‘Turn right at the Traffic Lights’: The Requirement for Landmarks in Vehicle Navigation Systems

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This paper argues for the use of landmarks (for example, traffic lights, churches, petrol stations) within the turn-by-turn visual and voice directions given by in-vehicle navigation systems. Such prominent features of the driving environment are consistent with basic human navigational strategies, are valued by drivers, and have been shown significantly to improve the usability of electronic in-car navigational aids. For future systems actively to include such information, it is critical that (a) only ‘good’ landmarks are used, (b) such landmarks are presented to the driver in the most appropriate way, and (c) the practical needs of industry are fully accounted for.

KEY WORDS

1. Vehicle Navigation. 2. Human Factors. 3. Design.

1. INTRODUCTION. Navigating in unfamiliar road environments is perhaps the most common and demanding cognitive activity that drivers undertake. There is a wealth of literature that indicates that many people experience difficulties in both planning and following efficient routes to their destinations (King, 1986; Wierwille *et al*., 1989). The resulting navigational uncertainty manifests itself in a number of ways, either for the individual driver (stress and frustration), their relationship with other road users (misleading use of indicators, sudden braking), or for the traffic system as a whole (poor route choices).

Route guidance and navigation systems for vehicles ‘provide information on community and/or individual user optimum route options for specified destinations’ (ISO TC204/WG1, 1996). For the majority of current systems, positioning information is received via GPS, an on-board compass, and wheel sensors, and this data is matched with a CD-ROM navigable map database holding information on roads, road features, priorities, etc. With respect to the driver-system interface, many of the systems that are presently available can be classified as being ‘turn-by-turn’. The driver is given instructions (using symbols and/or text and often voice messages) relating to the location and direction of each manoeuvre. Current voice messages tend to emphasise distance-to-turn information, using either absolute values (for example, ‘left turn in 300 metres’), or non-absolute, time-based terms (‘left turn soon’). Visual displays also tend to stress distance-to-turn information, and may use simple arrow symbols, or a junction-specific representation (see Figure 1).

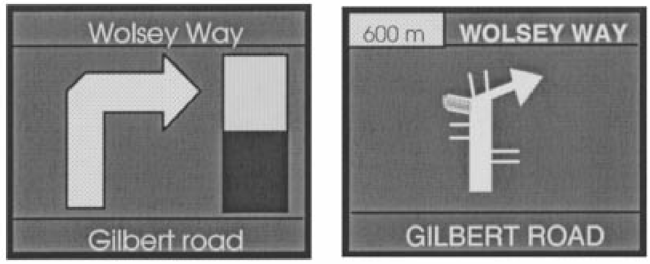

Figure 1. Examples of visual displays for current turn-by-turn vehicle navigation systems.

It has been claimed that the widespread implementation of vehicle navigation systems will:

(a) Encourage more efficient use of the existing road network, which in turn will lead to reduced environmental impact and significant resource savings (OECD, 1988).
(b) Reduce the demands that drivers experience with current methods, thus
  (i) alleviating the frustrations and anxieties of way-finding (Barrow, 1991),
  (ii) increasing safety in contrast with present 'un-safe' strategies and behaviour (Fastenmeier, Haller and Lerner, 1994),
  (iii) increasing driver confidence, and ultimately the mobility of those who are wary of travel within unfamiliar environments (such as, older and disabled people) (Burns, 1997).

It is now possible for drivers in many countries to purchase first-generation vehicle navigation systems. It has been predicted that such systems will be commonplace in vehicles throughout the developed nations in the near future (Zhao, 1997). Their popularity can already be seen in Japan, where it has been estimated that in excess of 3·5 million vehicles currently have route guidance systems installed (Rowell, 1999).

2. THE USABILITY OF CURRENT SYSTEMS.

The human factors approach places the needs, abilities, preferences, etc. of the intended users at the centre of the design process for a system. The usability of a system refers to the 'quality of interaction between a user and other parts of the system overall' (ISO 9241 – part 11, 1997, p2), and has been rated as one of the most important aspects of design for a vehicle navigation system (Barrow, 1991; French, 1997). Potentially, the use of such sophisticated systems while driving could adversely affect the ability of drivers to control their vehicles safely and respond to potential hazards. Lack of attention and distraction are already major contributory factors in many road accidents (Wierwille, 1995). Therefore, any system that might add to this problem must be carefully designed. In this respect, it is critical that vehicle navigation systems provide appropriate information when and where needed in a form that is easily understood by the driver.

