.6	5.88	0.106
39	24.23	522.8	1244.5	2296.3	3540.75	47.7	3910.8	7.00	3890.94	91.0	7554.91	13.6	5.68	0.110
40	24.85	536.2	1278.2	2477.5	3755.67	49.3	4011.1	7.24	4127.11	91.0	7748.63	13.6	5.47	0.113
41	25.48	549.6	1312.0	2668.0	3979.96	51.0	4111.3	7.49	4373.58	91.0	7942.34	13.6	5.26	0.117
42	26.10	563.0	1345.9	2868.0	4213.87	52.7	4211.6	7.74	4630.62	91.0	8136.06	13.6	5.04	0.121
43	26.72	576.5	1379.9	3077.8	4457.62	54.4	4311.9	8.00	4898.48	91.0	8329.77	13.6	4.82	0.125
44	27.34	589.9	1413.9	3297.5	4711.44	56.2	4412.2	8.26	5177.41	91.0	8523.49	13.6	4.59	0.129
45	27.96	603.3	1448.1	3527.5	4975.58	58.1	4512.4	8.53	5467.67	117.1	8717.20	13.6	4.36	0.104
46	28.58	616.7	1482.3	3767.9	5250.26	59.9	4612.7	8.81	5769.52	117.1	8910.92	13.6	4.12	0.107
47	29.20	630.1	1516.7	4019.0	5535.71	61.9	4713.0	9.09	6083.20	117.1	9104.64	13.6	3.88	0.111
48	29.83	643.5	1551.1	4281.1	5832.17	63.8	4813.3	9.37	6408.98	117.1	9298.35	13.6	3.63	0.114
49	30.45	656.9	1585.6	4554.2	6139.87	65.8	4913.5	9.67	6747.11	117.1	9492.07	13.6	3.38	0.118
50	31.07	670.3	1620.2	4838.8	6459.04	67.8	5013.8	9.97	7097.85	116.6	9659.09	13.6	3.09	0.122
51	31.69	683.7	1654.9	5135.0	6789.91	69.9	5114.1	10.27	7461.44	113.4	9659.09	13.3	2.60	0.129
52	32.31	697.1	1688.7	5443.0	7132.72	72.0	5214.4	10.58	7838.15	110.5	9659.09	13.0	2.11	0.136
53	32.93	710.5	1724.6	5763.1	7487.69	74.2	5314.6	10.90	8228.23	107.9	9659.09	12.8	1.63	0.144
54	33.55	723.9	1759.6	6095.5	7855.07	76.4	5414.9	11.22	8631.94	105.6	9659.09	12.6	1.15	0.151
55	34.18	737.3	1794.6	6440.5	8235.07	78.6	5515.2	11.55	9049.53	50.1	9659.09	12.3	0.67	0.328

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Table 2

Vehicle acceleration based on intermittent motor torque — Bajaj Autorikshaw 2/11/97

Performed on a 0 % Grade

Accel Time (S)	Speed (kph)	Speed (mph)	Distance (ft)	Wheel (rpm)	Rolling Res't (W)	Aero Drag. (W)	Grade Resistance (W)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (kW)	Availiabile Motor Torque (lb-ft)	Motor Power (kW)	Power for Accel (kW)	Energy Required for Accel (kW-h)
