ANALYSIS OF RELATIVE SAFETY PERFORMANCE OF BICYCLES AND SCOOTERS

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for

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CONTENTS

The views expressed in this report are those of the author and do not necessarily represent the views or policy of VicRoads.

Introduction

There is concern about increasing use of two-wheeled scooters on roads and footpaths. There are also concerns about small motorised two-wheeled scooters. Construction and operational restrictions are being considered. Opponents to such restrictions argue that these vehicles are no less safe than bicycles.

Vehicle Design and Research Pty Limited was engaged by VicRoads to investigate safety issues associated with two wheeled scooters. This involved comparing the relative performance of bicycles and scooters. It covered issues such as brakes and stability (see next section). The vehicles intended to be evaluated in the project were:

1. Typical BMX bicycle
2. 26" road bicycle
3. 26" road bicycle with a motor
4. Scooter with large pneumatic tyres
5. Scooter with large pneumatic tyres and motor
6. Scooter with small solid tyres and motor
7. Scooter with small solid tyres
8. "Razor" type fold-up scooter

However, enquiries revealed some of these were unobtainable and others were substituted, as described below.

Survey of available vehicles

Several bicycle shops were approached to determine available brands of equipment. Internet searches were also conducted. These enquiries revealed a very uncertain and changing market. Several dealers said they used to stock petrol motor scooters such as the Tami but ceased "because they were too much trouble". A further problem in NSW is that these vehicles do not meet the definition of a motor assisted pedal cycle (they do not have pedals) and are illegal on NSW roads because they are a motor vehicle and require (unobtainable) registration. Electric scooters have the same problem but this does not seem to stop some shops hiring them (as we did) for use on footpaths in NSW. In Victoria they are currently treated as motor-assisted bicycles and are therefore legal to use on roads if the power does not exceed 200W.

We finally selected the following vehicles for testing. Appendix A contains technical details for each.

Table 1 Tested Vehicles

Type	Make and Model	Comment
BMX bicycle	Diamond Back Viper	Used, in good condition
26" Mountain bicycle	Giant Iguana 650	Used, in good condition
26" Motorised bicycle	Rotary Cruiser (petrol)	Hired. Good condition
Scooter with large tyres	Holstar Sidewinder	New
Motorised scooter with large tyres - no seat	Tami Chrome (petrol)	New
Motorised scooter with large tyres and a seat	Tami Chrome (petrol)	Handles differently with seat attached
Motorised scooter with mid-size tyres	Tracker 2000 (electric)	Hired
Scooter with small solid tyres	Razor fold-up scooter	Used, good condition

Tami speed limiting

When we acquired the Tami scooter the shop assistant kindly showed us how to remove the restricting sleeve in the throttle cable in order to increase the maximum speed from 15km/h to about 25km/h. This was done in order to reach some of the desired test speeds.

Further comments are provided in the section "Results".

Performance tests

Australian/New Zealand Standard 1927:1998 "Pedal bicycles - safety requirements" applies to bicycles. It contains basic construction requirements and performance tests for stability and braking. *It does not apply to scooters*. The preface to the standard indicates that "there has been recent research into the stability of bicycles. Physical testing has at this stage been inconclusive, but the research is ongoing". This was written in 1998. A check with the convenor of the relevant standards committee revealed that no further stability tests have been developed at this stage. He did say, however, that a committee had just been formed to look at developing a standard for scooters. The committee would be interested in our test work.

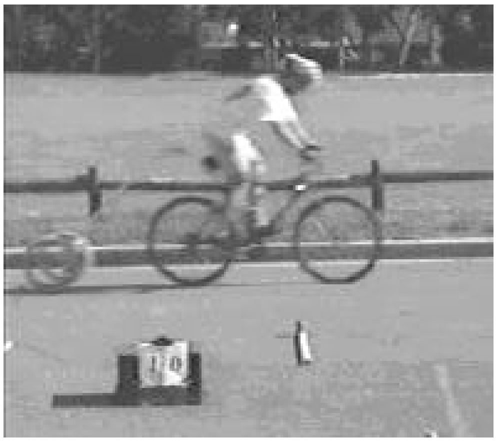
We contacted transport authorities in several US states to determine if any construction standards or performance tests applied to scooters. Responses were all negative (see "Accidents and Injuries"). Similarly the German highway authority BaST advised that no research had been conducted into scooter safety in Germany.

In 1973 the Transport and Road Research Laboratory (TRRL) in the UK conducted a series of tests on the stability and braking performance of several models of bicycle. Of particular interest were the manoeuvrability tests where the rider was required to ride a slalom course. Apparently this was derived from the National Cycling Proficiency Test.

After consideration of the technical issues it was decided to subject all scooters and bicycles to the following performance tests:

A. Braking test in accordance with AS/NZS 1927:1998 Appendix H

This involves the rider applying the brakes to until the vehicle comes to a complete stop. Initially the vehicle will be travelling at approximately 16km/h. By using a video camera the motion is captured for later analysis. The video footage is used to double check the initial speed immediately prior to braking, and to determine both the deceleration and stopping distance. The rider commences braking once a certain marked point has been passed. An indicating light attached to the frame of the vehicle shows when the brakes are applied and this is used in the video analysis.



Braking test showing indicator light

The standard sets a maximum stopping distance of 5.5m from 24km/h (or 16km/h for bicycles that cannot attain 24km/h). Because of the difficulty maintaining a constant speed with some of the vehicles the standard has a correction factor for speed variations. It is considered that average deceleration would be a better way of expressing braking performance. The prescribed stopping distance is equivalent to an average deceleration of 4.4 m/s^2. A smaller stopping distance is not prescribed for low speed bicycles and a 5.5m stop from 16km/h gives an average deceleration of 1.8 m/s^2.

B. Stability test in accordance with Appendix E of AS/NZS 1927:1998

The vehicle is ridden directly over a series of cleats (narrow planks), placed across the track at 1.75m spacing. The cleats are 25mm high and 50mm in width, with a 12mm chamber on the leading edge (see picture). They represent severe bumps in the road. The standard requires the vehicle to be ridden over the test course at about 5km/h as a preliminary trial and then at 25km/h (16km/h for bicycles incapable of such speeds). Because of the uncertainty about the stability of each vehicle the tests were conducted at approximately 5, 10 and 15km/h. If the tester considered it safe the test at 25km/h was then attempted.

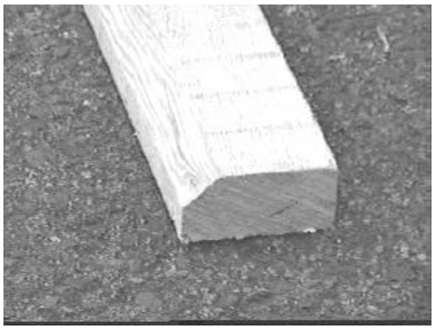
Subject to reasonable performance with the cleats set at 90^o, they were then set at 45^o to the direction of travel. This test configuration is not prescribed in the standard but was considered necessary in order to introduce asymmetric loading into the steering system.

45^o cleats for stability test

C. Manoeuvrability tests in accordance with TRRL LR500.

The rider must negotiate their way in a zig-zag pattern between 6 marker cones, each placed 1.5m apart along a straight line. The test is conducted at slow speed (about 5km/h).

A second manoeuvrability test is conducted with cleats between the marker cones.



Close up of cleat

D. Top speed test

Manoeuvrability course with cleats

The standard regards the top speed of a bicycle as the equivalent road speed when the highest gear ratio is selected and the pedals are turned at a rate of 1 revolution per second.

The top speed of non-motorised scooters is likely to be highly dependent on rider skill and concentration and the inherent stability of the vehicle. All two-wheeled vehicles are subject to several types of instability (see "Design Issues"). Some of these are speed dependent. The design intention should be that no instability occurs over the normal range of speed of the vehicle. A difficulty is defining this speed range - higher speeds, at which instability develops, may only be attained when descending steep hills.

No attempts were therefore made to determine the "top speed" of non-motorised vehicles, although it was considered that a practical top speed had been reached with some vehicles in the stability tests. Further comments are provided in the section "Design Issues".

In the case of motorised vehicles, the top speed on level ground was determined by applying full throttle and observing the maximum speed attained. In the case of the Tami scooter the test was also performed with the throttle restriction device operative.

Test Methods

A simple, lightweight fifth wheel device was developed for the purpose of the tests. It used an electronic bicycle speedometer. The intention was to give the rider an indication of road speed just prior to the commencement of a test run. In practice, it was only used on the braking and top speed tests. The wheels bounced around too much during the stability tests. These tests were therefore conducted after the brake tests so that the rider had a good feel for the vehicle when moving at around 16km/h. Subsequent video analysis showed that a reasonable range of speeds was achieved.

All on-road tests were assessed by video taping the event from the side and analysing the resulting digital video. This enabled initial speeds and braking distances to be determined. Theoretical analysis indicated that resulting measurement errors were minimal since key measurements were almost perpendicular to the line of sight. The video rate was 25 frames per second, which is equivalent to 200mm at 16km/h.

For the braking tests a bright light was fitted to the vehicle and was activated whenever the braking control was applied. The instant of application of the brakes was therefore evident on the video.