Previous research has shown the benefits that well-designed turn-by-turn systems can have over the use of paper maps. In particular, there is empirical evidence that the use of turn-by-turn systems compared to maps leads to less navigational errors and shorter journey times, reduced mental demands and increased confidence in navigating (Streeter, Vitello and Wonsiewicz, 1985; Walker, Alicandri, Sedney and Roberts, 1991). There are two main reasons why turn-by-turn systems offer such advantages over what is arguably the *worst case* scenario. First, only information that is relevant to the oncoming manoeuvre is presented; for instance, the system filters information, rather than the driver (Ross *et al*., 1995). Second, the use of turn-by-turn information that is largely verbal in nature conflicts less with the predominately visual-spatial task of driving (Wetherell, 1979).

In contrast with the research comparing turn-by-turn navigation systems with paper maps, there has been other research that has examined driver behaviour and performance when using turn-by-turn systems versus that attained from using instructions given by the passenger (Fastenmeier *et al*., 1994; Burnett and Joyner, 1997; Zaidel and Noy, 1997). It is argued by these authors that the passenger with detailed route knowledge who provides clear, timely instructions reflects the *ideal* situation. In these studies, when using a turn-by-turn navigation system versus instructions given by the passenger, drivers have been found to:

(a) make more navigational errors (Fastenmeier *et al*., 1994; Burnett and Joyner, 1997; Zaidel and Noy, 1997),
(b) take longer to complete a route (Fastenmeier *et al*., 1994; Burnett and Joyner, 1997;)
(c) spend less time looking towards the road ahead and mirrors (Burnett and Joyner, 1997),
(d) rate their mental workload to be higher (Burnett and Joyner, 1997),
(e) be rated by an expert to have lower *quality of driving* – e.g. speed and headway maintenance, lane position, dynamic time management (Zaidel and Noy, 1997)

Clearly, the performance of drivers using current turn-by-turn vehicle navigation systems does not attain the same level as that achieved when using the ideal navigator. Indeed, there is now some evidence from Japan that accidents are arising from the use of the vehicle navigation systems presently on offer. In a press release, the Japanese Ministry of Transport declared that, in the first six months of 1998, ninety-three people were injured and one person was killed in accidents linked to the use of in-car navigation systems on the move (Ito, 1998). If next-generation systems are to approach the 'ideal' standard, then it is imperative that more intelligent and naturalistic interfaces are developed.

3. WHY SHOULD SYSTEMS PRESENT LANDMARKS?

Current vehicle navigation systems present few landmarks (traffic lights, churches, telephone boxes, bridges, petrol stations, etc.) within their turn-by-turn (visual and voice) directions. However, as will be seen in the following sections (3.1 to 3.3), there is considerable evidence that such prominent features of the environment are essential for optimal human navigation. Three basic arguments can be made as to why landmarks should be an integral part of future vehicle navigation systems.

3.1. *Landmarks are consistent with basic human navigational strategies*. Studies conducted within the environmental psychology and human geography disciplines have indicated that landmarks are core components of peoples' mental representations of large-scale space (commonly termed 'cognitive maps'), and play an important part in the environmental learning process (Evans *et al*., 1984). As a result, they are among the most well-known features of the environment and can act as powerful cues for navigation. Thus, it is not surprising to find that they are widely used in traditional way-finding strategies; for example, as part of directions that people provide for others (Alm, 1990). Indeed, all of the 'ideal' passenger instructions used in the studies described in section 2 were reported to include a number of landmarks.

The fundamental need of people to use prominent landmarks for navigation is best illustrated by reference to environments where landmarks are not apparent. Mazes and labyrinths are inherently difficult to navigate within, and it is their essential lack of distinctive features that causes people to become disoriented and confused (Arthur and Passini, 1992). People need to be able to differentiate between the scenes present at intersections if they are to gain a cognitive understanding of an environment (Sorrows and Hirtle, 1999). For drivers, such understanding may enable individual 6turning decisions to be made, indicate that the correct route is being followed, and/or enable a sense of location in relation to the surroundings (Golledge, 1999).