0.0	0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.35	0.00	13.6	0.00	0.00	0.0000
0.0	1	0.6	0.0	13.4	15.1	0.0	0	336.8	0.35	0.02	13.6	0.65	0.63	0.0000
0.1	2	1.2	0.1	26.8	45.4	0.2	0	673.5	0.52	0.05	13.6	1.30	1.25	0.0000
0.1	3	1.9	0.2	40.2	75.7	0.9	0	1010.3	0.59	0.08	13.6	1.95	1.87	0.0000
0.2	4	2.5	0.4	53.6	106.2	2.2	0	1347.0	0.62	0.12	13.6	2.60	2.48	0.0000
0.3	5	3.1	0.7	67.0	136.7	4.4	0	1683.8	0.65	0.16	13.6	3.25	3.10	0.0001
0.3	6	3.7	1.0	80.4	167.3	7.7	0	2020.5	0.67	0.19	13.6	3.90	3.71	0.0001
0.4	7	4.3	1.4	93.8	198.1	12.3	0	2357.3	0.69	0.23	13.6	4.55	4.32	0.0001
0.5	8	5.0	1.9	107.2	228.9	18.6	0	2694.1	0.71	0.27	13.6	5.20	4.93	0.0001
0.5	9	5.6	2.4	120.7	259.8	26.7	0	3030.8	0.73	0.31	13.6	5.85	5.54	0.0001
0.6	10	6.2	3.0	134.1	290.8	36.8	0	3367.6	0.75	0.36	13.6	6.51	6.15	0.0001
0.7	11	6.8	3.7	147.5	321.8	49.2	0	3704.3	0.77	0.41	13.6	7.16	6.75	0.0001
0.8	12	7.5	4.4	160.9	353.0	64.1	0	4041.1	0.80	0.46	13.6	7.81	7.35	0.0001
0.8	13	8.1	5.2	174.3	384.3	81.8	0	4377.8	0.82	0.51	13.6	8.46	7.95	0.0002
0.9	14	8.7	6.1	187.7	415.6	102.4	0	4714.6	0.85	0.57	13.6	9.11	8.54	0.0002
1.0	15	9.3	7.0	201.1	447.0	126.3	0	5051.4	0.88	0.63	13.5	9.66	9.03	0.0002
1.0	16	9.9	8.1	214.5	478.6	153.6	0	5388.1	0.91	0.69	12.6	9.66	8.96	0.0002
1.2	17	10.6	9.8	227.9	510.2	184.6	0	3758.1	1.43	0.76	13.6	7.26	6.50	0.0003
1.3	18	11.2	11.6	241.3	541.9	219.5	0	3979.1	1.48	0.84	13.6	7.69	6.85	0.0002
1.4	19	11.8	13.6	254.7	573.7	258.5	0	4200.2	1.53	0.91	13.6	8.11	7.20	0.0003
1.5	20	12.4	15.6	268.1	605.6	301.9	0	4421.3	1.59	1.00	13.6	8.54	7.54	0.0003
1.6	21	13.0	17.8	281.5	637.6	350.0	0	4642.3	1.65	1.09	13.6	8.97	7.88	0.0003
1.7	22	13.7	20.1	294.9	669.6	402.8	0	4863.4	1.71	1.18	13.6	9.40	8.22	0.0003
1.9	23	14.3	22.6	308.3	701.8	460.8	0	5084.5	1.77	1.28	13.4	9.66	8.38	0.0003