Stability factors were assessed subjectively, based on the tester's determination of the reasonable limits of performance of the vehicle and the guidelines set out below. Tests were curtailed if there were any signs of severe instability.

Measurements of steering geometry were analysed for determination of the theoretical limits on stability (based on bicycle theory).

Stability assessments

Each of the tests was assessed for stability and control. The braking test also included an assessment of the perceived effectiveness of the brakes. The following guidelines were used for the assessment.

Stability

Unstable motion is regarded as a tendency for the vehicle to deviate from the desired direction of travel. This includes unintended steering action, sideways skidding of the tyres and body roll.

Good - the vehicle is stable at all times and does not require alertness on the part of the rider

Adequate - the vehicle is stable most of the time but the rider needs to be alert

Marginal - the vehicle is unstable for most of the time and requires constant rider attention

Poor - the vehicle is unstable and there is a high risk of a fall

Aborted - the test could not be completed due to instability

Control

The ability of the rider to control the direction and speed of the vehicle

Good - steering and braking controls are well modulated with good feedback to the rider

Adequate - steering and braking controls are well modulated but feedback is lacking

Marginal - steering or braking is poorly modulated but some degree of control is available

Poor - steering or braking is poorly modulated but and control is only possible with high skill. The control is difficult to operate or easily fumbled.

Aborted - the test could not be completed due to poor control.

Braking effect

This is based on the rider's perception of the degree of braking available. This includes factors such as imminent (or actual) wheel lock-up and the balance between front and rear brakes.

Performance issues related to the motor

The following items were evaluated:

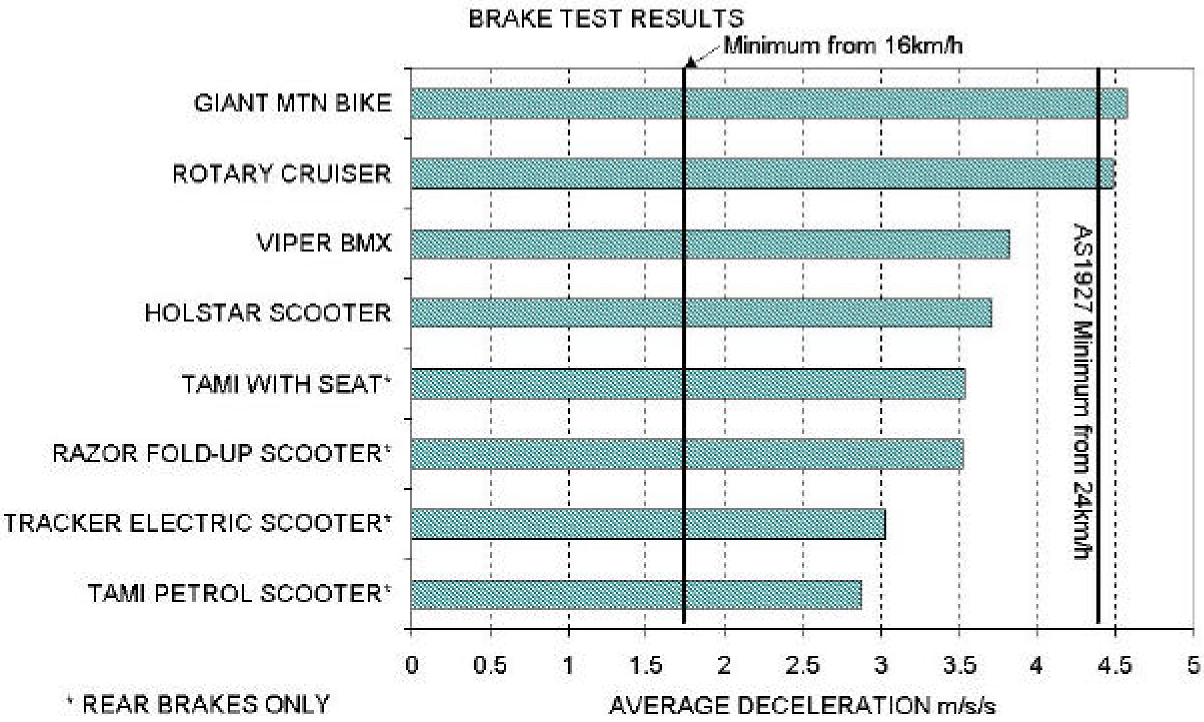
- effects of motor *controls* on riders ability to brake and steer vehicle (that is, is it more difficult to apply the brakes or steer the vehicle?),
- effects of motor *operation* on braking and stability (that is, does the manner in which the motor operates have an effect on braking and steering?),
- nuisance noise levels (can traffic be heard over the sound of the motor?)

Results

Performance Tests

Braking tests

Appendix B details the results of the braking tests.



Results of brake tests

Only the mountain bike and motorised bike achieved an average deceleration greater than 4.4 m/s^2 (applicable to vehicles capable of speeds of 24km/h or more). All vehicles achieved the average deceleration of 1.8 m/s^2 applicable to "low speed" bicycles, although the Razor had two runs where it failed to stop (discussed below under "Design issues"). It is considered that any vehicle intended to mix with other road traffic should be capable of the deceleration applicable to 24km/h.

The benefits of front brakes are evident from the average decelerations.

A comparison of the Tami with and without the seat indicates that the braking performance is better with the rider seated. This may be due to more favourable dynamic weight distribution (lower centre of gravity when seated) and the improved control.

The mountain bike was rated good for stability, control and effect.

Although the stopping distance of the Rotary Cruiser was close to that of the mountain bike stability and control were rated marginal and effect was rated adequate - the vehicle was considered to be cumbersome to handle.

The BMX bike was rated good for stability and control and adequate for effect.

The Holstar scooter was rated adequate for stability and control and marginal for effect. Even though the vehicle had front brakes it was found difficult to control them at speed.

The Tami petrol scooter with seat was rated marginal for stability and effect and adequate for control. Without the seat the stability improved to adequate but this may have been at the expense of lower braking effort (the Tami without seat had the worst average deceleration of all vehicles). Rear wheel skidding was evident in both tests.

Although the stopping distance of the Razor scooter was close to that of the bigger scooters the stability was rated marginal and the control and effect were rated poor. A serious drawback was the difficulty in applying the brake at speed. It was easy for the rider's foot to miss, or slip off, the rear mudguard.

The Tracker electric scooter was rated poor for stability and control and marginal for effect. It was difficult to prevent rear wheel skidding.

Braking test of Holstar scooter

Stability tests

Results of stability tests are set out in Appendix C. Note that the first low-speed test is intended as a preliminary test. The following comments refer to the tests at higher speeds, where possible.

The mountain bike was rated good for stability and control at all speeds and with cleats at 90^o and 45^o.

The Rotary Cruiser motorised bicycle was rated acceptable for stability and good for control in the 90^o cleat tests but control dropped to adequate in the 45^o cleat tests. Stability was borderline between adequate and marginal for those tests.

The BMX bike was rated marginal for stability and control in both tests (control was better at low speed).

The Holstar scooter was rated adequate for stability and control in the 90^o cleat tests but stability dropped to marginal in the 45^o cleat tests.

The Tracker electric scooter rated poor for stability in both tests. Control was rated poor in the 90^o cleat tests but marginal in the 45^o test. A serious problem was the inability to conduct a low speed test under power, due to the unmodulated throttle control.

The Tami petrol scooter without seat rated marginal to poor for stability in the 90^o, cleat tests and poor in the 45^o tests. Control was rated marginal in the 90^o cleat tests and poor in the 45^o test. Stability was slightly better with the seat (marginal stability and control in the 90^o cleat tests and poor in the 45^o tests).

The Razor scooter was unable to be ridden over the test course. The small wheels failed to roll over the cleats and the rider had to take evasive action.

Manoeuvrability tests

The Giant mountain bike was found to be adequate for stability and good for control, with and without cleats. The course was a little challenging for a vehicle of this size.

The Rotary Cruiser was too big and cumbersome for this test. It was rated adequate for stability without cleats and marginal for stability with cleats. Control was marginal in both tests. Throttle control was good.

With the rider on the seat the BMX bike was rated good for stability and adequate for control. This reduced to adequate and marginal respectively for the test with cleats. The results improved with the rider off the seat. Stability and control were good with no cleats and adequate with cleats. This is not unexpected since such vehicles are mostly used for this type of riding.

The Holstar scooter was rated good for stability and adequate for control with and without cleats. Note that the rider needed to push with his foot on the ground to maintain speed and this assisted in stability and control.

The powered test of the Tracker electric scooter was aborted because a low speed could not be maintained. A test without power (pushing with foot) was rated marginal for stability and control. A test with cleats under power was not conducted.

The Tami petrol scooter without seat rated good for stability and adequate for control without cleats. For the test with cleats it was rated marginal for stability and control. With the seat it rated marginal for stability and poor for control in both tests.

The Razor scooter rated marginal for stability and control with no cleats and could not be ridden over the course with cleats. Although, in theory, the small size of the vehicle should make this test easier than with larger vehicles it was found that the steering control was too sensitive.

