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User Perceived Benefits with Navigation Systems

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User Perceived Benefits with Navigation Systems

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USER PERCEIVED BENEFITS
WITH
NAVIGATION SYSTEMS

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1. INTRODUCTION

It has often been assumed that travel time savings are only beneficial to the users of route guidance and navigation systems. In particular, absolute travel time savings have been emphasized, but there has been little interest in **relative time savings** between equipped and unequipped vehicles. Part 2 of this report investigates to what extent relative travel time savings decrease as the percentage of equipped vehicles increases.

In order to compensate for a possible decrease in relative time savings, some other potential services that can be provided by navigation systems are identified in Part 3. This report focuses on a particular category of users: commuters. Unfamiliar drivers can be helped by the navigation system in the task of planning and following a route. Hence, it is likely that these users perceive some significant benefits. However, commuters do not need these services and are therefore a more difficult group of users to satisfy. Some field results from the LISB Route Guidance and Information System Berlin (Al 1) indicate that a majority of users familiar with a route seldom or never perceive travel time savings, while a majority of users unfamiliar with a route always or almost always perceive travel time savings. Thus, this report focuses on benefits for commuters, although some results are applicable for other users.

2. LIMITS OF THE TRAVEL TIME SAVER

2.1. INTRODUCTION

The user-benefits from navigation systems have often been assumed to be travel time savings. From research, benefits seem to depend mainly on:

- The network:
  - existence of freeways, arterials, number of traffic lights
- The level of congestion and city policies:
  - location of potential improvements
  - restriction on through traffic in residential areas
- Driver preferences and behavior:
  - route preferences, lateness tolerance, propensity to divert

Unfortunately, all these parameters are not included in all simulation models or in all theoretical approaches. That explains some of the differences found in the results. Hence, this part will not strive to find some very precise conclusions under some questionable assumptions. The goal is rather to investigate different approaches, in order to get a better idea of the essential trends.

Some studies show that benefits under recurrent conditions range from 0% **(B1),** 6% **(B7),** 11% **(B12),** up to 10% (B4) and from 15 to 30% **(B10).** Under incident conditions, time savings up to 37% **(B1)** and from 25 to 40% **(B10)** have been estimated. Time savings from departure time changes have been estimated from 10 to 22% **(B10).**

But these benefits are travel time savings for the first users of navigation systems. Indeed, diverting a significant number of vehicles from a usual to an alternate route would both increase travel time on the alternate path and decrease travel time on the usual route. These benefits are valid as long as the equipped vehicles have no influence on travel times on the network. This assumption holds as long as there is only a small percentage of vehicles equipped. As the percentage of vehicles equipped increases, it is expected that the difference in travel time between equipped and non-equipped vehicles will decrease. Nevertheless, benefits from gain in distance and from diversion around an incident will remain.

Them are four situations where potential travel time savings exist:

- Recurrent conditions, route change
  - average travel time savings on a monthly basis
- Recurrent conditions, departure time change
  - average travel time savings on a monthly basis
- Day-today variability
  - savings due to variations in travel times on a particular day on alternate paths or at different moments
- Incident conditions
  - savings due to avoiding congestion caused by incidents

Unfortunately, there is little data available on this decrease of benefits. Therefore this paper considers only route changes under recurrent conditions and incident conditions. For both situations, a theoretical approach and some results from simulation studies are provided.

For simplification purposes, the theoretical approaches and some simulation approaches assume that the travel time on alternate routes is not affected by the increase of flow due to diverted vehicles. This holds when many alternate paths exist or when the alternate paths are under capacity. Thus, only the effect of decreased travel times on the usual route is considered. The effect of increased travel times on the alternate route is ignored. Therefore, actual travel time savings are not as large as the ones found in this report.

2.2. RECURRENT CONDITIONS, ROUTE CHANGE

2.2.1. Theoretical Approach

In the theoretical approach, the network is an urban corridor composed of two mutes, as shown in Figure 2.1.