3.2. *Landmarks are valued by drivers.* Not only does it appear that landmarks are central to the navigational directions we provide for others, but they are also a significant feature of directions that we request or value *from* others. A survey of 1158 UK drivers has shown the importance that people attach to landmark information. Participants were asked what information they would want from the passenger to help them navigate, and rated landmarks as their second most popular information type (after left-right directions) (Burns, 1997), see Figure 2. There have

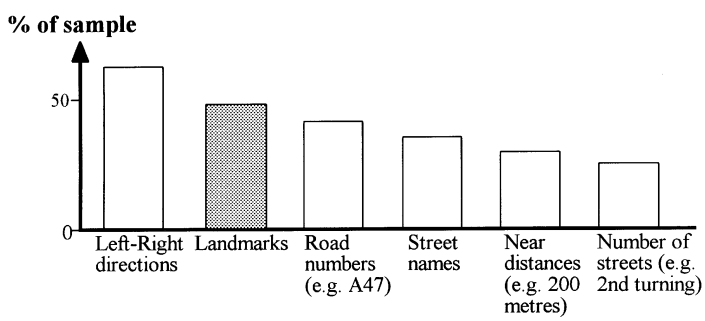

Figure 2. Percentage of sample who requested particular information from the passenger to help them locate turnings (After Burns, 1997).

been several other studies that confirm such findings (Streeter and Vitello, 1986; Burnett, 1998).

The perception of landmark value arises because of their role in direction-giving (as discussed above), but also largely due to their individuality. There are both objective and subjective aspects relating to what constitutes a landmark for a person. In addition to their purely sensory visual characteristics, the majority of landmarks have functions, and thus are associated with particular goals for an individual (restaurants, public houses, parks) (Kaplan, 1976). Furthermore, many landmarks have a symbolic, cultural and/or historical role within a community (monuments, town halls) (Sorrows and Hirtle, 1999).

3.3. *Landmarks can improve the usability of vehicle navigation systems.* The most direct evidence for the benefits to be gained from landmarks within vehicle navigation

Table 1. Relative frequency of indicator errors – with and without landmarks (after Bengler *et al.*, 1994).

Use of indicators	With landmarks	Without landmarks
Too early	0·029	0·080
Too late	0·020	0·100
Incorrect direction	0·005	0·020
Total	0·054	0·200

systems comes from the human factors literature. There have been several studies that have investigated the usability of systems including landmarks compared with those that do not. Usability can be defined as a function of effectiveness, efficiency and satisfaction (ISO 9241 – part 11, 1997). At this point, it is useful to employ these criteria to show how key research studies within the literature have found the usability of 'landmark' systems to be superior to 'non-landmark' systems for all three aspects of system usability.

3.3.1. *Effectiveness*. Effectiveness concerns the achievement or otherwise of the goals of the user. Commonly, a driver's navigational goals will be to reach a destination whilst taking no wrong turnings. Bengler, Haller and Zimmer (1994) conducted a simulator-based experiment that demonstrated how landmarks can improve the effectiveness of a vehicle navigation system. Twenty-four participants viewed a series of video-taped routes whilst carrying out a simple tracking task. Half of the participants were provided with visual-only navigation information – a simplified representation of the junction with no other information. The remaining participants were also provided with landmark information at junctions. Participants were instructed to use the guidance information to make navigational decisions, and to register their judgements by turning the steering wheel and employing the indicators. These parameters were therefore being used to indicate navigational, rather than driving, performance. Navigation information that included landmarks was found to reduce significantly the number of incorrect uses of the indicators (see Table 1). There was also a trend for reduced steering errors with landmark information (approximately 30 % fewer errors), but this difference was not significant.

3.3.2. *Efficiency*. Efficiency largely concerns the resources that are expended by a user to achieve their goals. For the use of a vehicle navigation system, such resources may be time-related (number/length of glances made to in-vehicle display, journey time), cognitive (mental workload) or relate to primary driving task performance (steering wheel variability, use of brakes and indicators, lane changing, traffic violations). Clearly, this category includes those measures that have the strongest links with system safety.

