TRAILER SCIENCE

Introduction

Carrying load by bike costs the cyclist energy. However some methods of carrying cost more energy than others. We consider three representative ways of carrying load, panniers, monowheel trailers, and two wheel trailers. We seek to demonstrate that two wheel trailers are frequently the most efficient way to carry loads.

Panniers fix the load rigidly to the bicycle, if the bike moves, the load moves. Some pannier systems mount the load low to the ground so when the bike leans the load doesn't move as much as if it had been higher on the bike. Mono wheel are almost as rigidly attached to the bike, significantly if the bike leans the load moves from side to side in a similar manner to low slung panniers. Two wheel trailers in contrast do not lean as the bike leans, they, and the load on them essentially stay still. It is this difference between panniers/monowheel trailers and two wheel trailers that is what we are focusing on.

ENERGY SAVING OF A TRAILER

Panniers move with their bike

Imagine a bike leaning slightly from vertical to the left or right. Panniers or monowheel trailers and their load also move as the bike leans. Moving this weight costs energy. The faster the bike leans the more energy is used, and the further the weight is moved from its original position the more energy is used. Panniers are further away from the ground than a monowheel trailer hence pannier loads mover more than mono wheel trailers loads for the same angle/speed of lean, and hence they use more energy.

Moving loads cost energy

Using energy to move the load when a bike leans is a waste. Worse than this the energy needs come from you, and pass through your bike frame to get to the load. This means so you need a stronger/heavier bike to cope with the extra energy flowing. Think of the lazy frame angles, extra strong frames, and extra spokes on touring bikes. Wouldn't it be great if you could lean your bike without moving the load it was carrying?

Two wheel trailers

Consider the same load on a two wheel trailer; if the bike leans, the trailer and hence its load does not move. If the load does not move, no energy is used. If no energy is used then the bike does not need to be stronger to cope with the extra twisting forces, and you are not wasting energy moving a load from side to side.

But how much does a bike lean?

But how much and how often does a bike lean during a given ride? Quiet a lot actually. Watch someone as they cycle; every time they turn their pedals they and their bike wiggles, slightly to the left then slightly to the right. That's a slight wiggle every turn of the pedals, 60 times a minute, 3600 times and hour. This is especially noticeable when the cyclist is pedalling out of the saddle, when accelerating or climbing a hill. Perfect cyclists do not wiggle, but the other 99% of us do. Cyclists are also continually correcting the balance of their bike, by leaning slightly left or slightly right. And finally as cyclists turn corners, again the bike will lean left or right.

ENERGY COST OF A TRAILER
So because the load does not move while the bike leans, energy is saved. However using a trailer also costs energy. There is the extra weight of a trailer that's got to be lifted up hills, the wind resistance of the trailer, and the drag from the trailers tyres/wheels. Does the benefit outweigh the cost?

Trailer weight
A trailer might weigh 5kg, but the bike towing it can be a few kg lighter than a touring bike, and it needs no panniers/racks, so the extra weight of the trailer needs compared against the savings made by using a lighter bike. We could assume that the bike can be 3kg lighter so the net weight gain could be as low as 2kg. Also the extra weight is not being wiggled, so uses less energy than the same weight were it on the bike or you. Also this extra weight is only there when a load is being carried. When you carry no load the bike weighs an extra 27 grams (our hitch weight) this cannot be said of panniers.

Aerodynamic drag
About 90% of your cycling energy is used in dragging you and the bike through the air. However a trailer sits very close behind your bike in a bubble of "turbulent" air that the bike pulls along anyway. The trailer is similar to a racing cyclist who tucks in behind the leader to save energy.

A rough drag coefficient can be guessed at if you know an objects frontal area. Most of a trailers frontal area is in the shadow of the rider, and will certainly not add more frontal area to a bike than panniers

Cycling with loose clothing would probably cost more energy than cycling with a trailer.

Tyre Drag
A bicycles tyre drag accounts for only a few percent of a cyclists energy. We use high quality touring tyres, and cartridge bearings to minimise this almost insignificant drag.

IN CONCLUSION
On balance we consider the energy savings of rotationally isolated loads offset the energy cost of tyre's and wind, so over the course of a ride two wheel trailers use less energy for a given load than panniers or monowheel trailers.

Costing less energy allows a cyclist to carry more or go further for a given input. More than this the bike needs no special adaptation or qualities to tow a trailer, and it feels "normal" when being cycled.

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Other things to note
Different riders wiggle the bike from side to side by different amounts so waste different amounts of energy. Also the same rider will wiggle different bikes by different amounts, depending on their cycling style, bike fit, and bike type/weight.

Only about 30% of a trailers vertical static load is supported by the bikes rear wheel, (the rest is supported by the trailer). However the vertical forces are largely supported by only the rear wheel, on its stronger side.

100% of the horizontal forces generated by a trailer/load accelerating pass through a bike. The horizontal forces are created by accelerating, braking and poor pedalling. In this consideration poor pedalling is where during every pedal stroke the cyclist accelerates forwards slightly and then slow down slightly, ie their not pedalling smoothly. This is noticed as the trailer tugging at the bike, and it tends to reform the cyclist into smoother pedalling.

For lean isolation the optimum position for a trailer to hitch to a bike is where the rear tyre touches the ground. The closest practical alternative to this is the bikes rear wheels axle stub.

When a bike turns the trailer is at an angle to it. If it brakes while turning the trailer will try to push the bike upright. The further the trailers hitch point is from where the bike tyre touches the ground the greater the force generated is. Hence two wheel trailers that attach to the seat post are rotationally decoupled, but can make the bike “feel funny” through corners because when slowing and turning at the same time the trailer is trying to push the bike upright.