- one major arterial
- one alternate path using secondary roads, having a lot of turns

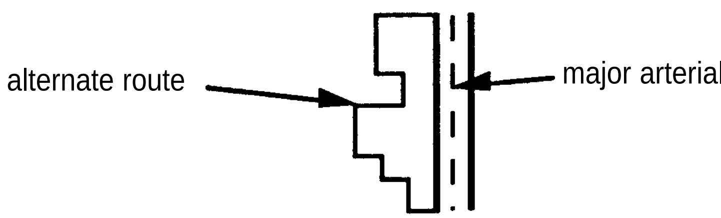

Figure 2.1: Corridor model

The major arterial is congested during peak travel hours. Travel time on the alternate path is significantly shorter. But driving on the alternate path is less attractive (if travel times were the same) since there are many turns, several route changes and the route has more intersections, which are less protected. Hence, diverting users to alternate paths provides relative time savings which offset its other disadvantages.

The "BPR" (Bureau of Public Roads) formula will be used to estimate travel time on the arterial:

$$T = T_o [1 + 0.15 (v/c)^4]$$

where T_o: free-flow traveltime
v : traffic volume
c : arterial capacity

Using $T_o = 30$ minutes and c = 3,000 vehicles/hour results in the following example. Figure 2.2 shows the evolution of travel times.

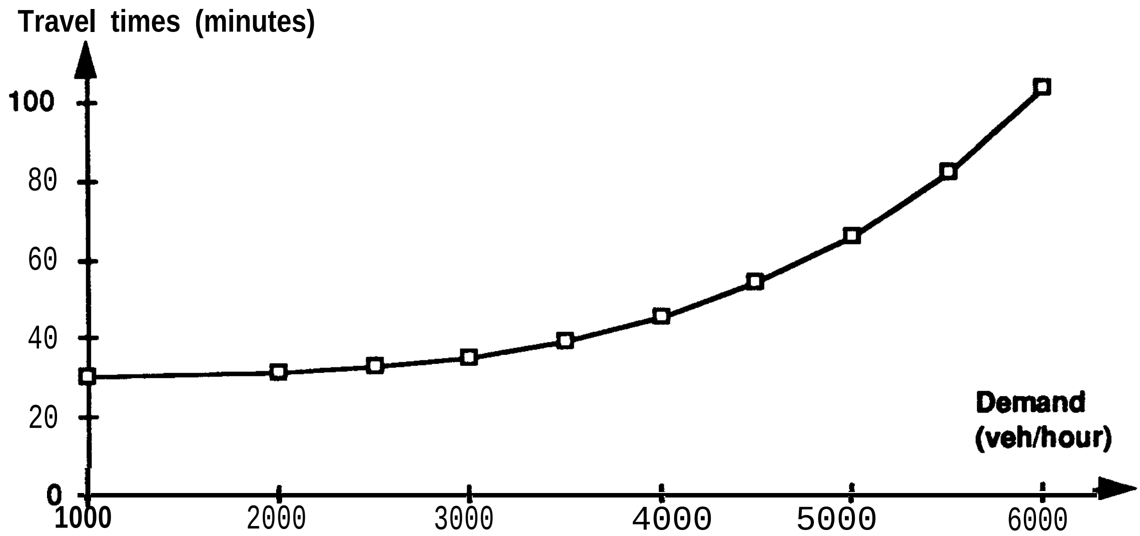

Figure 2.2: Travel time - volume characteristics

The travel time on the alternate path is 40 minutes, and it will be assumed that travel time is unaffected by diverted vehicles. It is obvious from the travel time model that the effect of the demand on travel times depends heavily on the congestion level. Hence, two initial loading demands will be assumed: 4,500 vehicles/hour and 5,000 vehicles/hour. Relative time savings are considered as the travel time on the main route minus 40 minutes. Table 2.1 and Figure 2.3 show the relative time savings, &pending on the percentage of vehicles equipped.

% vehicles equipped / main route loading	0.01	1.00	5.00	10.0	15.0	20.0	25.0
4,500 veh/hour	12.8	11.9	8.8	4.9	1.9	—	—
5,000 veh/hour	24.7	23.5	18.3	12.8	8.1	4.2	1.0

