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Vleugel, Jaap; Bal, Frans

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A BUSINESS-LEISURE TRAVELLER GOES TO VALENCIA: FUEL, CO$_2$, TIME AND COST

JAAP M. VLEUGEL[1] & FRANS BAL[2]
[1]Delft University of Technology, Faculty of Civil Engineering and Geosciences,
Department of Transport and Planning, The Netherlands
[2]Utrecht University of Applied Sciences, Institute for Applied Safety and Security Studies,
The Netherlands

ABSTRACT

Tourism is a fast-growing key industry, which provides an economic rationale for governments to stimulate it. The more it grows, the higher the negative environmental effects and the more the use of space, resources, pollution and travel. Sustainable tourism aims to strike a balance between the environmental, economic and social effects of tourism. The aim of this article is to find the optimal itinerary for an individual traveller to a congress hotel in Valencia. The main research question is as follows: Which itinerary has the best overall score in terms of CO$_2$ per passenger kilometre, travel time and direct cost? Three scenarios were compared: Airplane plus, train plus and car only. The choice of these three suits the travel purpose and length. Literature was used to find the necessary trip and vehicle data. This was fed into a microsimulation model. The main outcome of the simulation experiment is that the environment would benefit if the traveller would favour the train plus scenario. This, however, has a time penalty compared to the airplane plus scenario. A trip by car is the least preferable, because of CO$_2$ emissions, travel safety and time. Direct costs of all three scenarios are comparable. Rail has the lowest emissions per passenger in the scenarios, hence it is important that network improvement programs continue and ticket prices stay in line with the price of travelling by car or airplane. An individual traveller was chosen for different reasons. One reason is that after understanding individual touristic travel decisions and their impact, it is a small step to estimate what is feasible if many more individuals would become ecofriendly touristic travellers. A second reason is that it allows an advice for governments and businesses to target individual tourists. Finally, there is the communicative impact of simplification on individual tourists.
Keywords: CO$_2$ emissions, fuel consumption, simulation, sustainability, Tourism.

1 INTRODUCTION

Tourism is a major and fast-growing economic activity. It accounted for 10% of the world's GDP, 7% of global trade and one in ten jobs by 2017 [1]. Growth in tourism can be explained (qualitatively) by many related factors (see e.g. [2]):

— Growing disposable income per household;
— Greater awareness of how and where to spend ones' free time through traditional (advertising) and modern means of communication (social media);
— Travelling has become habitual; more leisure time is used for more and more frequent tourist trips;
— Growing car ownership;
— Development of infrastructure and communication networks;
— Wider choice of destinations over time;
— The rise of low-cost airlines, which has pushed the price of flying to the bottom. In Europe, their share in total air traffic grew to 30%; a 50% rise since 2007 [3].

Table 1: Growth in tourism (in million international arrivals) [1,2,4].

	Year				
	1990	2000	2010	2017	2030
Europe	261.5	385.6	476.6	671	–
Asia and the Pacific	55.8	110.1	203.8	324	–
Americas	92.8	128.2	149.8	207	–
Africa	14.8	26.5	49.5	63	–
Middle East	9.6	24.1	60.3	58	–
Global	434.5	675	940	1,323	1.8

The number of passengers arriving at a destination is a common way to measure the size of tourism per time period. In 2017, this number grew to 1,323 billion. As Table 1 indicates, many more are expected. Europe accounted for 50% of global tourism in 2017.

A major downside of tourism is its (irreversible) impact on the environment, both locally and globally. The local impact refers to the negative impact of local facilities on the environment: Infrastructure: roads, (air)ports and the tourist and leisure facilities themselves. This impact includes physical changes and pollution of air, water and soil. The global impact refers to the depletion of the ozone layer and climate change [5]. The explosive growth of tourism is nothing short of a disaster for the environment.

A movement called sustainable tourism is developing to not only increase awareness, but also to change tourist behaviour. It addresses the environmental, economic and sociocultural impact of tourism [6]. Bringing these diverse perspectives or interests together is a challenge.

There is eco-awareness among business, especially among the larger hotel chains [7]. They manage the resource use in their accommodations. This is where environmental and economic arguments come together, because savings on water and energy consumption also reduce operations cost. Their policies may also include the choice of (hotel) location or a bus service to and from airports and stations and a reduction of the parking space needed at the accommodation.