2.0	24	14.9	25.3	321.7	734.0	524.0	0	5305.5	1.83	1.38	12.8	9.66	8.28	0.0003
2.2	25	15.5	29.5	335.1	766.4	592.8	0	3787.2	2.78	1.49	13.6	7.32	5.82	0.0004
2.4	26	16.2	33.9	348.6	798.8	667.3	0	3938.7	2.88	1.61	13.6	7.61	6.00	0.0004
2.6	27	16.8	38.5	362.0	831.3	747.8	0	4090.1	2.99	1.74	13.6	7.90	6.17	0.0004
2.7	28	17.4	43.4	375.4	863.9	834.6	0	4241.6	3.10	1.87	13.6	8.19	6.33	0.0004
2.9	29	18.0	48.5	388.8	896.6	927.8	0	4393.1	3.21	2.00	13.6	8.49	6.48	0.0005
3.1	30	18.6	53.8	402.2	929.4	1027.8	0	4544.6	3.33	2.15	13.6	8.78	6.63	0.0005
3.3	31	19.3	59.4	415.6	962.3	1134.6	0	4696.1	3.45	2.30	13.6	9.07	6.77	0.0005
3.5	32	19.9	65.3	429.0	995.2	1248.6	0	4847.6	3.58	2.47	13.6	9.36	6.90	0.0005
3.8	33	20.5	71.4	442.4	1028.3	1370.1	0	4999.1	3.71	2.64	13.6	9.66	7.02	0.0005
4.0	34	21.1	78.1	455.8	1061.5	1499.1	0	5150.6	3.85	2.81	13.2	9.66	6.85	0.0006
4.2	35	21.7	85.4	469.2	1094.7	1636.0	0	5302.0	3.98	3.00	12.8	9.66	6.66	0.0006
4.6	36	22.4	99.0	482.6	1128.0	1781.0	0	3609.9	6.23	3.20	13.6	6.97	3.78	0.0010
5.1	37	23.0	113.4	496.0	1161.4	1934.3	0	3710.2	6.45	3.40	13.6	7.17	3.77	0.0009
5.5	38	23.6	128.6	509.4	1194.9	2096.2	0	3810.5	6.68	3.62	13.6	7.36	3.74	0.0009
6.0	39	24.2	144.9	522.8	1228.5	2266.8	0	3910.8	6.91	3.84	13.6	7.55	3.71	0.0010
6.4	40	24.9	162.2	536.2	1262.2	2446.5	0	4011.1	7.15	4.08	13.6	7.75	3.67	0.0010
6.9	41	25.5	180.6	549.6	1296.0	2635.4	0	4111.3	7.40	4.32	13.6	7.94	3.62	0.0011
7.5	42	26.1	200.3	563.0	1329.9	2833.8	0	4211.6	7.65	4.58	13.6	8.14	3.56	0.0012
8.0	43	26.7	221.4	576.5	1363.8	3042.0	0	4311.9	7.90	4.84	13.6	8.33	3.49	0.0012
8.6	44	27.3	244.0	589.9	1397.9	3260.0	0	4412.2	8.17	5.12	13.6	8.52	3.40	0.0013
9.2	45	28.0	268.4	603.3	1432.0	3488.3	0	4512.4	8.44	5.41	13.6	8.72	3.31	0.0014
9.8	46	28.6	294.7	616.7	1466.2	3727.0	0	4612.7	8.71	5.71	13.6	8.91	3.20	0.0016
10.5	47	29.2	323.2	630.1	1500.5	3976.3	0	4713.0	8.99	6.02	13.6	9.10	3.09	0.0017
11.2	48	29.8	354.3	643.5	1534.9	4236.5	0	4813.3	9.28	6.34	13.6	9.30	2.96	0.0018