table 2.1: Travel time savings in minutes on alternate path

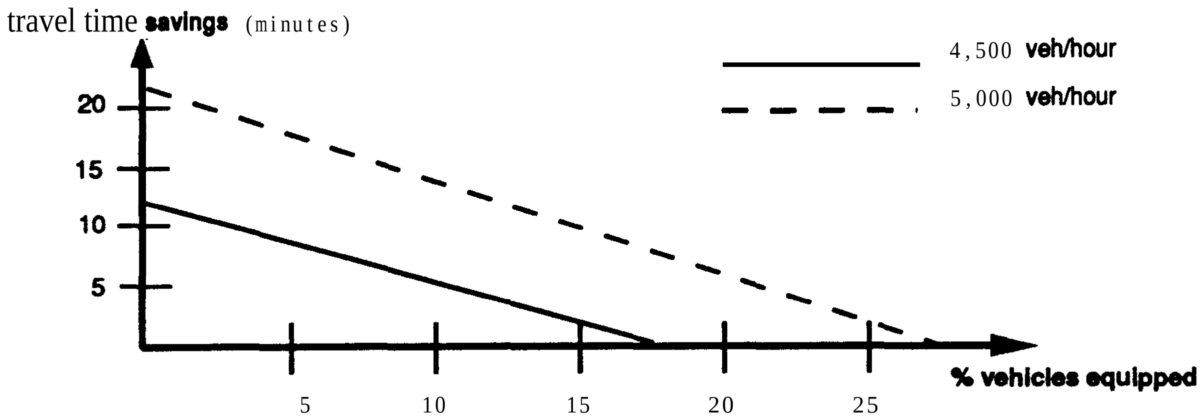

Figure 2.3: Travel time savings for equipped vehicles

Hence, relative time savings decrease almost linearly as the percentage of vehicles equipped increases. The rate of decrease depends on the initial congestion level. Obviously, there are no relative time savings when travel time on the main route is equal to 40 minutes. This occurs when the demand equals 3,650 vehicles/hour.

The number of equipped vehicles with a navigation system which can be diverted cannot be greater than the initial demand minus 3,650 vehicles for each hour. It is likely that the initial demand would not exceed 6,000 vehicles/hour, which corresponds to a travel time of 102 minutes, since unequipped drivers would probably look for alternate paths before travel times become unbearably high.

Assuming an initial demand of 6,000 vehicles/hour on an original preferred route, diverting 40% of the travellers would decrease the travel time from 102 minutes to 40 minutes. Therefore, in reality, the difference in travel times between equipped vehicles and unequipped vehicles would be insignificant when the percentage of vehicles equipped is higher than 40%, assuming essentially unlimited capacity on the alternate routes.

2.2.2. Simulation Approach

Mahmassani et al. (B9), while investigating user response to network information, used a simulation approach to estimate travel times for both equipped and unequipped vehicles. They found that, for two different loading patterns, and whatever the driver response to information is, relative travel time savings between equipped and unequipped vehicles decrease significantly as the percentage of vehicles equipped increases. For the loading pattern which they believe to be the closest to the actual loading pattern, relative travel time savings from 9% to 14% were found with 10% of vehicles equipped, depending on driver response to information. However, with 50% of vehicles equipped, relative travel time savings ranged from -1.5% to 2%.

Nevertheless, among researchers, there is not a unanimous agreement that the difference in travel times decreases as the percentage of vehicles equipped increases. Koutsopoulos et al. (B8) found a travel time difference of 4% which remains steady as the percentage of informed users increases, and the effects of equipped vehicles are included in the simulation. This simulation is based on a stochastic user equilibrium reflecting the difference in perception of travel times among drivers. Perceptions of travel times are modelled by a distribution around the actual value. Free-flow travel times are based on the measured length of road links and the maximum allowed speed.

The discrepancies between the result from this study and the previous one can be explained by two hypotheses:

1) The network - It is possible that, on some networks, relative travel time savings do not decrease significantly as the percentage of vehicles equipped increases.

2) The simulation idiosyncrasies - The assumption that free-flow travel time can be estimated from speed limits and length of roads may be too simplistic for an accurate evaluation of travel time difference between a few percentage points. In addition, scenery, controlled access, presence of pedestrians, perceptions of safety, and speed limit enforcement have a significant effect on travel times.