The average accommodation owner still lets (short-term) individual interests prevail over (longer-term) public interest. On their part, most tourists also choose the cheapest travel option and witness the growth of low-cost flying. This is an example of what has been described as The Tragedy of the Commons nearly 60 years ago [8], itself one of the key principles of environmental–economics. It is, in turn, an example of a generic problem with strong moral 'sentiments' as described by probably the greatest man in Western economic science [9].

The aim of this article is to find the optimal itinerary for an individual traveller to the congress hotel in Valencia. The outcome allows to say more about the feasibility of more sustainable tourist travelling.

The analysis starts with the decision about the itinerary by the individual traveller. It is assumed that this decision is based on three key decision factors: travel time, trip cost and CO_2 emissions. The trip experience (nature or urban scenery) is not factored in, because it is difficult to objectively model it. From this choice or itinerary follow environmental impacts, in this case the CO_2 emissions related with motorized transportation.

The article combines an analysis of the causes of unsustainable tourist travel, its key environmental impacts, feasible alternatives from the level of individual traveller and policy-making. This integral approach differs from the partial analysis frequently found in other

publications. An example is [5], which contains an excellent problem analysis. It has an extensive policy part, which focuses solely on the supply side – what can governments do to make tourism more sustainable – but the two most important parameters for the tourist – journey time and cost – are not discussed.

The main research question is as follows: *Which itinerary has the best score in terms of CO_2 per passenger, travel time and generalized cost?*

The answer to this question is found by addressing the following sub-questions:

Q1 – How has tourism developed globally in the past 30 years and what are the main stimulating factors? *Sub-question 1* was addressed above.

Q2 – Is the emission of CO_2 by tourism regarded as a serious problem by governments and industry?

Q3 – What are feasible trip scenarios for the case study?

Q4 – What are the private consequences of such a scenario?

Q5 – Which scenario has the lowest CO_2 emission per traveller?

Q6 – Should policy-makers stimulate such a scenario?

Q7 – If yes, what options do they have at their disposal?

A sustainable touristic travel study deals with ways to make the transport mode(s) used by the traveller(s) more fuel efficient and less polluting [10]. The article is scoped as follows:

— It covers three modes: private car, passenger train and airplane;
— These modes will be compared in terms of fuel consumption, CO_2 emission, all-in trip time and out-of-pocket cost.

The case study is an example of the approach followed in the article. That could also be applied to larger groups of tourists, in other regions and countries.

2 THE SYSTEM AND THE PROBLEM

There are two main ways to reduce fuel consumption and emissions to the air from motorized vehicles [11]. The first is to improve the fuel economy of current (fossil fuel combusting) vehicles and to remove the harmful emissions. Fuel economy improvement depends on the actions of manufacturers, consumers and governmental agents. The three modes of transport considered are different in this respect. In the car market – largely a mass consumer market – manufacturers focus on performance and much less on fuel economy or emissions [12]. This explains why legislation regarding fuel economy and emissions was needed to improve fuel economy and reduce exhaust emissions.

Airplanes and trains are primarily owned by large businesses. The number of buyers and sellers is restricted and vehicles are sold as customized units. Fuel costs were between 20 and 30% of the operating costs of the average airline by 2018 [13], hence of the air fare. The profit margin per seat is around 1% for years, which is a sign of an industry with a "persistently poor profitability" [14]. Hence, professional buyers of airplanes (airlines) have a direct interest in fuel economy. Emissions are again dealt with via legislation. In the past decades, fuel economy of airplanes has been improved drastically, which has reduced CO_2 emissions per km flown. However, the growth in air traffic leads to more airplanes, which altogether consume more kerosene fuel, hence the increasing CO_2 emissions. This is, in particular, true if a traffic grows exponentially. Air transports' fuel consumption in 2035 may be 50% above its 2008 level and its share in transport emissions will rise as a consequence [15].

Railways have been a public service in most countries and there is competition from cars and airplanes, which has its impact on profitability, but many system improvements including new high-speed services are in place or underway to make the system more competitive to car and airplane. Yet, in most countries, it is regarded as a public service, which leads to partial subsidization (of the services and/or the infrastructure).