12.0	49	30.4	388.3	656.9	1569.4	4507.8	0	4913.5	9.57	6.68	13.6	9.49	2.81	0.0020
12.8	50	31.1	426.2	670.3	1604.0	4790.4	0	5013.8	9.87	7.03	13.6	9.66	2.63	0.0022
13.8	51	31.7	472.0	683.7	1638.7	5084.6	0	5114.1	10.17	7.39	13.3	9.66	2.27	0.0027
15.0	52	32.3	528.9	697.1	1673.5	5390.7	0	5214.4	10.48	7.76	13.0	9.66	1.90	0.0033
16.6	53	32.9	603.3	710.5	1708.3	5708.7	0	5314.6	10.80	8.15	12.8	9.66	1.51	0.0042
18.7	54	33.6	708.6	723.9	1743.3	6039.1	0	5414.9	11.12	8.55	12.6	9.66	1.11	0.0058
22.3	55	34.2	883.4	737.3	1778.3	6381.9	0	5515.2	11.45	8.97	12.3	9.66	0.69	0.0094
														0.05487 kW-hr

Actual Time (sec)	Actual Speed (mph)	Calculation Use Only Time (sec)	Calculation Use Only Speed (mph)	Vehicle cceleratio (mph/s)	Wheel Speed (rpm)	Calculation Use Only Distance (ft)	Actual Distance (ft)	Power Due to Grade (W)
0.00	0	0.00	0	0.00	0.00	0.00		
0.04	1	0.04	1	28.38	21.57	0.03		
0.09	2	0.09	2	18.67	43.15	0.14		
0.15	3	0.15	3	16.72	64.72	0.36		
0.21	4	0.21	4	15.88	86.30	0.69		
0.28	5	0.28	5	15.41	107.87	1.11		
0.34	6	0.34	6	15.10	129.45	1.65		
0.41	7	0.41	7	14.89	151.02	2.29		
0.48	8	0.48	8	14.72	172.60	3.04		
0.55	9	0.55	9	14.59	194.17	3.89		
0.62	10	0.62	10	14.48	215.75	4.85		
0.68	11	0.68	11	14.39	237.32	5.92		
0.75	12	0.75	12	14.30	258.90	7.10		
0.83	13	0.83	13	14.23	280.47	8.39		
0.90	14	0.90	14	14.16	302.05	9.79		
1.90	15	1.90	15	1.00	323.62	31.06		
2.90	15	2.90	15	0.00	323.62	53.06		
3.90	15	3.90	15	0.00	323.62	75.06		
4.90	15	4.90	15	0.00	323.62	97.06		
5.90	15	5.90	15	0.00	323.62	119.06		
6.90	15	6.90	15	0.00	323.62	141.06		
7.90	15	7.90	15	0.00	323.62	163.06		
8.90	15	8.90	15	0.00	323.62	185.06		
9.90	15	9.90	15	0.00	323.62	207.06		
10.90	15	10.90	15	0.00	323.62	229.06		
11.90	15	11.90	15	0.00	323.62	251.06		
11.44	14	12.90	15	2.20	302.05	273.06		
10.99	13	13.90	15	2.20	280.47	295.06		
10.53	12	14.90	15	2.20	258.90	317.06		
10.08	11	15.90	15	2.20	237.32	339.06		