In some recent road-based work, the efficiency-related benefits of using landmarks for navigation were shown (Burnett, 1998). Twenty participants drove unfamiliar routes within an urban area using either a vehicle navigation system (turn-by-turn directions on both a display and voice) that emphasised landmarks or one that stressed distances for the purposes of locating manoeuvres (see Table 2). When using the landmark system, relatively few glances were made towards the display (on average 1·6 on the approach to a turning), and workload was perceived to be lower (mean 26·8 on a 1–100 scale, where 1 = low and 100 = high), in comparison with the

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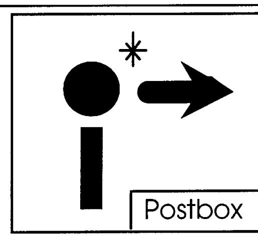
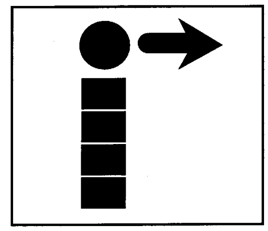
Table 2. Evaluated interfaces in road trials (Burnett, 1998).

	Landmark emphasised interface	Distance-to-turn emphasised interface
Typical visual display		
Typical auditory display	"Turn right at the Post-box"	"Turn right in 200 metres"

figures attained for a distance-to-turn oriented interface (mean number of glances: 5·0; mean workload 40·6). Furthermore, in contrast with previous assessments of vehicle navigation system interfaces (Wierwille *et al.*, 1989; Burnett and Joyner, 1997), the duration of glances towards the landmark display were low (mean 0·66 secs).

3.3.3. *Satisfaction.* Satisfaction is an important element of usability, and techniques such as questionnaires and interviews have been commonly used in the literature to measure it. It is this component of system usability for which there is greatest evidence for the benefits of landmarks, and two significant studies are reported here.

Alm, Nilsson, Järmark, Savelid and Hennings (1992) conducted a road trial in which twenty drivers used a simulated vehicle navigation system that provided simultaneous visual and aural directions. In the control group, ten participants were presented with only very simple left/right/straight on information, whereas in the experimental group, the remaining drivers received the same information plus information regarding landmarks along the route. Participants in the landmark condition felt significantly more confident as to where to turn, and generally more satisfied with the content of visual information (non-significant trend).

Green, Hoekstra, Williams, Wen and George (1993) conducted a simulator-based study in which 48 drivers followed routes using four different types of navigation system interface: visual navigation information only, visual with landmarks, auditory navigation information only, auditory with landmarks. Participants were instructed to press one of three buttons when they could see the junction referred to by the system (left/ right/straight on). In this study, drivers strongly preferred the interfaces that contained landmarks over those without. Indeed, observation of Table 3 reveals that the inclusion/exclusion of landmarks factor had a greater influence on driver preference than did the factor of interface modality.

4. HOW CAN SYSTEMS INCLUDE LANDMARKS?

It is apparent from the theoretical and empirical research described above that there are considerable benefits to be gained from the use of landmarks by vehicle navigation systems. Despite this potential, there are a number of fundamental research and practical challenges that must be met to ensure these strong visual cues become an integral part of future systems.

Table 3. Drivers' preferences for different vehicle navigation system interfaces. (After Green *et al.*, 1993).

Vehicle Navigation System Interface style	Drivers' preferences Mean Rank (1 = Best; 4 = Worst)
Voice *with* landmarks	1·8
Visual *with* landmarks	2·0
Voice *without* landmarks	2·9
Visual *without* landmarks	3·3

4.1. *Predicting good landmarks.* The quality of landmarks for navigationrposes can vary considerably throughout the environment. This issue is critical in the driving context, since the use of 'poor' landmarks (for instance, those which are difficult to find or uniquely identify) may lead to driver confusion, increase workload, and reduce driving safety. In the human factors literature, there have been some attempts to generate lists or examples of 'good' landmarks. Studies have been conducted where lists of those landmarks most commonly reported by drivers have been drawn up (Alm, 1990; Akamatsu *et al.*, 1997), or a limited number of landmarks have been evaluated within a prototype navigation system (Alm *et al.*, 1992; Bengler *et al.*, 1994; Green, Levison, Paelke and Serafin, 1995). The central problem with such work has been that they lead to results that are wholly environment, country and study specific.