The potential for fuel economy improvement is restricted in fossil fuelled engines. This explains why a second, more fundamental strategy is called for, namely to replace fossil fuels by renewable fuels and introduce adapted or new vehicle engines, at least for passenger trips that cannot for whatever reason be substituted by slow modes like walking or cycling [10]. Mainline trains are usually electric, which means that "tank-to-wheel" (TTW) emissions are not an agenda issue. However, a higher fuel economy makes also sense for trains, because it means less use of electricity, hence lower emissions by power plants, lower fuel costs and restricted rise in fares.

What all cars, airplanes and trains have in common is that they are used by large numbers of people, at least in Europe.

Tourism has significant economic benefits, which is why it is promoted around the globe. But, more "traditional" tourism means more destruction of the environment, which is also a very relevant issue on the political agenda. Tourism is an integral part of the United Nations policies on poverty, good health and well-being, quality education, decent work and economic growth, sustainable cities and environment, climate action etc. Next to that, sustainable tourism has become a key issue on the agenda of the World Tourism Organisation (UNWTO) [1].

To answer *sub-question 2*, there may be some awareness, but practical steps are scarce, as promotion of tourism majors over environmental concerns. The idea of ecotourism or sustainable tourism is also problematic if travelling towards the destinations carries on as it has done for decades.

Traveling to and from a touristic destination should ideally take place in the least environmentally damaging way. There are several options in this respect, behavioural as well as technical:

— Route choice – Take the shortest available route. For most drivers, this is the option chosen primarily to save on travel time and fuel cost. With trains this strategy becomes more difficult, because of the lower network density and fixed time schedules. With airplanes, a traveller probably has the least influence on the operational decisions during the travel;
— Travel (partially) with a (the) transport mode with the lowest CO_2 emission;
— Compensate trip emissions by buying into a CO_2-emission compensation scheme;
— Use the transport mode with the lowest emissions. Here technology becomes more prominent. With cars, a car owner could buy a car, which is low on fossil fuels or buy an electric car. Trains could (partially) run on green electricity. Airplanes could partially fly on bio-kerosene.

This non-exhaustive list contains interesting options to explore by means of trip scenarios, which is the purpose of section 4.

3 METHODOLOGY

The following research tools were used to write this article: desk research, scenarios, simulation models and (quantitative) evaluation.

The single agent in this article is a business traveller who is going to attend a scientific congress abroad. It is assumed that this traveller prefers a modest travel time. An inner-EU trip should be possible in approximately 24 h including stopovers.

A model can help him or her to compare available travel options. It is assumed that the traveller cares about the environment, but also about the journey time and cost. The quality of the scenery is not a factor in his decision-making. To simplify decision-making, the traveller has access to a simulation model built in MS© Excel©. The model core has already proven its forte in earlier papers. For this application, it was enhanced to estimate the fuel consumption and emissions of trip scenarios with trains and airplanes using different available engine–fuel combinations. The main modules of the model are:

— A module to build trip scenarios. A scenario describes an origin–destination pair (transport link) in km, the mode of transport, engine technology, energy category (diesel, alternative) and fuel specification (fuel-blend), electricity composition (grey, green);
— Tables with fuel consumption and emission factors (EFs). Fuel consumption data and EFs from public sources (academic and professional) were used to estimate emissions. Only TTW emissions were considered;
— An output module to present the results of the simulation.

To simplify modelling and subsequent analysis, the following choices were made. One was a simplified point-to-point routing of the vehicles instead of detailed network maps. The fuel consumption is estimated as the sum of the estimated fuel consumption per length of a network section. EFs are speed dependent and were treated as such to estimate the emissions of CO_2, NO_x and PM_{10} by this simulated trip. It has to be realized though that PM_{10}, because of the larger particle size, is known to be less damaging for human health than $PM_{2.5}$. Emission data for the latter were not available, however.

The time horizon is manually adjustable, which allows a partial upgrading or replacement of the vehicle fleet and fuel infrastructure in line with regular technical or investment policies for such facilities.

4 A CASE STUDY

There are various ways to travel between the TU Delft and the congress hotel in Valencia. Three alternative trip scenarios were simulated in the model. It is assumed that the return trip is exactly the reverse of the trip to the congress.