The distribution of perceived travel times is actually not consistent with results from the following relevant studies. Wachs, in a study made in the U.S. in 1967 (RU8), reports that many drivers associate trip time with trip distance and congestion. Fox, in a study made in the U.S. in 1965 (RU2), concluded from his research that drivers appear to value time spent in stop and go traffic differently from time spent traveling at a constant speed. In addition, participants in this survey overestimated work trip time by an average of 2.5 minutes. Louviere et al., in a study made in the U.S. in 1981 (U4), reported that drivers systematically overestimate travel times by an average of 20%. They also found that the degree of overestimation depends on actual travel times and perceived comfort. Hamerslag, in a study made in the Netherlands in 1981 (R7), compared perceived and actual delays at intersections. Results in Table 2.2 show that perceived &lays are significantly higher than actual &lays and that the difference between actual &lay and perceived delay increases as congestion increases.

	Perceived delav	Actual delav
Right-turn and Straignt	50 sec.	30 sec.
Left-turn	2 min. 30 sec	45 sec.

Table 2.2: Perceived and actual delays at intersections

In conclusion, it seems that the distribution of perceived travel times has a significant bias towards overestimation, and depends on the road characteristics.

Smith et al. (B1 1) estimated travel time savings. They found that benefits for equipped vehicles decrease while benefits for unequipped vehicles increase. These results are shown in Table 2.3.

% Equipped	equipped vehicles	unequipped vehicles
10	-6.9	-2.2
20	-6.3	-2.5
30	-6.6	-3.1
100	-6.0	--

Table 2.3: % of changes in travel times for equipped & unequipped vehicles

The difference drops from 4.7% with 10% equipped to 3.5% when 30% equipped, but no results are given beyond that point.

2.2.3. Conclusion

Therefore, when a majority of vehicles are equipped, commuters who have been directed to the alternate route may not be satisfied if they know there is no significant difference in travel time. The satisfied drivers are more likely to be the unequipped ones, who have not used the alternate route and did not pay for a navigation system. However, equipped drivers can have the choice between accepting a little delay on the main route while enjoying the comfort of the route, or selecting one of the preferred alternate paths. Nevertheless, if the navigation system guides some users to the alternate route, they may not be satisfied since the inconvenience of taking the alternate route provided may not justify the small savings in travel time.

In this situation of small potential savings, providing information and leaving the decision up to the commuter is preferred in terms of customer satisfaction over guiding the driver to an "optimized" route. In reality, there is no "risk" involved if users are informed about travel time on each known alternative before making their decision. Although benefits in terms of travel time decrease, users may feel advantaged since they have some accurate data about travel times and are thus able to choose the route they prefer. If travel times change in the long run, they can change their decision.

2.3. INCIDENT CONDITIONS

2.3.1. Theoretical Approach

In the theoretical approach, a five-lane freeway with a capacity of 10,000 vehicles per hour will be used. A typical peak-hour demand of 8,000 vehicles/hour is taken from empirical results.

In the event of a slight incident reducing the capacity to 8,500 vehicles/hour, speed is expected to be reduced at the location of the incident, but not enough to significantly increase travel times. On the other hand, in the event of a major incident reducing the capacity to 6,000 vehicles/hour, a queue will form at the bottleneck since the demand is 8,000 vehicles/hour. Figure 3.1 shows the number of vehicles leaving the bottleneck.