In addressing this concern, it would be important to establish the specific characteristics or attributes of a landmark that will influence the ease with which it can be processed and remembered. Alm (1990), Akamatsu *et al.* (1997) and Green *et al.* (1995) have all commented on this issue. Alm suggests that people consider some landmarks to be more useful than others for navigation purposes primarily because of their commonality across urban areas. Furthermore, he states that popular landmarks tend to be visible in most conditions, and are easy to differentiate and learn. In agreement to a certain extent, Akamatsu *et al.* (1997) feel that the landmarks commonly referred to by subjects in their study were visible from a distance, unique in appearance, and were close to, or part of, the road infrastructure. Green *et al.* (1995) have also stressed similar characteristics of 'good' landmarks. They believe the best landmarks are those that can be seen at a great distance (at all times), are close to the road, near intersections, and are relatively permanent.

It is apparent that the 'common sense' observations made by all of these authors are rather casual. No human factors research to date has addressed exactly which characteristics or attributes of an object within the physical environment result in it being used, or considered useful, as a landmark for navigational purposes. Work conducted outside the human factors discipline has little to offer on this issue. Geographers and urban planners have aimed to identify the attributes of landmarks that make them distinctive or memorable (Appleyard, 1969; Hirtle and Sorrow, 1999), whereas psychologists have focused on the role of landmarks within peoples' cognitive maps (Sadalla, Burroughs and Staplin, 1980; Tversky, 1993). What is needed is a structured and generic approach to choosing appropriate navigational landmarks, which can ultimately be used in any environment (for instance, across different countries or regions).

4.2. *Understanding context*. To produce an informed choice of landmarks for navigation, there is a need to understand the relevant contextual factors. A number of individual (person-related) and environmental factors that may be of significance can be hypothesised.

4.2.1. *Individual differences*. An individual factor of potential relevance to the use of landmarks for wayfinding is perceptual style, commonly referred to as field dependence/independence. Field-independent people are better at distinguishing relevant cues from irrelevant cues in their environment than those who are field-dependent. Several studies have produced evidence that field-dependent drivers are more likely to have accidents than field-independent drivers (Harano, 1970). Goodenough (1976) believes the reasons for this, among others, are that field-dependent drivers do not quickly recognise developing hazards, and are slower in responding to embedded road signs (those surrounded by many other stimuli). It may be hypothesised that these reasons would influence an individual's preference for, and use of, potentially embedded information within the environment, such as landmarks (Gould, 1989).

In addition, certain drivers may prefer particular landmarks based on lifestyle considerations. As discussed in 3.2, there are strong subjective components to what constitutes a 'landmark' for an individual, based largely on its functional characteristics. As a result, when giving navigational directions, many people use landmarks that are appealing to them. A typical example can be seen in the person who provides directions based mainly on particular types of shops.

4.2.2. *Environmental factors*. Undoubtedly, it is critical that drivers are able to see landmarks clearly from a distance. The prevailing weather and time of day are critical environmental factors that influence landmark visibility. All previous research concerning the interface for vehicle navigation systems has been conducted during daytime hours in generally clear conditions. Yet, it is likely that the strategies adopted by people when navigating under degraded visual conditions (travelling at night-time on unlit roads) vary considerably from those used in optimal situations.

4.3. *Identifying appropriate presentation methods*. It will be extremely important for the design of a vehicle navigation system to establish exactly how to present landmark information to the driver. A large number of different landmark types could potentially be presented by a system, and a poor visual and/or aural representation of a landmark will have implications for the effectiveness, efficiency and degree of satisfaction of a system.

A road-based study aimed specifically to establish effective ways of visually presenting landmarks within a vehicle navigation system (Pauzié, Daimon and Bruyas, 1997). Two approaches were examined: a generic presentation (the same visual icon for all churches); or a specific presentation (a representation of a given church). In an urban driving environment, ten participants negotiated a route using a simulated vehicle navigation system in which turn-by-turn directions (visual only) were provided. It was apparent from driver feedback that the *familiarity* of the landmark representation was the most important factor determining whether drivers considered the specific or generic design to be more useful for navigation. For instance, specific presentations that included a well-known logo or name (MacDonalds, Natwest) were preferred to their generic equivalent (a symbolic representation of a burger, coins and notes). By contrast, in situations where the generic design was familiar (a church icon), the more detailed specific representation was generally rated less favourably.