Some simplifications and assumptions were needed. Fuel consumption and emission data are the best approximation of actual values. EFs for TTW and fuel data from open sources were used. Value of time is not considered explicitly, but a travel time window adds realism to the scenarios. This section will answer *sub-question 3*.

4.1 Itinerary 1: Airplane plus

The traveller walks from the TU Delft to the station and from there takes a train to Amsterdam International Airport Schiphol (AMS). There (s)he embarks on an airplane. It was assumed that this choice defines a very time-conscious person, who definitely ignores a local bus service. Taxi kilometres [16] would also be reimbursed.

At first glance, we have a rather optimistic time schedule that ignores many time-consuming activities that go along with this trip:

— Security checks at the departure airports (within Schengen area around 2 h);
— Security check at the airport of arrival (within Schengen around 1 h);

Table 2: Airplane scenario one-way door-to-door Delft-Valencia.

Mode	Itinerary	Distance (km)	Travel time (h)	CO_2 (g)
Walking[a]	TU Delft to Delft railway station	2	0:16	0
Train[b]	Delft to Amsterdam Airport Schiphol (AMS)	47	0:40	0
Airplane[c]	AMS to Valencia Aeroporte (VLC)	1,480	2:14	100,577
Taxi[d]	VLC to conference hotel	21	0:20	1,829
Total		1,550	3:30 + 3:00	102,406

Notes: [a]Local taxi drivers do not accept very short trips, while waiting may take more time than the rather straightforward walk;
[b]Dutch rail passenger operator NS buys green electricity;
[c]Based on a medium size, narrow body with 162 seats. The outcome approximates [17] which calculates 0.11 ton of CO_2;
[d]0.69 l as consumed by a VW Superb diesel taxi.

— (Seasonal) delays at both airports, lost luggage and other regular inconveniences of air travel;
— Possible traffic jams and inner-city traffic problems.

In real life, at least another 3 h of travel time must be added. Since the value of time is out of scope, this time penalty will not be considered in the analysis. Table 2 presents the simulated trip and its estimated CO_2 emission.

4.2 Itinerary 2: Train plus

Governments and environmentalists regard a trip per train as the preferred alternative for long-distance trips [18]. There are several itineraries to choose from. The most direct one was chosen. It was assumed that our traveller takes a bus from the station to his hotel in Valencia, which suits an average train user. The whole trip takes approximately 24 h [19]. Many assumptions had to be made to estimate the emissions (Table 3). First, to keep the overall travel time at 24:00 hours, our traveller will use high-speed trains where possible. Second, moving at higher speeds takes more energy than at lower speeds mainly due to aerodynamic resistance; hence one would assume a higher CO_2 emission than for a normal-speed train. But, in practice, it is the CO_2 emission per passenger that matters. Normal-speed trains tend to have a lower average occupancy rate and accelerate and stop more often. They also lack the aerodynamically optimized design and light-weight–high-strength body materials of high-speed trains. These technical and operational differences explain why a high-speed train with a high occupancy rates has a lower CO_2 emission per passenger than its conventional relative [20]. Third, the actual occupancy rate is needed to exactly estimate the emission per passenger. This rate cannot be found in advance due to the many uncertainties regarding (actual use of) reservations and the intermediate stops where travellers may (un)board a train. A second best solution was to use the averages from French rail operator SNCF's website. This is a convincing approximation, because most of the trip is made with high-speed trains like the Thalys, who are largely similar.

Table 3: Train scenario one way door-to-door Delft-Valencia.

Mode	Itinerary	Distance per section (km)	Average CO_2 emission per traveller (g/train km) [20]	E-grid emission factor (g/kWh)	CO_2 (g)
Walking	TU Delft to Delft railway station	2	–	–	0
Intercity	Delft–Rotterdam CS	16	IC:12	0	0
High speed	Rotterdam CS–Belgian border[a]	65	Thalys: 11.6[c]	0	0
High speed	In Belgium	127	Thalys: 11.6[c]	153	1,473
High Speed + semi-metro[b]	In France	1,009	TGV: 3.2[c] Semi-metro: 3.1	50–53	8,522
High speed + intercity	French/Spanish border to Barcelona S + Barcelona S to Valencia EdN[e]	448	AVE: 12[c] IC: 12[c]	238 [17]	5,376
City bus diesel[d]	Valencia EdN-conference hotel	21	2,650 g/l	–	663
Total	~ 24:00	1,672	–	–	16,034

Notes: [a]Dutch rail passenger operator NS uses green energy;
[b]Transfer by (RATP) between the Gare du Nord and Gare de Lyon in Paris;
[c]Data from SNCF. Data for Spain (RENFE) could not be found. France uses nuclear energy to power the rail network, while Spain uses mainly renewable sources. The actual EF and emissions will therefore be higher;
[d]About 0.25 l/passenger on this trip;
[e]Estacio del Nord.