9.62	10	16.90	15	2.20	215.75	361.06		
9.17	9	17.90	15	2.20	194.17	383.06		
8.71	8	18.90	15	2.20	172.60	405.06		
8.26	7	19.90	15	2.20	151.02	427.06		
7.80	6	20.90	15	2.20	129.45	449.06		
7.35	5	21.90	15	2.20	107.87	471.06		
6.89	4	22.90	15	2.20	86.30	493.06		
6.44	3	23.90	15	2.20	64.72	515.06		

2/11/97

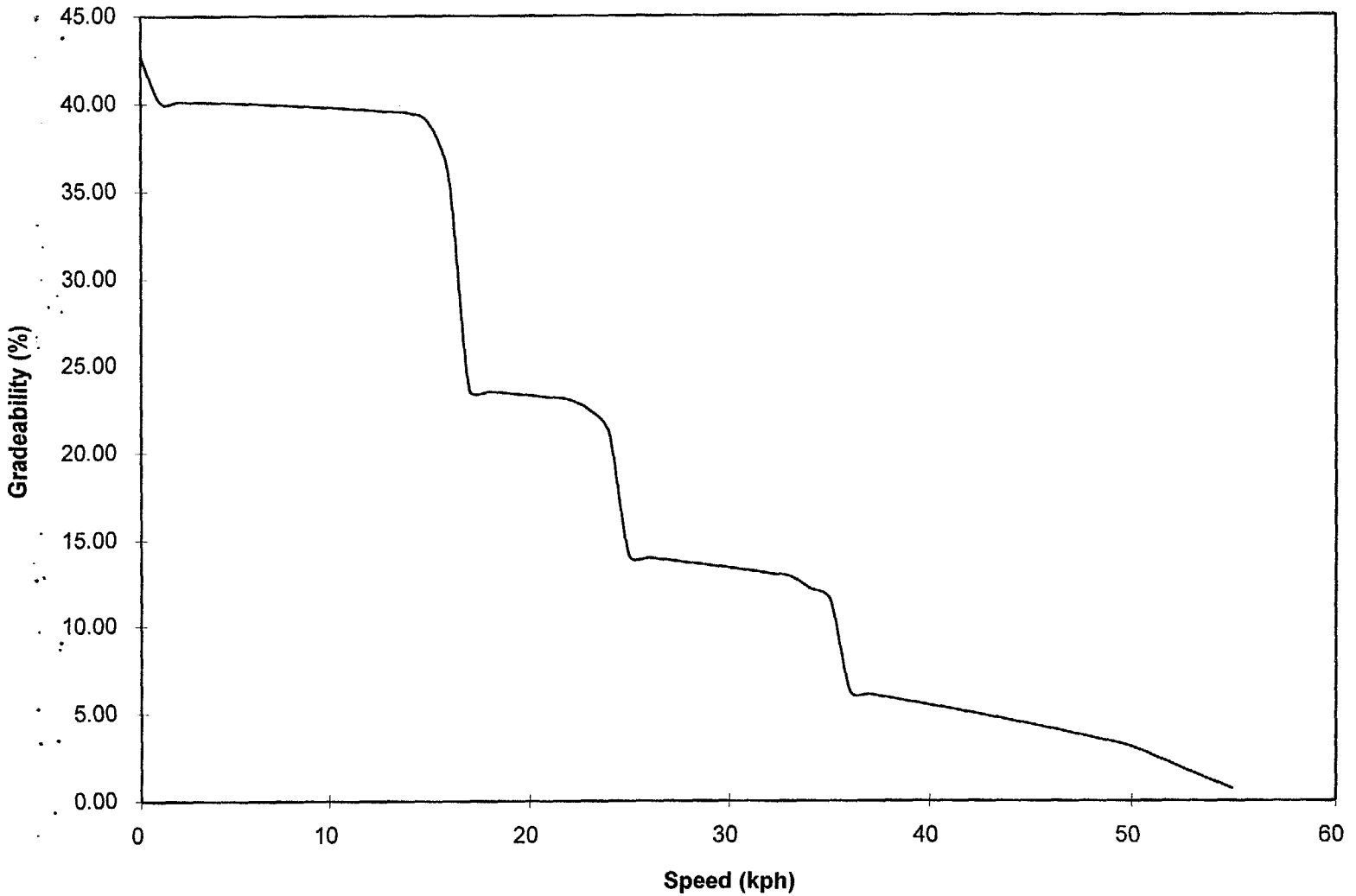
Table 1

Constant speed requirements and maximum gradeability based on continuous motor rating

Speed (kph)	Speed (mph)	Wheel (rpm)	Rolling Res't (W)	Aero Drag. (W)	Wheel Power (W)	Wheel Torque (lb-ft)	Motor Speed (rpm)	Required Motor Torque (lb-ft)	Motor Power (W)	Mtr/Cntr Effic'y (%)	Availiabile Motor Power (W)	Motor Torque (ft-lb)	Continuou Grade (%)	Road Energy (kWh/km)
0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.00	75.7	0.00	13.6	42.68	0.000
1	0.62	13.4	30.2	0.0	30.24	15.9	336.8	0.69	33.23	75.7	650.55	13.6	40.14	0.044
2	1.24	26.8	60.5	0.3	60.80	16.0	673.5	0.70	66.82	75.7	1301.11	13.6	40.12	0.044
3	1.86	40.2	90.9	1.0	91.92	16.1	1010.3	0.70	101.01	75.7	1951.66	13.6	40.10	0.044
4	2.49	53.6	121.3	2.5	123.82	16.3	1347.0	0.71	136.07	75.7	2602.21	13.6	40.08	0.045
5	3.11	67.0	151.9	4.8	156.74	16.5	1683.8	0.72	172.25	85.3	3252.77	13.6	40.05	0.040
6	3.73	80.4	182.6	8.4	190.92	16.7	2020.5	0.73	209.80	85.3	3903.32	13.6	40.01	0.041
7	4.35	93.8	213.3	13.3	226.57	17.0	2357.3	0.74	248.98	85.3	4553.87	13.6	39.96	0.042
8	4.97	107.2	244.1	19.8	263.95	17.3	2694.1	0.76	290.05	89.1	5204.42	13.6	39.91	0.041
9	5.59	120.7	275.0	28.2	303.27	17.7	3030.8	0.77	333.26	89.1	5854.98	13.6	39.85	0.042
10	6.21	134.1	306.1	38.7	344.77	18.1	3367.6	0.79	378.87	89.1	6505.53	13.6	39.79	0.043
11	6.84	147.5	337.2	51.5	388.68	18.6	3704.3	0.81	427.12	91.0	7156.08	13.6	39.72	0.043

12	7.46	160.9	368.3	66.9	435.24	19.0	4041.1	0.83	478.29	91.0	7806.64	13.6	39.64	0.044
13	8.08	174.3	399.6	85.0	484.68	19.6	4377.8	0.86	532.61	91.0	8457.19	13.6	39.55	0.045