Top speed tests

The Giant bicycle had a speed of about 30km/h with the pedals rotating at 1 cycle per second. Stability and control were good at this speed.

The Rotary Cruiser reached 24km/h under power. Stability and control were good.

The BMX bike had a speed of about 20km/h with the pedals rotating at 1 cycle per second. Stability and control were adequate at this speed. At higher speeds the fast pedalling rate may contribute to instability.

With considerable effort the Holstar scooter reached 18km/h during two of the brake tests. Stability and control were adequate at this speed.

The Tracker electric scooter reached 17km/h under power. Stability and control were marginal at this speed. With an unmodulated throttle it was cumbersome to travel at less than this speed.

The Tami petrol scooter reached 30 km/h with no speed limiting. Stability and control were marginal at this speed. With the speed limiting device fitted it reached 18km/h.

With great effort the Razor reached 18km/h during the brake tests on smooth ground but stability and control were rated poor. The stability tests were aborted at 10km/h. The rider had a high risk of falling off at higher speeds.

Design Issues

Steering geometry and stability

The science of bicycles was established during the late 1800s and was set out in a classic book *Bicycles and Tricycles* by Archibald Sharp, originally published in 1896 and republished in 1977 by MIT Press. That work was supplemented by the book *Bicycling Science* by F. Whitt and D.Wilson, first published in 1982. In essence both books point out the importance of front wheel trail for safe, stable riding. Trail is the distance between the centre of the tyre contact patch and the point where the steering axis intersects the ground. AS1927 sets limits for steering head angle (between 65^{o} and 75^{o} from the horizontal) and a dimension related to trail (see diagram). The standard prescribes a limit on the length of the vertical side of a triangle formed by the steering axis and a vertical line through the axle - for a conventional 26" wheel this means the trail should be between 30mm and 120mm. Generally bicycles have a trail about the middle of this range.

(a) the steering head angle be not more than 75 degrees and not less than 65 degrees in relation to the ground line; and

(b) the steering axis intersect a line perpendicular to the ground line, drawn through the wheel centre, at a point not lower than 15 percent and not higher than 60 percent of the wheel radius when measured from the ground line.

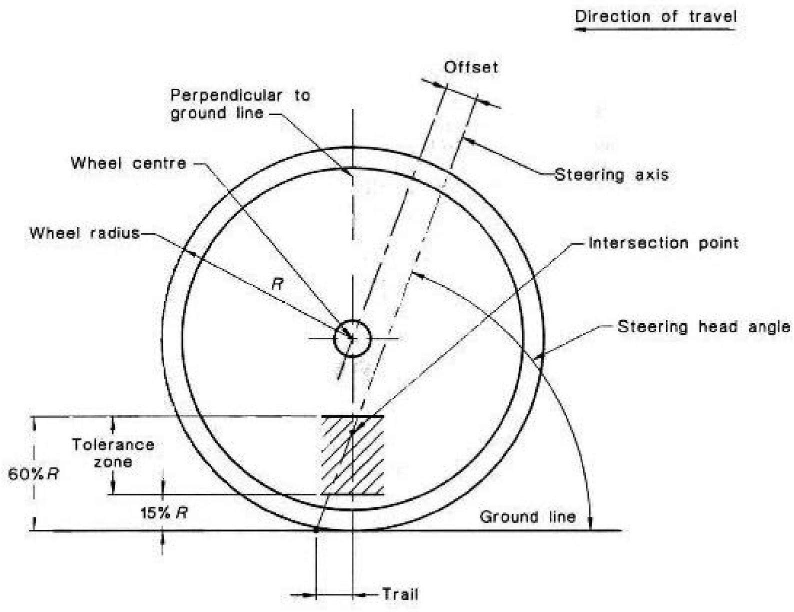


FIGURE G1 STEERING GEOMETRY

Extract from AS1927 - Appendix G

Whitt and Wilson provide a method of calculating stability from steering geometry, based on steering head angle, wheel diameter and fork offset (horizontal distance from the front axle to the steering axis). These calculations have been applied to the range of vehicles tested, although caution should be used in interpreting the results because the method was not intended to be applied to scooter configurations.

Table 2. Steering Geometry Calculations

DESCRIPTION	Wheel Dia mm	Steer Angle	COMPLIES WITH AS?	Trail mm	ASMax mm	ASMin mm	COMPLIES with AS?	Offset	Mu
GIANT MTN BIKE	665	70	Y	76	120	30	Y	45	-2.9
ROTARY CRUISER	665	70	Y	80	120	30	Y	41	-3.0
TRACKER ELECTRIC SCOOTER	190	75	Y	30	34	9	Y	-5	-4.3
VIPER BMX	500	75	Y	50	90	23	Y	17	-2.7
TAMI PETROL SCOOTER	210	80	N	0	38	9	N	19	-0.1
HOLSTAR SCOOTER	315	70	Y	20	57	14	Y	37	-1.5
RAZOR FOLD-UP SCOOTER	100	82	N	0	18	5	N	7	-0.1

"Mu" is a stability factor derived by Whitt and Wilson. They state "experience indicates that bicycles have good steering characteristics when Mu is between -1 and -3". A Mu approaching or exceeding zero indicates unstable characteristics.

This analysis suggests that the Tami petrol scooter and the Razor fold-up scooter have steering characteristics that would be undesirable on a bicycle.

Steering trail is associated with the restoring moment that occurs when the front wheel is turned slightly at speed. With a good design of bicycle this is felt as feedback through the steering wheel. In other words, the more the rider turns the handlebars the higher the resistance to turning becomes. This is a very important feedback mechanism that enables bicycle riders to remain stable and upright without too much concentration - this issue is discussed further under "Human factors".

In effect, over a range of speeds, this steering characteristic is self correcting - a tendency to veer to one side results in steering action that brings the bicycle back to the centre. It is the reason that most bicycles can be ridden with hands off the handlebars. In contrast all of the scooters tested, including those with relatively large trail, were found to be unstable when any attempt was made to let go of the handlebars. This is not surprising since the handlebars need to be held to control roll as well as yaw.

The stability theory predicts that instability will become more of a problem with increased speed. This was evident in Tracker and Tami stability tests, where the stability and/or control rating got worse with increased speed. The three bicycles and the Holstar scooter did not experience this degradation with increased speed.

Due to their configuration it is doubtful whether any significant improvements could be made to the design of the tested scooters in order to raise their stability performance to that of bicycles.

Self-correcting steering is the simplest form of stability applying to two-wheeled vehicles and it is applicable to all speeds. At higher speeds other modes of instability come into play. These are typically more a concern with motorcycles and high performance racing bicycles and are unlikely to be encountered with conventional bicycles and scooters. An exception might be where speed builds up during a long descent.

Rees (1978) describes the following modes of instability during a discussion of factors in motorcycle crashes:

- roll oscillation about a longitudinal axis- the self-correcting steering action tends to cause the vehicle to roll from side to side as it moves along the road (in fact, the centre of gravity tends to move in a straight line and the wheels weave from side to side causing the roll effect). Generally this oscillation is readily damped by the rider holding onto the handlebars and might not even be noticed. It can sometimes build up and be observed if the rider lets go of the handlebars at about 60km/h. With motorcycles the typical frequency is about 1 Hertz.
- yaw oscillation about a vertical axis - a small disturbance from the road can cause a yaw oscillation with a frequency of about 1 Hertz that is sometimes coupled with the roll oscillation. The yaw oscillation is generally very well damped by tyre/road interaction and is seldom a problem with motorcycles below 100km/h. It can become a problem if the gyroscopic forces from the wheels become dominant - for example installation of heavy wheels can destablize the yaw mode. Low slip-angle tyres, such as "knobby" tyres used on off-road motorcycles, can also contribute to yaw instability.
- front wheel flutter or shimmying - the steering assembly starts to oscillate about the steering axis with a frequency of about 4 Hertz. The self-aligning action of the steering system tends to overshoot the centre position and an oscillation develops. With motorcycles this flutter instability is generally not encountered until very high speeds are reached. Once wheel flutter starts it is very difficult to eliminate except by rapidly reducing speed. Destabilizing factors are increased mass or moment of inertia of the steering assembly and low slip-angle tyres.

There has been conjecture that some accidents involving children on small bicycles have been due to wheel flutter while descending hills at abnormal speeds (author's recollections when working for the RTA). It is also possible that rider inexperience contributes to instability through inappropriate movement of the handlebars or shifting of body weight. Subtle but important rider responses have made advanced modelling of two wheeled vehicle stability very difficult (Whitt and Wilson 1982).

Braking

Front brakes are important for maximising the available friction forces. With relatively high centres of gravity, bicycles and scooters are subject to higher dynamic load transfer to the front wheels than cars. The rear wheels carry less load in these circumstances and will lock up and skid more easily. Rear wheel skids can lead to yaw instability. AS1927 requires front and rear brakes on bicycles. The Tami, Tracker and Razor scooters did not have front brakes.

Table 3 shows the theoretical limit to deceleration for the tested vehicles when only the rear brakes are used. The "K ratio" shown in the table is height of the centre of gravity divided by its horizontal distance to the front axle. Coefficient of friction C is assumed to be 1. Load transfer effects are evident by comparing the static and dynamic loads on the rear axle.