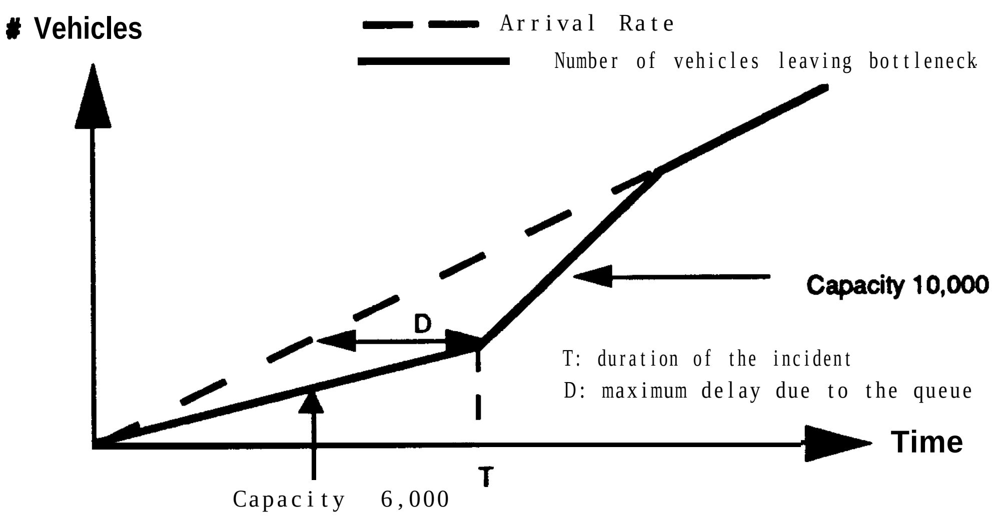

Figure 3.1: Situation without any diverted drivers

The actual delay D experienced by freeway drivers is the difference shown on the horizontal axis between the arrival rate and the curve representing the number of vehicles leaving the bottleneck. Figure 3.2 shows the evolution of this &lay over a period of time.

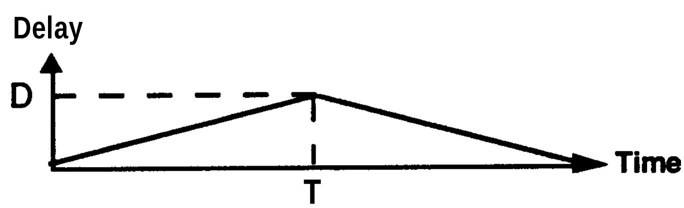

Figure 3.2: Delay without any diverted Vehicle

Equipped vehicles can be diverted to alternate paths, However that will decrease arrival rate and decrease the &lay. Figure 3.3 illustrates the situation when equipped vehicles divert in order to accomplish a savings in travel time.

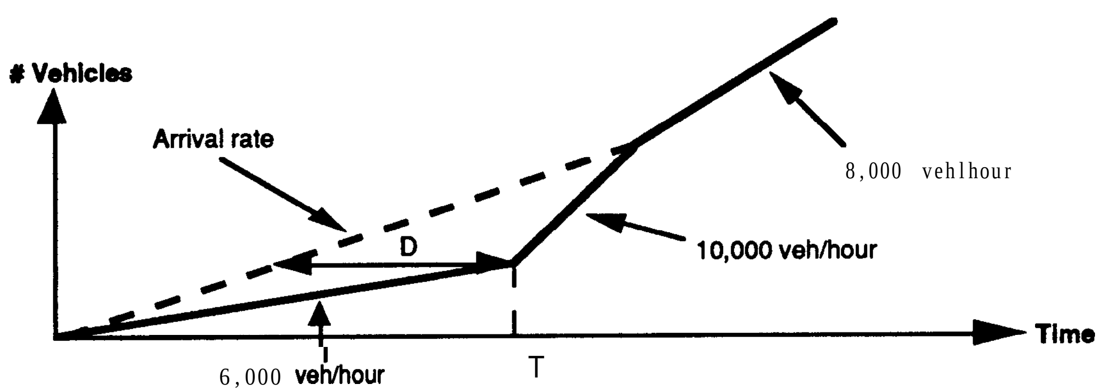

Figure 3.3: Situation when users divert for any delay

The maximum delay, "D", is then: $D = \frac{A - 6}{A} \times T$

A is the arrival rate in thousands of vehicles/hour, and
T represents the duration of the incident.

The delay for equipped vehicles depends on the existence and availability of a fast alternate route. Considering the extra time required to reach and drive on the alternate route, and the inconvenience of leaving the freeway, it is assumed that drivers only divert if the delay will be longer than five minutes. Hence, drivers will not divert right after an incident occurs, but when the delay proves to be longer than five minutes. Similarly, drivers will stop diverting when the delay is reduced to under five minutes. Figure 3.4 illustrates this situation and Figure 3.5 shows the delay evolution.