    Fourth, another key input in the emission calculations is the power mix (input sources) of the electricity grid. For private cars data, the mix of the public electricity grid was used to estimate emissions. For public transport, this may not be relevant, because its operator may use its own grid or have a special private contract with its electricity provider. In addition, many countries switched to green energy already years ago. The use of published EFs of the countries crossed during the trip and, if available, gives an impression of the actual variations between EU countries.

4.3 Itinerary 3: Car only

Taking efficiency of routing, hence overall trip duration, as main restriction on route choice leads to a rather straightforward route from Delft to Antwerp-Brussels-north of France into Paris. Travel from Paris to the south of France can be done via two most efficient itineraries:

  — Paris, Route du Soleil, then Barcelona (Spain) to Valencia;

Table 4: Estimated emissions of the car only scenario.

	Itinerary (km) + time		E5 / E95 petrol	Diesel
Delft (NL) via Paris (F) to Valencia (S)	1,859	CO_2 (g)	236,381	231,704
Total	17:00 + (A, B)			

— the 60 km longer and probably slightly faster, due to the avoidance of traffic near/at Paris, route via Reims (France), then the Route du Soleil, Barcelona etc.

The first alternative itinerary is chosen, because it follows a trajectory in the same geographical space as the train, which allows a direct comparison of both. An online trip planner [21] estimates a travel time by car of about 17 h. There is of course a major caveat, because a single person cannot drive safely for 17 h without any rest, in particular when driving abroad in high-density mixed traffic on unfamiliar and varying road conditions. The general advice to take at least a 15-min break after each 2 h of driving (A) and even stop driving after 10 h (B) [22] would lead to at least one night in a hotel. If A is taken on-board and B ignored, then at least 4 h should be added to the travel time. This then would approach the one from the rail scenario.

Still, it is questionable whether the traveller will be fit enough to participate actively in the congress after such a trip, but one could for the moment assume a well-trained person, which is actually beyond the capabilities, likings or age of the average academic congress participant. However, with the rapid development of autonomous vehicles at the horizon, this alternative will likely become feasible for at least part of the trip in the next decade.

Two factors determine the fuel consumption and level of emissions, viz.

a. The power train of the mode of transport used;
b. The energy source used.

A variety of cars can be used in practice. Clearly, the specific technical specifications of the vehicle actually used largely determine the performance and thus the environmental footprint of the car. The assumption is made that a medium-size, regular model car will be used. The vehicle occupancy rate is important for the estimation of fuel consumption and emissions per passenger. With more people in one car, this becomes less negative, of course. It is assumed that this is a single-person trip. Hence, the emissions per person are equal to the CO_2 emissions per car kilometre. Table 4 shows the estimated CO_2 emissions, which vary according to fuel type.

4.4 Comparison

In order to answer sub-questions 4 and 5, the outcomes of the three scenarios should be compared. This leads to Table 5.

The airplane has the shortest route and shortest net travel time. It scores second in terms of CO_2 emissions. The train has by far the lowest emissions, but the travel time is much longer than by airplane and comparable or better than the time by car. The direct travel costs of each

Table 5: Comparison of the three tourist scenarios.

Delft–Valencia	Itinerary (km)	Travel time	CO_2 (g)	All-in costs (Euros) one way[a]
Airplane	1,550	3:30 + PM	102,406	250
Train	1,672	24:00	16,034	250
Car	1,859	17:00 + PM	236,381 (P)	300 (P)
			231,704 (D)	265 (D)

Note: [a]Valid at the time of writing.

scenario are similar, but this depends also on promotions and discounts. Travel costs are of secondary interest, because the employer reimburses them.