Such results appear to be of particular relevance to the choice of landmarks, although this is not mentioned by the authors. Many landmarks will frequently change their labelling (a BP petrol station becoming Shell), whilst maintaining their basic function. As a consequence, landmarks that lend themselves to a generic presentation may be preferable for use within a vehicle navigation system.

In addition to this work, there have been several studies that have assessed a particular representation of a landmark as part of an overall vehicle navigation system evaluation (Alm *et al*., 1992; Bengler *et al*., 1994). Of these, Green *et al*. (1995) are the only authors to use the results of their evaluations to make some points regarding efficient means of representing landmarks. In their paper outlining some preliminary guidelines for designers, they state that landmarks should be provided both visually (as graphics, rather than text) and aurally. Furthermore, they specify that traffic light and stop sign graphics should be placed in the centre of the intersection representation. Although such a recommendation would appear to constitute good human factors practice, it should be noted that the evaluations were conducted in the state of Michigan, USA which has a predominantly grid-based road layout. It is possible that this particular guideline would be more difficult to achieve in cities which have more complex junction layouts.

Despite the initial progress made, there still remains a need for research that compares alternative iconic and verbal representations for a wide range of landmarks. It will be particularly important to develop standard iconic representations of landmarks for use in visual displays. Many drivers will use different cars and navigation systems on a frequent basis (habitual hire-car users), and it will be necessary to ensure an appropriate transfer of learning.

4.4. *Accounting for industry's requirements*. To develop a given vehicle navigation system product, a number of design stages take place, involving several different organisations (map database providers, navigation system suppliers, vehicle manufacturers). There has been no research to investigate landmarks in the context of this design process. In practical terms, such knowledge is essential if landmarks are to be actively used within future vehicle navigation systems. Issues regarding the underlying navigable-map database would seem of particular importance, for instance:

(a) The extent to which appropriate landmarks are already present within map databases. In this respect, it is worth noting that map databases do contain an increasing number of Points of Interest (POIs), stored as places to which a driver might wish to go. Potentially, many of these POIs will be suitable for navigation purposes.

(b) The process by which additional landmarks could be specified for inclusion within the database. Ground-level data gathering would seem to be the ideal opportunity for considering the suitability of landmarks for navigation purposes. Unfortunately, visits to locations are extremely labour-intensive, and are generally only considered as a last resort if other strategies (such as, use of aerial photographs, existing maps, phone calls) for data gathering are not successful (van Duren and Lydon, 1997).

(c) The means by which map databases are maintained, both now and in the future. Ideally, for reliably good landmarks, what is required is 'as is' map data, whereby information in the database reflects exactly what is present within the road environment. Database providers are well aware of the need for frequent updates of their maps, and there are several means by which better 'ground truth' map data can be achieved, for instance by:
  (i) improving the up-dating process by using a Help Desk for users to report corrections – Temes (1996)
  (ii) distributing maps more efficiently by the use of kiosks at car dealerships for providing map databases (Gupta and Angerman, 1996), or a centralised storage of maps that are transmitted via wireless communications (Hakula, Vehviläinen and Ojala, 1996).

5. CONCLUSIONS. Electronic GPS-based vehicle navigation systems are now available to drivers in Europe and North America, and these will soon be affordable by the mass market. Optimum design of the driver-system interfaces is critical for the safe and effective deployment of the technology. The level of usability of typical vehicle navigation systems can be said to lie between that of existing paper maps and that of instructions given by the informed passenger. Studies within the human factors discipline and elsewhere have shown that the safety, effectiveness and acceptability of these in-vehicle systems could be significantly enhanced, if the interface reflected basic human navigational strategies, and incorporated landmarks within turn-by-turn directions.

However, it is not a simple task to include landmarks within vehicle navigation systems. There is a vast number of different types of landmark that could potentially be presented to drivers to support them in the navigation task, and designers need guidance on which are appropriate in a given context, and how these should best be presented. Future research must establish the salient attributes of landmarks that make them effective cues for navigation purposes, and ascertain how the navigational effectiveness of landmarks can be predicted. The optimum means of representing landmarks must also be investigated. Finally, there is a practical need to identify how effective landmarks can be incorporated within navigable map databases for presentation by future vehicle navigation systems.

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