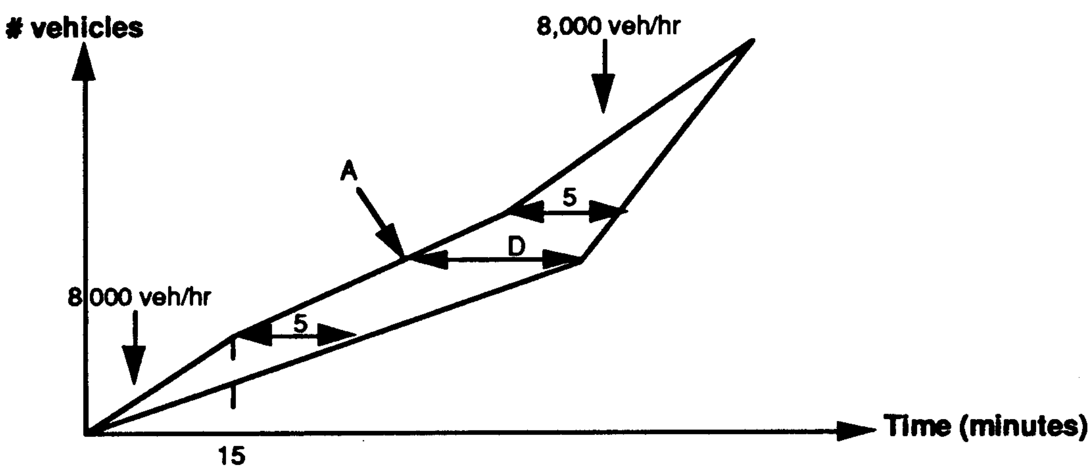

Figure 3.4: Situation when users divert for a delay longer than 5 minutes

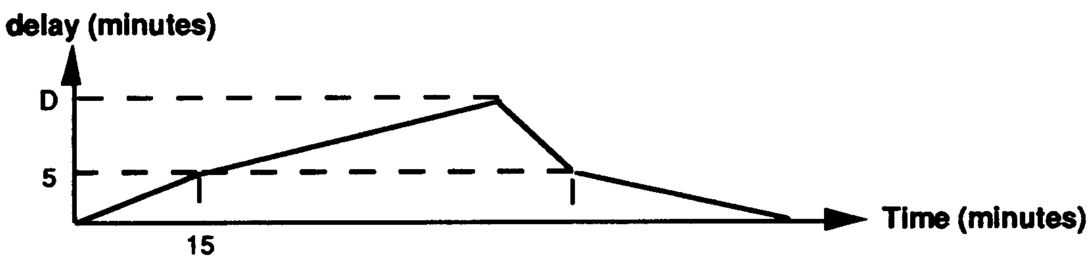

Figure 3.5: Delay when users divert for a delay longer than 5 minutes

When T > 15 minutes, the maximum delay D is then : $D = 5 + \frac{A - 6}{A}(T - 15)$

The arrival rate A is : $A = \frac{100 - n}{100} \times 8$

where n is the percentage of vehicles equipped. Hence,

$$D = 5 + \left[1 - \frac{6}{8(1 - n/100)} \right] (T - 15)$$

Table 3.1 shows the maximum delay for a 45 minute and a 90 minute incident.

% vehicles equipped	0	5	10	15	20	25
45 min incident	12.5	11.3	10	8.5	6.8	5
90 min incident	23.7	20.7	17.5	13.8	9.6	5

Table 3.1: Maximum delay on freeway (minutes)

As seen in Table 3.1, the maximum delay decreases almost linearly as the percentage of vehicles equipped increases. Relative travel time savings are eliminated when the percentage of vehicles equipped equals the percentage of excess demand over capacity. This percentage of excess demand depends mainly on the congestion level and also on the number of lanes affected by the incident.

2.3.2. Simulation Approach

Gardes et al. (B3) have investigated potential benefits in a freeway-closure simulation. Using data from actual peak hour flow, all the lanes on the freeway are completely blocked for ten minutes. Equipped users are diverted to some alternate route while unequipped vehicles remain on the congested freeway. This situation can be represented on a graph showing the number of vehicles leaving the bottleneck. The &lay experienced by freeway drivers is represented by the difference between the arrival rate on the horizontal axis and the curve portraying the number of vehicles leaving the bottleneck. Therefore this delay decreases linearly from 10 minutes to 0 minutes when the congestion disappears (*t* = to).