Max deceleration = 9.8 x Static rear load x C / Laden mass x (1 + CK)

Table 3. Limits to rear wheel braking

DESCRIPTION	WHEEL-BASE mm	HEIGHT C of G mm	STATIC REAR LOAD kg	LADEN MASS kg	K RATIO	MAX DECEL m/s^2	DYN REAR LOAD kg	MEAS. DECEL m/s^2
GIANT MTN BIKE	1040	950	45	70	0.91	3.29	24	4.57*
ROTARY CRUISER	1090	900	26	61	0.83	3.76	35	4.48*
TRACKER ELECTRIC SCOOTER	800	850	50	75	1.06	3.17	24	3.03
VIPER BMX	950	800	50	68	0.84	3.91	27	3.82*
TAMI PETROL SCOOTER	790	850	42	72	1.08	2.75	20	2.88
HOLSTAR SCOOTER	843	850	35	74	1.01	2.31	17	3.71*
RAZOR FOLD-UP SCOOTER	565	850	35	61	1.50	2.25	14	3.52
TAMI WITH SEAT	790	700	48	73	0.89	3.42	25	3.54

* Front brakes also used

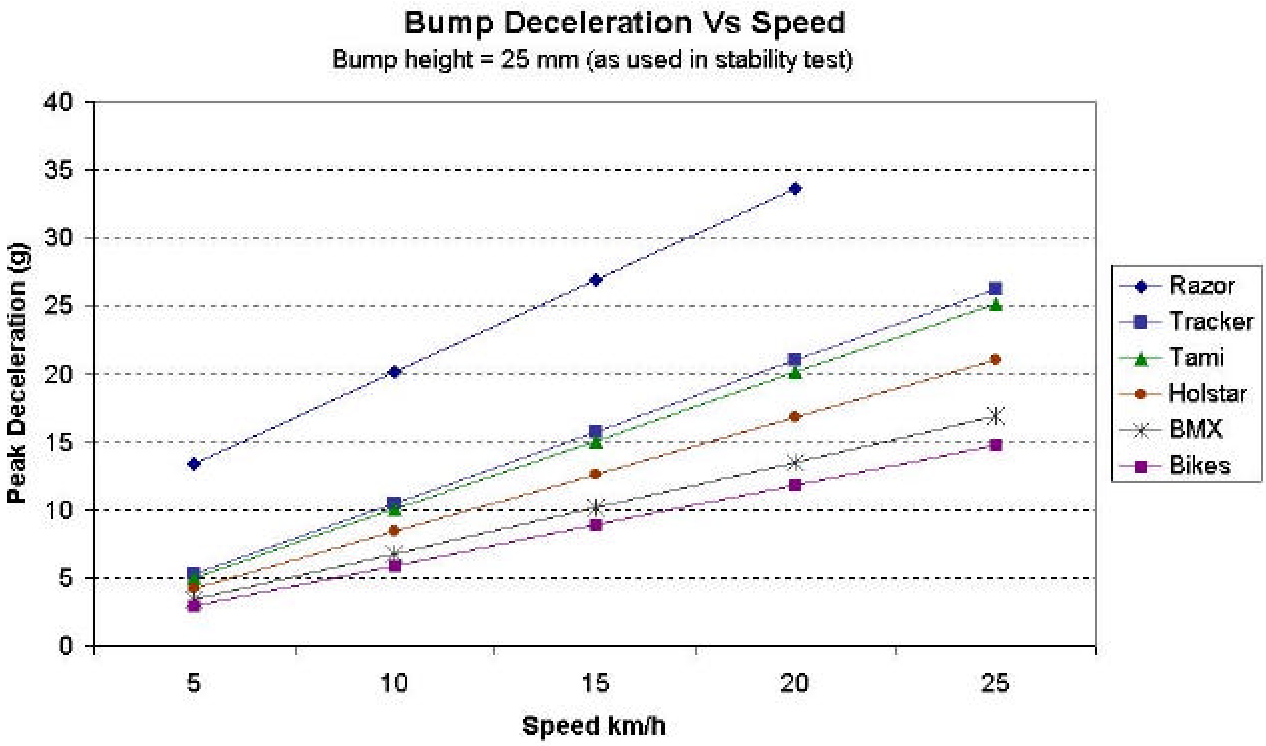
The analysis confirms the experimental result that the Tami with seat had better brake performance than with no seat. The Razor is an unusual case because the rider must apply load to the rear mudguard, thereby increasing the load on the rear axle and improving the braking performance available. The above analysis assumes that the longitudinal location of the centre of mass is unchanged but this is not the case with the Razor.

The benefits of front brakes are evident from the measured average decelerations for the Giant mountain bike, Rotary Cruiser and Holstar scooter. In each case the measured value, using front and rear brakes was much better than the theoretical value using rear brakes only. Despite this the Holstar had braking performance that was only marginally better than the scooters without front brakes. One factor would be the relatively low proportion of the total mass carried by the rear wheels in the case of the Holstar.

The relatively poor performance of the BMX bike may have been due to the brakes reaching the limit of their capacity since rear wheel skidding was not evident. Braking effect was rated adequate in the tests.

Bumps

The stability tests (involving driving across cleats) revealed that small-wheeled vehicles are much more sensitive to bumps than vehicles with larger wheels. It can be demonstrated theoretically that the (horizontal) deceleration forces generated when a wheel strikes a bump are proportional to the square root of the bump height divided by the wheel diameter. The graph shows the theoretical response of each vehicle to the 25mm bump used in the stability test. This assumes high stiffness in the tyres. In practice, pneumatic tyres tend to deform to the profile of the bump and therefore the responses for pneumatic tyres can be expected to be better than those derived below.



Theoretical bump response of each vehicle

During the stability tests the Tracker and Tami scooters experienced stability and control deterioration when the speed increased from 10 to 15 km/h. From the graph this suggests that a peak deceleration around 15g was sufficient to cause problems associated with poor bump response. Applying this notional value to the other vehicles the Razor would be limited to no more than 5km/h, the Holstar scooter to about 18km/h and the BMX and large bikes exceed 20km/h. This assumes that the maximum bump height encountered in the riding environment is 25mm.

Motors

The Rotary Cruiser bicycle and Tami scooter have 2 stroke petrol motors. The Tami engine displacement volume is 33cc and the brochure claims 1.7HP@ 7000 RPM = 1270 W. This high engine speed was unlikely to have been reached in any of our tests and it is considered unlikely that a rider would want to operate the engine at sustained high speeds. The label on the motor suggests that the power is limited to 196W when the collar is in place on the throttle cable.

The Rotary Cruiser has a 30cc engine and the brochure indicates a power of 200W. It probably has a power-limiting device but this was not evident from external components.

Whitt and Wilson provide a power/speed curve for human-powered bicycles. They indicate that 200W is consumed at 30km/h. The curve is very steep (100W is consumed at 25km/h). Our experience with the Rotary Cruiser and Tami suggest that the extra weight and driveline inefficiencies contribute to significantly lower speeds when under power - they achieved between 25 and 30 km/h. In the case of the Tami this was with the throttle unrestricted.

Both the Rotary Cruiser and Tami have centrifugal clutches that automatically engage when the engine revolutions increase. This was well controlled but a possible problem is that the vehicle may move when the throttle is accidentally operated.

The Tracker has a 200W electric motor. Its top speed of around 17km/h suggests considerable inefficiencies. The Tracker has to be human-propelled to about 8km/h before the motor is engaged. It then accelerates to a cruise speed of about 15km/h.

The Tracker motor was very quiet. The Rotary Cruiser motor was well silenced and did not cover up the noise of traffic. In contrast the Tami motor was noisy and other traffic could not be heard. The noise levels were considered irritating for the community.

Lights

Only the Rotary Cruiser had lights. Lights are optional under AS1927. Front, rear, side (spoke) and pedal reflectors are mandatory under the standard. The Rotary Cruiser had all reflectors and the mountain bike only had spoke reflectors (the others had probably broken off during off-road riding). None of the other vehicles had reflectors.

Human Factors

Control of vehicle

All vehicles had conventional handlebars for steering control. During the performance tests the Razor steering was found to be very sensitive to steering input. This was probably due to the combination of narrow handlebars and stiff, solid tyres.

All vehicles except the Razor used hand levers for brake control. These were all well modulated but control was limited by other factors such as stability and skidding. As mentioned above, the Razor mudguard brake was prone to being missed.

The Rotary Cruiser has a motorcycle style rotary handgrip for the throttle. This was easy to use and well modulated.

The Tami had a hand lever on the handlebars for throttle control. Although it was well modulated a serious flaw is that it is easy to mix up the throttle and brake levers (left and right hand controls respectively).

The Tracker electric scooter has a simple on/off switch. Engine control is unmodulated and the only way to achieve lower speeds under power is to continually switch the motor on and off. Riders would be reluctant to do this and therefore may not slow down to an appropriate speed for the conditions.

Rider cognitive tasks

The task of controlling a vehicle is very demanding. Vehicle direction and speed must be monitored and controlled. The road environment and other road users must be continually assessed and control action taken, if appropriate. These tasks can become overwhelming in an emergency situation.