14	8.70	187.7	431.0	106.2	537.22	20.2	4714.6	0.88	590.35	117.1	9107.74	13.6	39.46	0.036
15	9.32	201.1	462.5	130.6	593.11	20.8	5051.4	0.91	651.77	115.4	9659.09	13.5	38.87	0.038
16	9.94	214.5	494.0	158.6	652.57	21.4	5388.1	0.94	717.11	106.2	9659.09	12.6	35.82	0.042
17	10.56	227.9	525.7	190.2	715.83	22.1	3758.1	1.47	786.63	91.0	7259.93	13.6	23.61	0.051
18	11.18	241.3	557.4	225.8	783.14	22.8	3979.1	1.52	860.59	91.0	7686.99	13.6	23.51	0.053
19	11.81	254.7	589.2	265.5	854.72	23.6	4200.2	1.57	939.25	91.0	8114.04	13.6	23.40	0.054
20	12.43	268.1	621.1	309.7	930.79	24.4	4421.3	1.63	1022.85	91.0	8541.10	13.6	23.29	0.056
21	13.05	281.5	653.1	358.5	1011.61	25.3	4642.3	1.69	1111.66	117.1	8968.15	13.6	23.17	0.045
22	13.67	294.9	685.2	412.2	1097.39	26.2	4863.4	1.75	1205.92	117.1	9395.21	13.6	23.05	0.047
23	14.29	308.3	717.4	471.0	1188.37	27.1	5084.5	1.81	1305.90	114.3	9659.09	13.4	22.46	0.050
24	14.91	321.7	749.6	535.1	1284.78	28.1	5305.5	1.87	1411.85	108.1	9659.09	12.8	21.20	0.054
25	15.53	335.1	782.0	604.9	1386.86	29.1	3787.2	2.83	1524.02	91.0	7316.13	13.6	14.12	0.067
26	16.16	348.6	814.5	680.4	1494.83	30.2	3938.7	2.94	1642.67	91.0	7608.78	13.6	13.98	0.069
27	16.78	362.0	847.0	761.9	1608.94	31.3	4090.1	3.04	1768.06	91.0	7901.42	13.6	13.84	0.072
28	17.40	375.4	879.6	849.8	1729.40	32.4	4241.6	3.15	1900.44	91.0	8194.07	13.6	13.69	0.075
29	18.02	388.8	912.3	944.1	1856.46	33.6	4393.1	3.27	2040.06	91.0	8486.71	13.6	13.54	0.077
30	18.64	402.2	945.2	1045.2	1990.34	34.8	4544.6	3.39	2187.19	117.1	8779.36	13.6	13.38	0.062
31	19.26	415.6	978.1	1153.2	2131.28	36.1	4696.1	3.51	2342.07	117.1	9072.00	13.6	13.21	0.065
32	19.88	429.0	1011.0	1268.5	2279.51	37.4	4847.6	3.64	2504.96	117.1	9364.65	13.6	13.04	0.067
33	20.51	442.4	1044.1	1391.1	2435.26	38.8	4999.1	3.77	2676.11	117.1	9657.30	13.6	12.87	0.069
34	21.13	455.8	1077.3	1521.5	2598.77	40.1	5150.6	3.90	2855.79	112.3	9659.09	13.2	12.16	0.075