This means that if the traveller cares about the environment and does not mind the longer trip time, which also has not considered benefits (scenery, social, work time and rest), then the train scenario may have an edge over the two other alternatives.

4.5 Policy-making

If governments are serious about sustainable tourism, then the CO_2 emissions of mass touristic travelling can no longer be ignored, in particular because they are growing exponentially worldwide. To reduce the CO_2 emissions related with fuel consumption, trains have a definite edge over airplanes and private cars. Improvement of the European railway network is on the agenda of EU policy-makers for decades. Networks are being upgraded (Trans European Network (TEN) and more liberalization and harmonization has brought more competition and new and improved services. These will ultimately lead to better connected countries and shorter, more competitive travel times. The impact is not universal though [23].

If railways are to be promoted, then it is important to do this in a careful way and not waste money on solutions that improve travel time, but are actually not cost-effective due to excessive investment cost [24] or external cost. Construction of railway lines through nature areas is something that has to be prevented, not only because it destroys nature values, thereby also reducing touristic potential, but also because it reduces carbon sinks, hence contributing to climate change.

Still, governments cannot ignore the economic importance of air transport. The car industry is also a major force to be reckoned with, however. Stricter emission standards offer a partial, technical solution to the complex problem of reducing the climate impact of tourist travelling.

5 CONCLUSIONS

Tourism is growing exponentially worldwide. This is caused by many economic, social and other factors.

The emission of CO_2 by tourist (travellers) is on the agenda of policy-makers worldwide; however the urgency of the problem is not yet reflected in policy measures, most likely because policy-makers give priority to economic interests over ecological concerns. The leisure industry is aware of the problem, but its policies are usually confined to their local operations and to a limited extend with what happens beyond that.

Sustainable touristic travelling is a complex, multilayer issue. The choice of itinerary offers a way to drastically reduce these emissions. In the case study presented in this article, an

environment-aware traveller will choose his or her optimal itinerary based on journey time, cost and CO_2 emissions. The ideal itinerary would have the shortest time, lowest cost and lowest CO_2 emissions. This optimum is not available. In case of a switch from airplane to train, the main consequence is a much longer journey time. If travellers would switch from car to train, then the travel time difference is comparable. Whether journey time really matters depends on the individual preferences and the way the journey can be used (alternatively) for leisure or work. Not discussed additional benefits from travel by train are the view outside, time to work or rest and also social contacts.

The train plus scenario has the lowest CO_2 emission per traveller kilometre. The major reduction in emissions of a switch to rail indicates that policy-makers should do more than creating a level playing field between car, airplane and train services. Cost-effective investments in railway networks are already underway in many places in Europe.

For the airplane, there is the option to compensate the CO_2 emission by paying a bit more for a ticket. This has not been considered in any of the three cases. It would shift the balance in favour of the airplane plus scenario. Not polluting seems better for the environment than first polluting and then compensating the impact later, however. If the goal is to reduce CO_2 emissions overall, then compensation is really insufficient. The compensation scheme should also be transparent.

In the car-only scenario also more details could be added, for instance whether the traveller has a car or could rent it or if he or she likes driving long distances. The case of alternative fuels, in particular electricity, has not been considered, because of the lack of an integrated battery charging network throughout Europe.

Another addition to all scenarios could be: Who pays for the journey? If it is not the traveller because his or her administration accepts any reasonable bill, then the travel costs are not relevant for the choice of transport mode or itinerary any more.

These peculiarities make a case study more realistic and influence individual decision-making. But, they also influence the complexity of modelling the scenarios and the simulated outcomes.

The individual choice process can be extended to the level of society. The classical dilemma between individual and social costs and benefits becomes visible. A traveller who favours the fastest journey pollutes more, hence creating higher social costs. Governments in Europe have a difficult task when it comes to influencing individual journey decisions. How to reduce the climate impact of tourist travel without causing damage to CO_2-emitting industries? The polluter pays principle looks efficient on paper, but practice is much more complex. By improving railway networks, journey time by train can be reduced, which makes (high-speed) rail a more attractive alternative. At the same time, governments cannot ignore the economic benefits of air transport. Airports are important economic hubs. Finally, the car industry is also a major force to be reckoned with. Stricter fuel efficiency and emission standards offer a partial, technical solution to the complex problem of reducing the climate impact of tourist travelling.

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