Two wheeled vehicles place additional demands on the rider because of the need to maintain balance. The two wheeled vehicle is much less forgiving if control momentarily lapses and road user protection in the event of a collision is minimal.

With the range of scooters that we tested it is evident that the time it takes for the vehicle to veer out of control is much less than that for a conventional bicycle. The rider needs to constantly monitor and adjust the vehicle. Compounding this problem is the lack of steering feedback with a typical scooter. With a bicycle it is possible to ride it for a short time with eyes closed. This is because the rider receives feedback from the steering system.

With a scooter the only feedbacks to the rider are visual and the sense of balance. Since changes need to be detected in order to recognise destablising motion the rider must be constantly aware of changes. This raises serious dilemma when the vehicle mixes with other traffic - particularly cars - because the rider must choose between monitoring the vehicle and monitoring other traffic. They cannot afford the luxury of looking around for more than a fraction of a second to assess the traffic situation. In contrast, bicycle riders can take a second or two to look around. This is a fundamental limitation to the ability of these types of scooters to mix with other traffic.

Extreme riding

Skilful riders can be seen jumping stairs and other obstacles on Razor scooters. If the rider is aware of the obstacle then such tricks can be performed. Problems arise, however, when there is little or no warning of an obstacle, as typically occurs on the road. As we found in our tests, a 25mm high bump is sufficient to cause severe difficulties with small wheeled scooters such as the Razor. It also caused problems for Tami and Tracker powered scooters.

Road Environment

Mixing with traffic

For the types of scooters tested the rider is unable to devote sufficient attention to other traffic. They are therefore more likely to get into a dangerous situation than the rider of a conventional bicycle.

The overall height of a rider/scooter combination is usually less than that of a bicycle so other motorists are less likely to see a scooter rider. Another concern is that a common mode of falling off scooter is a sudden and severe sideways motion. There may, therefore, be more likelihood of a scooter rider falling into the path of a car.

Impacts between cars and erect scooter riders are likely to be more severe than with bicycles because the scooter rider's torso is closer to the ground and therefore vulnerable to direct impact. The risk of head impacts with colliding vehicles is likely to be similar, although the body kinematics would be different.

In summary, it is considered that none of the tested scooters is suitable for mixing with normal traffic on public roads. The non-motorised scooters could continue to be used for recreational purposes where there is only slow-moving traffic. It is doubtful whether riders of motorised scooters would confine themselves to such situations. Very specialised facilities such as bicycleways might provide a safer environment for commuter travel using motorised scooters but bicycle riders might have a good case for objecting to sharing such facilities with motorised vehicles.

Mixing with pedestrians

Very little research appears to have been done into the risk to pedestrians from collisions with riders of recreational devices. Most research seems to concentrate on injured riders who were admitted to hospital (see next section). As a general rule any situation where pedestrians are likely to be involved in collisions at 10km/h or more should be avoided. This includes joggers, bicycles, scooters, skateboarders and in-line skaters. Higher speeds present problems for collision avoidance (pedestrians don't have time to get out of the way and riders don't have time to dodge a hazard) and injury avoidance. Collisions with unyielding objects at such speeds can cause fractures and severe head injuries (Henderson and Paine, 1997). With frail pedestrians there is extra hazard from being knocked over, or falling over when trying to avoid a collision.

Since both of the motorised scooters that were tested are likely to be ridden well in excess of this speed (indeed the Tracker could not be easily ridden under power at less than 15km/h) it is considered that they should not be used in circumstances where they mix with pedestrians.

Accidents and Injuries

It was not part of the brief for this project to carry out an extensive review of literature concerning injuries involving scooters. A simple review was conducted to obtain an indication of the research material available on this subject, and possible issues concerning vehicle design. This was in addition to material set out in the brief.

A reference was found to an article "Scooters cause 9500 injuries in US in 8 months" by D. Josefson and S Francisco, Western Journal of Medicine, Nov 2000, 173 (5). It is evident that scooter-related injuries are a recent cause for concern in the USA.

A German study (Feiler S and Frank M, 2000) of skateboarding injuries found the risk was one injury per rider per 1000 hours of exposure time. 18% of injuries were fractures, mainly to arms and wrists. Head injuries were not identified in this work but other studies found 3.5 to 9% of reported injuries to skateboarders involved head injuries (Fountain JL and Meyers MC, 1996). The authors noted "most injuries occur when the skateboard strikes an irregularity in the riding surface".

It is considered that scooter injury risk and patterns would be similar to those of skateboarders, where the vehicles are used in similar circumstances.

The following email was received from Mr Mark Ross from the U.S. Consumer Product Safety Commission:

"I am not aware of any study by the U.S. Consumer Product Safety Commission on braking or stability of scooters. We do track death and injury data relating to scooters, which is posted on our web site in the Press Room section of story suggestions. Here is the latest update we have...There were two deaths reported relating to non-powered scooters, both in September 2000. A man died in Richmond, Va., after falling and hitting his head. A 6-year-old boy was hit by a car while riding a scooter in Elizabeth, N.J. There have been nearly 30,000 scooter-related emergency room-treated injuries reported from January 1 through November 15, 2000, based on CPSC's National Electronic Injury Surveillance System (NEISS). There were about 6,100 emergency room-treated injuries relating to non-powered scooters in August 2000. There were about 8,600 emergency room-treated injuries reported in September 2000, and about 6,800 injuries reported in October 2000. As of November 21, 2000, there have been about 2,500 emergency room-treated injuries reported for the first half of November 2000. About 85 percent of the injuries are to children under 15 years of age.

We issued a press release on September 5, 2000 recommending that people wear safety equipment, including a helmet and knee and elbow pads to prevent and reduce injuries, along with other recommendations."

Further correspondence it contained in Appendix F.

Conclusions

Summary for each vehicle

Giant Mountain Bike

The Giant mountain bike complied with the brake performance and the steering geometry requirements specified in Australian Standard 1927:1998. Average deceleration was sufficient to comply with the stopping distance requirement from 24km/h (the test was conducted at 16km/h so that the test was the same for all vehicles). It was rated good for stability and control in braking and stability tests prescribed in that standard. It was rated adequate for control in the manoeuvrability tests that were based on the UK Bicycling Proficiency Test. The tests confirmed theoretical calculations that the vehicle had stable characteristics.

Rotary Cruiser motorised bicycle

The Rotary Cruiser complied with the brake performance and the steering geometry requirements specified in AS1927. Average deceleration was sufficient to comply with the stopping distance requirement from 24km/h. It was rated marginal for stability and control in braking test and adequate in the stability test prescribed in that standard. It was rated adequate to marginal for control in the manoeuvrability tests.

Diamond Back BMX Bike

The BMX complied with the brake performance and the steering geometry requirements specified in AS1927, although average deceleration would not have been sufficient to meet the stopping distance requirement from 24km/h. It was rated good for stability and control in braking test and marginal in the stability test prescribed in that standard. It was rated adequate to marginal for stability in the manoeuvrability tests.

Tracker Electric Scooter

The Tracker complied with the brake performance and the steering geometry requirements specified in AS1927, although average deceleration would not have been sufficient to meet the stopping distance requirement from 24km/h. It was rated poor for stability and control in braking and stability tests prescribed in that standard. It was unable to be ridden under power in the manoeuvrability tests due to the lack of throttle modulation. It is difficult to ride this vehicle under power at less than 15km/h.

Holstar Large-wheeled Scooter (no motor)

The Holstar complied with the brake performance and the steering geometry requirements specified in AS1927, although average deceleration would not have been sufficient to meet the stopping distance requirement from 24km/h. It was rated adequate for stability and control in braking and stability tests prescribed in that standard. Stability dropped to marginal with the cleats at 45^o. It was rated good for stability and adequate for control in the manoeuvrability tests. This was considered to be the best performing of all of the scooters tested.

Tami Petrol Scooter

The Tami complied with the brake performance requirements specified in AS1927, although average deceleration would not have been sufficient to meet the stopping distance requirement from 24km/h. It did not comply with the steering geometry requirements in the standard and theoretical analysis indicated that it would have unstable steering characteristics. It was rated marginal to poor for stability in the braking and stability tests prescribed in that standard. It was rated good for stability and adequate for control in the manoeuvrability tests without cleats but was marginal with cleats. Manoeuvrability was worse with the seat fitted but braking was better.

There are several safety concerns about the design of the Tami:

- the power-limiting mechanism can be very easily removed, giving a power output well in excess of 200W and excessive potential speed.
- the use of a hand lever for a throttle - this could easily be confused with the brake lever.
- the security and vulnerability of the petrol tank
- the vulnerability of the fuel lines, which pass between the mudguard and the tyre and through sheet metal holes with no grommets.
- the high noise level from the motor covers up the noise of other traffic.

Razor Fold-up Scooter

When operated correctly the Razor complied with the brake performance requirements specified in AS1927, although average deceleration would not have been sufficient to meet the stopping distance requirement from 24km/h. However, the method of applying the brake, by placing a foot on the hinged rear mudguard and pressing down, is prone to mistakes. The Razor did not comply with the steering geometry requirements in the standard and theoretical analysis indicated that it would have unstable steering characteristics. It was rated marginal for stability and poor for control in the braking. The stability tests could not be performed due to the inability of the vehicle to negotiate the 25mm high bumps. It was rated marginal for stability and control in the manoeuvrability tests without cleats but could not be ridden over the test course with cleats.