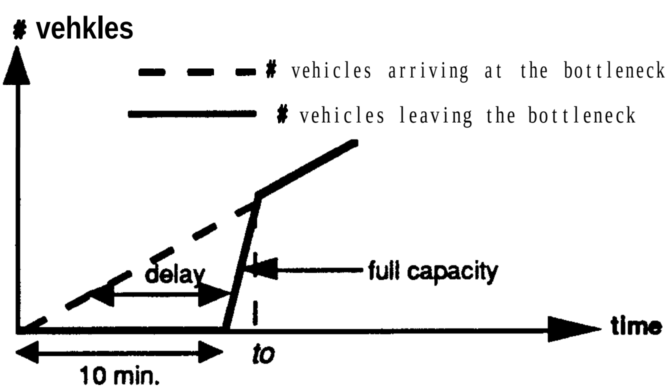

Figure 3.6: Situation without any diversion

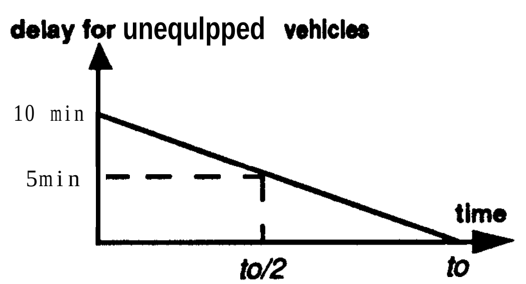

Figure 3.7: Delay

Equipped vehicles can be diverted to an alternate path. That will decrease the arrival rate and reduce ***to*** (Figure 3.8). The delay for equipped vehicles depends on the existence of a fast alternate route. As in the last example, it is assumed that users divert only for a delay longer than five minutes (Figure 3.9).

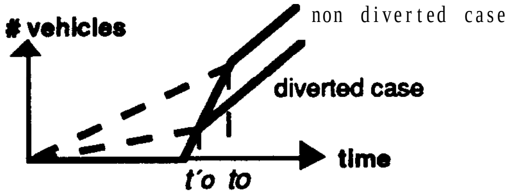

Figure 3.8: Effect of diversion

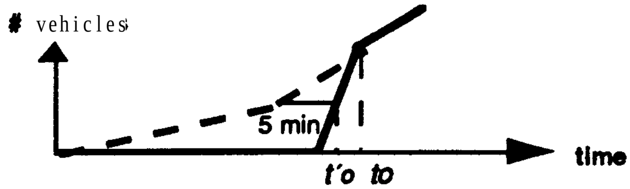

Figure 3.9 : Effect of diversion when users divert for a delay longer than 5 minutes

In this case, the arrival rate will be reduced as long as the &lay is greater than five minutes. When the delay is less than five minutes, equipped vehicles do not divert and thus no improvements in arrival rate are achieved. The &lay for unequipped vehicles is then:

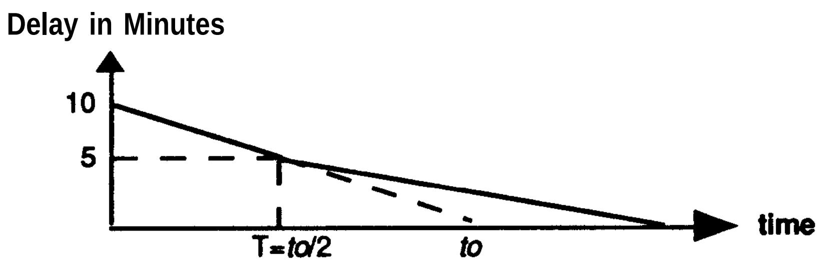

Figure 3.10 : Delay when users divert for a delay longer than 5 minutes

The congestion then takes longer to disappear. However, the time frame during which equipped vehicles can be diverted is still ***to/2***. Hence, there is **a** potential to save a significant amount of travel time for equipped vehicles for T = ***to/2*** minutes. This possible diversion time, T, decreases as the percentage of vehicles equipped increases. From the actual data in the report **(B3),** ***to*** depends on the percentage of vehicles equipped in one of two situations: a lightly loaded and a heavily loaded freeway.

% equipped vehicles / freeway load	0.01	10.0	20.0	30.0	40.0	50.0
lightly loaded	8.5	7.9	7.4	7.0	6.6	6.3
heavily loaded	16.8	13.5	11.4	9.8	8.6	7.7

Table 3.2: Possible diversion time in minutes

T remains steady for a lightly loaded freeway, since no serious congestion has formed yet T decreases significantly for the heavily loaded freeway, demonstrating that the queue length formed is dramatically reduced by diversion. Most likely, the case closest to real life would be the heavily loaded freeway since navigation systems will probably sell and be used where congestion is significant. Hence, in the event of a road closure, the possible diversion time decreases significantly as the percentage of vehicles equipped increases. And as this time decreases, a smaller portion of equipped vehicles will be assisted and rerouted by the navigation system. Therefore a smaller portion of users will feel it has been useful to them. Instead of saying, "My navigation system is useful for incident avoidance once a week," the average user will say, "My navigation system is useful for incident avoidance about twice a month." This reaction may **make a** big difference in terms of customer satisfaction.