35	21.75	469.2	1110.6	1659.7	2770.26	41.6	5302.0	4.04	3044.25	108.2	9659.09	12.8	11.48	0.080
36	22.37	482.6	1143.9	1806.1	2949.98	43.0	3609.9	6.32	3241.73	91.0	6973.76	13.6	6.27	0.099
37	22.99	496.0	1177.3	1960.8	3138.14	44.5	3710.2	6.54	3448.51	91.0	7167.48	13.6	6.08	0.102
38	23.61	509.4	1210.9	2124.1	3334.99	46.1	3810.5	6.77	3664.82	91.0	7361.19	13.6	5.88	0.106
39	24.23	522.8	1244.5	2296.3	3540.75	47.7	3910.8	7.00	3890.94	91.0	7554.91	13.6	5.68	0.110
40	24.85	536.2	1278.2	2477.5	3755.67	49.3	4011.1	7.24	4127.11	91.0	7748.63	13.6	5.47	0.113
41	25.48	549.6	1312.0	2668.0	3979.96	51.0	4111.3	7.49	4373.58	91.0	7942.34	13.6	5.26	0.117
42	26.10	563.0	1345.9	2868.0	4213.87	52.7	4211.6	7.74	4630.62	91.0	8136.06	13.6	5.04	0.121
43	26.72	576.5	1379.9	3077.8	4457.62	54.4	4311.9	8.00	4898.48	91.0	8329.77	13.6	4.82	0.125
44	27.34	589.9	1413.9	3297.5	4711.44	56.2	4412.2	8.26	5177.41	91.0	8523.49	13.6	4.59	0.129
45	27.96	603.3	1448.1	3527.5	4975.58	58.1	4512.4	8.53	5467.67	117.1	8717.20	13.6	4.36	0.104
46	28.58	616.7	1482.3	3767.9	5250.26	59.9	4612.7	8.81	5769.52	117.1	8910.92	13.6	4.12	0.107
47	29.20	630.1	1516.7	4019.0	5535.71	61.9	4713.0	9.09	6083.20	117.1	9104.64	13.6	3.88	0.111
48	29.83	643.5	1551.1	4281.1	5832.17	63.8	4813.3	9.37	6408.98	117.1	9298.35	13.6	3.63	0.114
49	30.45	656.9	1585.6	4554.2	6139.87	65.8	4913.5	9.67	6747.11	117.1	9492.07	13.6	3.38	0.118
50	31.07	670.3	1620.2	4838.8	6459.04	67.8	5013.8	9.97	7097.85	116.6	9659.09	13.6	3.09	0.122
51	31.69	683.7	1654.9	5135.0	6789.91	69.9	5114.1	10.27	7461.44	113.4	9659.09	13.3	2.60	0.129
52	32.31	697.1	1689.7	5443.0	7132.72	72.0	5214.4	10.58	7838.15	110.5	9659.09	13.0	2.11	0.136
53	32.93	710.5	1724.6	5763.1	7487.69	74.2	5314.6	10.90	8228.23	107.9	9659.09	12.8	1.63	0.144
54	33.55	723.9	1759.6	6095.5	7855.07	76.4	5414.9	11.22	8631.94	105.6	9659.09	12.6	1.15	0.151
55	34.18	737.3	1794.6	6440.5	8235.07	78.6	5515.2	11.55	9049.53	50.1	9659.09	12.3	0.67	0.328

Gradeability



Acceleration