Conclusions and recommendations

A range of bicycles and recreational scooters have been evaluated using performance tests that were developed for bicycles. These tests revealed that, in general, scooters (motorised and human-powered) are less stable and controllable than bicycles and, in particular, are more susceptible to road irregularities. Sudden falls sideways into the path of passing cars are more likely than with bicycles. Theoretical analysis of stability and reaction to bumps supports this finding and suggests that instability would become worse at higher speeds than those involved in the tests. There do not appear to be any ways to significantly improve the design of scooters to increase their stability at higher speeds.

Consideration of the human factors issues revealed that recreational scooters require near-continuous monitoring of the state of the vehicle by the rider, due mainly to the lack of force feedback through the handlebars. This raises a serious dilemma when the vehicle mixes with other traffic - particularly cars - because the rider must choose between monitoring the scooter and monitoring other traffic. In contrast, bicycle riders can take a second or two to look around because they feel feedback through the handlebars. There is therefore a fundamental limitation to the ability of recreational scooters to mix with other road traffic. The problem is compounded by the vulnerability of scooter riders to injury in collisions with cars.

In the case of motorised scooters, it was found that they typically travel too fast to safely mix with pedestrian traffic. On level ground non-motorised scooters cannot be ridden at such speeds for sustained periods. They are still a hazard, however, in pedestrian areas that are congested or have frail or very young people.

It is recommended that:

a) recreational scooters not be permitted on any public roads where cars are likely to travel at more than 40km/h (impacts above this speed are much more likely to be fatal - Paine and Coxon 2000)

b) recreational scooters not be permitted in general pedestrian areas that are congested or usually have frail or very young people.

c) local councils be encouraged to set up suitable facilities for riding scooters, skateboards and similar recreational devices.

d) helmet wearing be encouraged for all scooter riders

e) motorised recreational scooters not be permitted on any public roads, footpaths or pedestrian areas.

f) motorised bicycles (200 W power limit) continue to be permitted to operate on public roads but a maximum speed (on level ground under power) also be specified to discourage tampering with power limiting mechanisms and to aid enforcement.

Prepared by

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Manager, Vehicle Design & Research Pty Limited

4 December, 2001

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Appendix A Vehicle Specifications

TEST CODE	DESCRIPTION
A	26" Mountain bicycle
B	26" Motorised bicycle
C	Motorised scooter with mid-size tyres
D	BMX bicycle
E	Motorised scooter with large tyres - no seat
H (E)	Motorised scooter with large tyres and a seat
F	Scooter with large tyres
G	Scooter with small solid tyres

Technical Specifications: A - Mountain bicycle

General

Make and Model: Giant Iguana

Description: Typical "mountain bike", used extensively as a road bike.

General view of vehicle

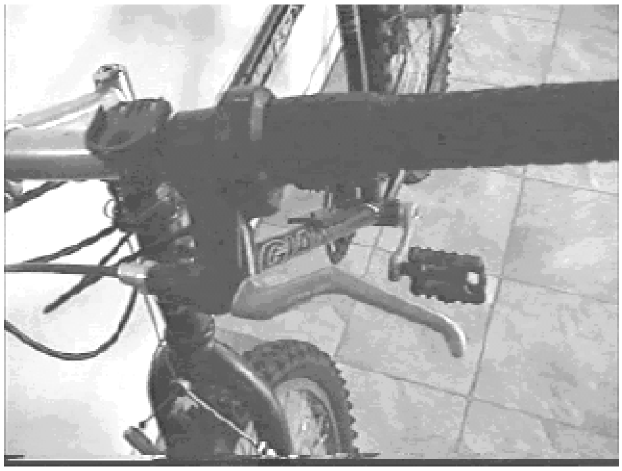
Braking system

Caliper brakes, front and rear. Operated by hand levers.

Power

Pedal. 21 gear ratios.

Maximum speed on level: About 30km/h



Brake hand levers.

Mass and Dimensions

Unladen mass: Front 6 kg Rear 6 kg
Total 12 kg

Laden mass: Front 25 kg Rear 45 kg

Total 70 kg

Front % of total: 36 %

Estimated height of centre of mass (laden):

950 mm

Wheelbase: 1040 mm

Height/wheelbase: 91 %

Steering geometry

Steering head angle: 70 degrees

Trail: 76 mm

Vertical intercept: 200 mm

Tyre outer diameter: 665 mm

Rim outer diameter: 565 mm

Tyre type: Pneumatic

Tyre size: 26x1.95

Comments: Good feedback from tyre side slip.

View of steering geometry

Technical Specifications: B - Motorised bicycle

General

Make and Model: Rotary Cruiser

Description: Large framed bicycle with a small petrol motor mounted on the rear hub.

General view of vehicle

Braking system

Caliper brakes front and rear. Operated by hand levers.

Brake lever

Power

30cc 2 stroke petrol motor rated at 200W (brochure). Twist grip throttle control on right handlebar. Easy to modulate. Centrifugal clutch cuts in when motor is revved.

Maximum speed on level: 25km/h under power only.

4.5 litre metal fuel tank mounted on crossbar. With fuel cut-off valve.

Motor

Mass and Dimensions

Unladen mass: Front 12 kg Rear 22 kg

Total 34 kg

Laden mass: Front 27 kg Rear 63 kg

Total 90 kg Front % of total: 30 %

Estimated height of centre of mass (laden): 900 mm

Wheelbase: 1090 mm Height/wheelbase: 83 %

Steering geometry

Steering head angle: 70 degrees

Trail: 80 mm

Vertical intercept: 210 mm

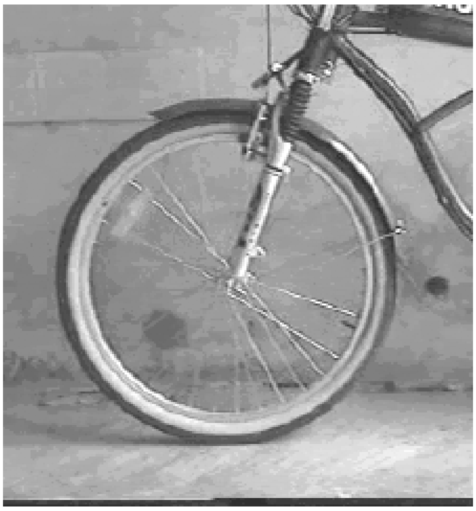
Tyre outer diameter: 665 mm

Rim outer diameter: 570 mm

Tyre type: Pneumatic

Tyre size: 26X2.125

Comments: Wide handlebars. Good feedback from tyreslip but vehicle is more cumbersome to handle than a conventional bicycle.



View of steering geometry

Trail measurement

Technical Specifications: C - Electric Scooter

General

Make and Model: Tracker 2000

Description: Scooter with mid-size wheels. Electric motor driving rear wheel. .

General view of vehicle

Braking system

Band brake on rear wheel. Operated by hand lever.

Power

200W electric motor. Direct belt drive with no clutch. 12V battery.

Maximum speed on level: about 20km/h

Hand levers - large lever is brake. Short lever is throttle (on/off).

Mass and Dimensions

Unladen mass: Front 7 kg Rear 8 kg
Total 15 kg

Laden mass: Front 25 kg Rear 50 kg
Total 75 kg Front % of total: 33 %

Estimated height of centre of mass (laden): 850 mm

Wheelbase: 800 mm

Height/wheelbase: 106 %

Steering geometry

Steering head angle: 75 degrees
Trail: 30 mm

Vertical intercept: 90 mm

Tyre outer diameter: 190 mm

Rim outer diameter: 120 mm

Tyre type: Pneumatic

Tyre size: 200x50

Comments:

View of steering geometry

Technical Specifications: D - BMX bicycle

General

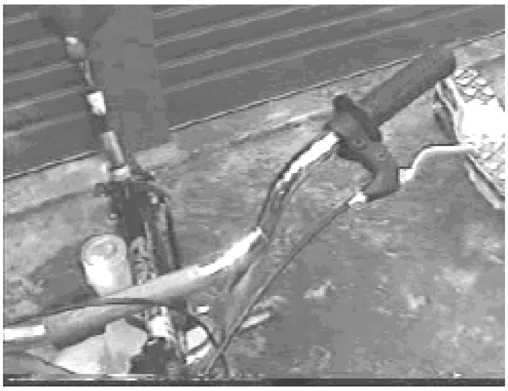
Make and Model: Diamond Back Viper

Description: Typical BMX bike, used for off-road courses

General view of vehicle

Braking system

Caliper brakes front and rear, operated by hand levers.



Hand Brake Lever

Power

Pedals.

Maximum speed on level: About 20km/h

Mass and Dimensions

Unladen mass: Total 13.2 kg

Laden mass: Front 18 kg Rear 50 kg

Total 68 kg Front % of total: 26 %

Estimated height of centre of mass (laden): 800 mm

Wheelbase: 950 mm Height/wheelbase: 84 %

Steering geometry

Steering head angle: 75 degrees

Trail: 50 mm

Vertical intercept: 190 mm

Tyre outer diameter: 500 mm

Rim outer diameter: 430 mm

Tyre type: Pneumatic

Tyre size: 20X1.75

Comments: Good feedback from tyre sideslip.

View of steering geometry

Technical Specifications: E - Motorised scooter with large wheels

General

Make and Model: Tami Chrome

Description: Large-wheeled scooter especially designed for a petrol motor.

Braking system

Band brake on rear wheel. Operated by hand lever.

Power

33cc 2 stroke petrol motor. Brochure claims 1.7HP@ 7000 RPM = 1270 W (this is an exceptionally high RPM - a more realistic maximum power would be about 800W). A mechanical device is fitted to the throttle cable and a small sign indicates "195W Power Set Up". It was easily removed.

Maximum speed on level: About 30km/h without speed limiting and 18km/h with speed limiting.

Mass and Dimensions

Without seat

Unladen : Front:5 kg Rear:10 kg Total:15 kg

Laden: Front:30 kg Rear:42 kg Total:72 kg

Front % of total: 42 %

Est height of centre of mass (laden): 850 mm

Wheelbase: 790 mm

Height/wheelbase: 107 %

With seat

Unladen : Front:5 kg Rear:11 kg Total:16 kg

Laden: Front:25 kg Rear:48 kg Total:73 kg

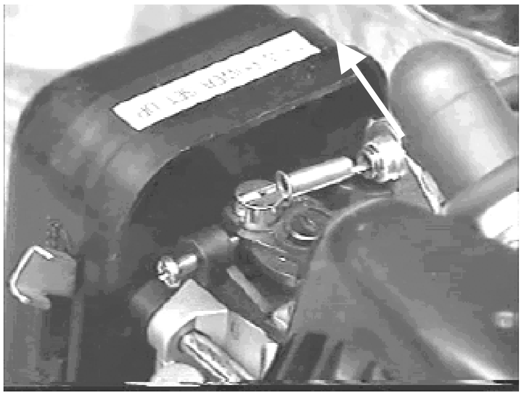
Front % of total: 34 %

Est height of centre of mass (laden): 700 mm

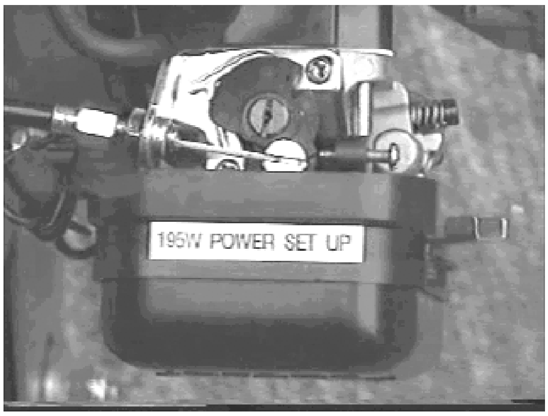
Wheelbase: 790 mm

Height/wheelbase: 89 %

General view of vehicle



Speed limiter in place



Speed limiter removed

Steering geometry

Steering head angle: 80 degrees

Trail: Nil mm

Vertical intercept: N/A

Tyre outer diameter: 210 mm

Rim outer diameter: 120 mm

Tyre type: Pneumatic

Tyre size: 2.5-4

Comments:

View of steering geometry

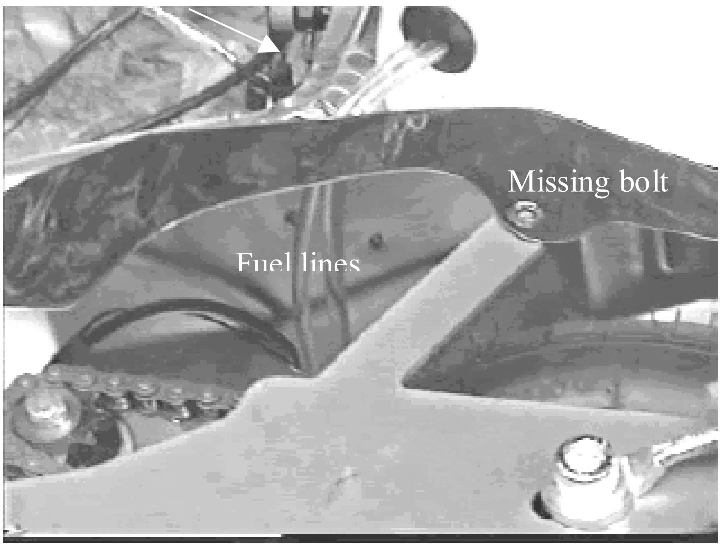
Tami with seat

Design issues

The fuel tank is in a vulnerable position. After the tests it was found that the single bolt that secures the fuel tank to the frame had fallen off and the fuel tank was only held in place by a keyed slot.

The plastic fuel lines pass through ungrommetted holes on either side of the mudguard and are therefore unprotected from chaffing. They pass between the mudguard and the wheel and are unprotected from stones and other debris thrown up by the tyres.

The foot platform is wide enough for placing two feet side by side but there is insufficient room to place the feet fore and aft - the most stable riding position. The rider therefore has to rely on the handlebars to maintain balance.



Fuel lines passing between tyre and mudguard

Technical Specifications: F - Large scooter

General

Make and Model: Holstar Sidewinder

Description: Large push scooter with pneumatics wheels.

General view of vehicle

Braking system

Front and rear lever operated caliper brakes

Caliper brake - rear wheel

Power

Push

Maximum speed on level: About16km/h

Mass and Dimensions

Unladen mass: Front 6kg Rear 3 kg
Total 9 kg

Laden mass: Front 39 kg Rear 35 kg
Total 74 kg

Front % of total: 53 %

Estimated height of centre of mass (laden):
850 mm

Wheelbase: 843 mm Height/wheelbase: 100 %

Steering geometry

Steering head angle: 70 degrees

Trail: 20 mm

Vertical intercept: 40 mm

Tyre outer diameter: 315 mm

Rim outer diameter: 210 mm

Tyre type: Pneumatic

Tyre size: 57-203

Comments: Well designed steering setup. Some feedback from tyre sideslip.

View of steering geometry

Hand brake lever

Technical Specifications: G - Small fold-up scooter

General

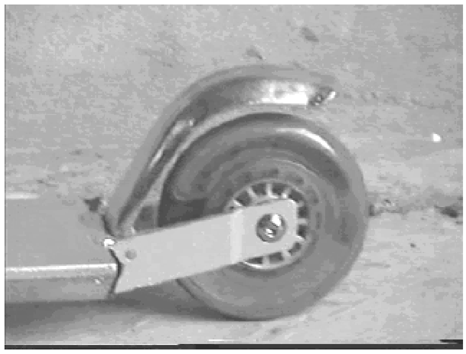
Make and Model: Razor JD

Description: Small, lightweight fold-up scooter with small wheels.

General view of vehicle

Braking system

Rear mudguard acts as a footbrake. It is on a spring hinge and the rider presses his heel on the mudguard. Friction between the aluminium mudguard and the tyre causes the braking action.



Razor brake

Power

Pushed with one foot on the ground.

Maximum speed on level: About 18km/h

Mass and Dimensions

Unladen mass: Total 3 kg

Laden mass: Front 26 kg Rear 35 kg Total 61 kg
Front % of total: 43 %

Estimated height of centre of mass (laden): 850 mm

Wheelbase: 565 mm Height/wheelbase: 150 %

Steering geometry

Steering head angle: 82 degrees

Trail: Nil mm

Vertical intercept: Nil mm

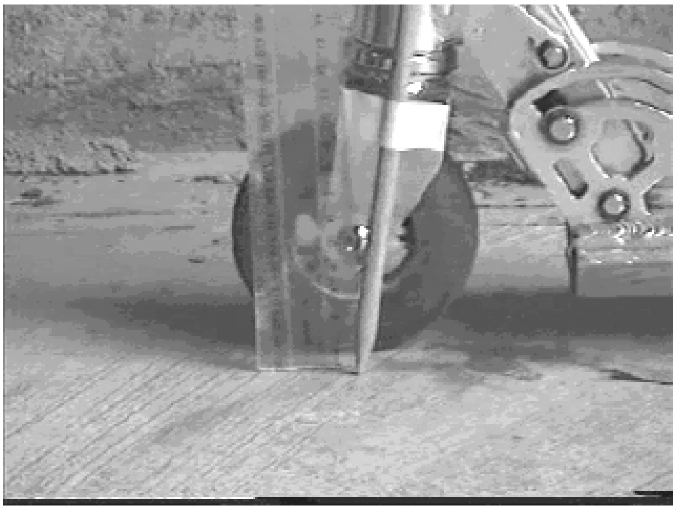
Tyre outer diameter: 100 mm

Rim outer diameter: N/A

Tyre type: Solid plastic

Tyre size: Proprietary

Comments: Steering very sensitive to transverse and vertical irregularities. No force feedback from tyre sideslip.



View of steering geometry

Appendix B - Brake Test Results

Table 2 Braking Tests

VEHICLE	SPEED km/h	ADJ STOP DIST m	AV.DEC m/s/s	STABILITY	CONTROL	EFFECT
GIANT MTN BIKE	18	2.09	4.73	G	G	G
GIANT MTN BIKE	19	2.14	4.62	G	G	G
GIANT MTN BIKE	19	2.14	4.61	G	G	G
GIANT MTN BIKE	18	2.14	4.62	G	G	G
GIANT MTN BIKE	18	2.30	4.30	G	G	G
		Av	4.57			
ROTARY CRUISER	19	2.39	4.13	M	M	A
ROTARY CRUISER	19	2.11	4.69	M	M	A
ROTARY CRUISER	17	2.08	4.74	M	M	A
ROTARY CRUISER	18	2.26	4.36	M	M	A
		Av	4.48			
TRACKER ELECTRIC SCOOTER*	16	3.26	3.03	P	P	M
TRACKER ELECTRIC SCOOTER*	16	3.26	3.03	P	P	M
TRACKER ELECTRIC SCOOTER*	17	3.27	3.02	P	P	M
TRACKER ELECTRIC SCOOTER*	16	3.27	3.02	P	P	M
		Av	3.03			
VIPER BMX	19	2.69	3.67	G	G	A
VIPER BMX	17	2.50	3.96	G	G	A
VIPER BMX	18	2.58	3.84	G	G	A
		Av	3.82			
HOLSTAR SCOOTER	17	2.63	3.76	A	A	M
HOLSTAR SCOOTER	16	3.19	3.09	A	A	M
HOLSTAR SCOOTER	17	2.29	4.32	A	A	M
HOLSTAR SCOOTER	18	2.70	3.65	A	A	M
		Av	3.71			
RAZOR FOLD-UP SCOOTER*	18	2.60	3.80	M	P	P
RAZOR FOLD-UP SCOOTER*	18	3.03	3.26	M	P	P
RAZOR FOLD-UP SCOOTER*	16	2.82	3.50	M	P	P
		Av	3.52			
TAMI PETROL SCOOTER*	18	3.53	2.79	A	A	M
TAMI PETROL SCOOTER*	18	3.42	2.89	A	A	M
TAMI PETROL SCOOTER*	18	3.63	2.72	A	A	M

TAMI PETROL SCOOTER*	17	3.48	2.84	A	A	M
TAMI PETROL SCOOTER*	18	3.15	3.14	A	A	M
		Av	2.88			
TAMI WITH SEAT*	16	2.77	3.56	M	A	M
TAMI WITH SEAT*	17	3.01	3.28	M	A	M
TAMI WITH SEAT*	16	2.65	3.73	M	A	M
TAMI WITH SEAT*	19	2.83	3.48	M	A	M
TAMI WITH SEAT*	18	2.71	3.65	M	A	M
		Av	3.54			

* Rear brake only

Key

G	Good
A	Adequate
M	Marginal
P	Poor
X	Aborted

Appendix C - Stability tests

1. Cleats at 90^o

VEHICLE	SPEED km/h	STABILITY	CONTROL
GIANT MTN BIKE	7	G	G
GIANT MTN BIKE	12	G	G
GIANT MTN BIKE	15	G	G
GIANT MTN BIKE	16	G	G
GIANT MTN BIKE	20	G	G
GIANT MTN BIKE	24	G	G
ROTARY CRUISER	14	A	G
ROTARY CRUISER	20	A	G
TRACKER ELECTRIC SCOOTER*	7	P	X
TRACKER ELECTRIC SCOOTER*	10	P	M
TRACKER ELECTRIC SCOOTER*	15	P	P
VIPER BMX	8	A	M
VIPER BMX	12	M	M
VIPER BMX	22	M	M
TAMI PETROL SCOOTER*	5	A	A
TAMI PETROL SCOOTER*	10	M	M
TAMI PETROL SCOOTER*	14	P	M
HOLSTAR SCOOTER	4	A	A
HOLSTAR SCOOTER	15	A	A
HOLSTAR SCOOTER	16	A	A
RAZOR FOLD-UP SCOOTER*	10	X	X
RAZOR FOLD-UP SCOOTER*	10	X	X
TAMI WITH SEAT*	7	M	M
TAMI WITH SEAT*	14	M	M

Key

G	Good
A	Adequate
M	Marginal
P	Poor
X	Aborted

2. Cleats at 45^o

VEHICLE	SPEED km/h	STABILITY	CONTROL
GIANT MTN BIKE	7	G	G
GIANT MTN BIKE	14	G	G
GIANT MTN BIKE	22	G	G
ROTARY CRUISER	6	A	A
ROTARY CRUISER	7	M	A
ROTARY CRUISER	10	A	A
ROTARY CRUISER	19	M	A
TRACKER ELECTRIC SCOOTER*	8	M	A
TRACKER ELECTRIC SCOOTER*	14	P	M
VIPER BMX	7	A	G
VIPER BMX	26	M	M
TAMI PETROL SCOOTER*	6	M	P
TAMI PETROL SCOOTER*	16	P	P
TAMI PETROL SCOOTER*	23	P	P
HOLSTAR SCOOTER	7	A	A
HOLSTAR SCOOTER	16	M	A
HOLSTAR SCOOTER	17	M	A
RAZOR FOLD-UP SCOOTER*	9	X	X
TAMI WITH SEAT*	11	M	M
TAMI WITH SEAT*	14	P	P

Key

G	Good
A	Adequate
M	Marginal
P	Poor
X	Aborted

Appendix D - Manoeuvrability Tests

Manoeuvrability tests based on TRRL LR500 (UK National Cycling Proficiency Test)

The cleats were 20mm high, 40mm wide and had a 12mm radius edge.

VEHICLE	CLEATS	STABILITY	CONTROL	NOTE
GIANT MTN BIKE	NO	A	G	
GIANT MTN BIKE	YES	A	G	
ROTARY CRUISER	NO	A	M	
ROTARY CRUISER	YES	M	M	TOO CUMBERSOME
TRACKER ELEC SCOOTER	NO	X	X	ABORTED
TRACKER ELEC SCOOTER	NO	M	M	NO POWER
VIPER BMX	NO	G	A	ON SEAT
VIPER BMX	NO	G	G	OFF SEAT
VIPER BMX	YES	A	M	ON SEAT
VIPER BMX	YES	A	A	OFF SEAT
TAMI PETROL SCOOTER*	NO	G	A	
TAMI PETROL SCOOTER*	YES	M	M	
HOLSTAR SCOOTER	NO	G	A	
HOLSTAR SCOOTER	YES	G	A	
RAZOR FOLD-UP SCOOTER*	NO	M	M	
RAZOR FOLD-UP SCOOTER*	YES	X	X	
TAMI WITH SEAT*	NO	M	P	
TAMI WITH SEAT*	YES	M	P	

Key		
	G	Good
	A	Adequate
	M	Marginal
	P	Poor
	X	Aborted

Appendix E - Top Speed

VEHICLE	SPEED km/h	STABILITY	CONTROL
GIANT MTN BIKE	30	G	G
ROTARY CRUISER	24	G	G
TRACKER ELECTRIC SCOOTER	17	M	M
VIPER BMX	20	A	A
HOLSTAR SCOOTER	18	A	A
RAZOR FOLD-UP SCOOTER	18	P	P
TAMI WITH SPEED LIMITER	18	A	A
TAMI UNLIMITED	30	M	M

Key

G	Good
A	Adequate
M	Marginal
P	Poor
X	Aborted

Appendix F - Correspondence

New York State

Dear Mr. Paine:

This excerpt is from the New York State Department of Motor Vehicles

website http://www.nysdmv.com/dmvfaqs.htm#go-ped The Lazor fold up scooter you mention would fall into this category and is illegal for use on public highways, sidewalks and parking lots in New York State.

Go-Peds, Mini-Bikes, Dirt Bikes, Go-Karts, Motor Assisted Bicycles

The following types of motorized devices and similar devices may not be registered in NYS, and may not be operated anywhere on public streets or highways in NYS. These devices are motor vehicles which are not equipped or designed for on-road operation.

Go-ped - a device similar to a skateboard with a motor attached and a handlebar for a standing rider.

Mini-bike - small, two-wheeled motorized device designed for off-road operation. A mini-bike does not qualify as a moped, a motorcycle or an ATV .

Dirt Bike - two-wheeled motorized device similar to a motorcycle, but designed and used for off-road use. Some vehicles described as "dirt bikes"

may meet the definition of an All-Terrain Vehicle (ATV) and qualify for registration and operation off-road as an ATV.

Go-Kart - Small, four-wheeled motorized device designed and used for off-road operation. A Go-Kart is not equipped as, and may not be registered as, either a motor vehicle or an ATV.

Motor-assisted Bicycle - a bicycle to which a small motor has been attached.

A motor-assisted bicycle is not equipped as, and does not qualify for registration as a motorcycle, moped or ATV.

Operating any of these devices on any street or highway or other area, such as a parking lot open to public motor vehicle traffic, may result in arrest for operating a motor vehicle without a registration, license, inspection, insurance or proper equipment. DMV cannot provide any information regarding operation of such devices on private property. Contact local authorities and property owners.

Holly New, Web Administrator

NYS Governor's Traffic Safety Committee