This decrease in frequency of rerouting can be applied to the situation of **a** single lane closure on a four-lane freeway. The only difference is the effect on the percentage of vehicles equipped, which is much more significant. Al-Deek and May **(B2)** have evaluated potential benefits under different demands and incidents for four origin-destination trips. This study has been conducted on the SMART corridor (Figure 3.1 **1),** where an incident has been simulated downstream, close to the end of the commuting trips.

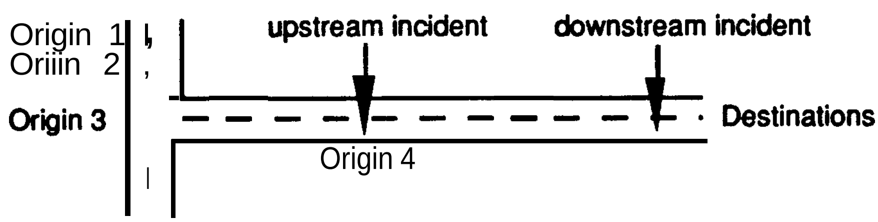

Figure 3.11 : The SMART Corridor

The incident is represented as a two-lane hindrance blocking the freeway for 45 minutes. Using results from the report **(B2),** Table 3.3 shows the possible diversion time, depending on the demand for each origin representing four different starting points.

traffic demand / origin	average	105% average	110% average
origin 1	15 min	30 min	I h
origin 2	30 min	45 min	I h
origin 3	1 h45	3 h	3 h 15
origin 4	I h	I h	1 h15

Table 3.3 : Possible diversion time for a 45 minute incident blocking 2 lanes

This study can provide information about the effect of equipped vehicles. As mentioned earlier, diverting vehicles from the freeway reduces the demand. Using a base of **110%,** a demand of 105% corresponds to 4.5% of vehicles diverted and a demand of 100% corresponds to 9% of vehicles being diverted. The possible diversion time decrease significantly as the demand decreases. Therefore, as the percentage of vehicles equipped increases, a smaller portion of users experience some diversion under incident conditions. Hence the perceived utility of the navigation system is likely to decrease. This simulation assumes that travel times on alternate paths **are** not affected by diverted vehicles. Therefore, the decrease in travel time savings reported overestimates the actual travel times. Table 3.4 shows the travel time savings for a downstream incident, close to the end of the trip, and an upstream incident.

downstream incident

Origin \ Demand	110%	105%	100%
Origin 1	11	8	5
Origin 2	12	8	5
Origin 3	14	10	5
Origin 4	9	8	8

upstream incident

Origin \ Demand	110%	105%	100%
Origin 1	8	8	6
Origin 2	9	9	8
Origin 3	11	11	10

Table 3.4: Travel time savings in minutes

In the upstream incident, travel time savings remain significant. This is due to the fact that as the demand increases the queue length becomes longer, yet beyond the origin of the observed trips. Hence, there is little difference for them. In the downstream incident, travel time savings are significantly decreasing for origins 1 through 3, but remain steady for origin 4. Indeed, as the demand increases, the queue length becomes longer, yet beyond origin 4, but not beyond origin 1 through 3. Therefore, relative time savings from incident conditions decrease both in amplitude and frequency as the percentage of vehicles equipped increases.

2.3.3. Conclusion

If a majority of vehicles are equipped, some diverted drivers may not be satisfied since relative travel time savings may appear insignificant to them. Nevertheless, relative time savings may still exist since only part of the users would accept diversion. For example, some users may not divert unless it would enable them to avoid being late. Drivers who would leave the freeway two exits earlier than planned may be much more willing to divert than those drivers who would have to exit the freeway, travel through an unfamiliar area and then reenter the freeway. Some drivers may divert to avoid frustration caused by congestion.

Since only part of the users would accept diversion, there may be a high percentage of vehicles equipped, but a low percentage of diverted equipped vehicles. It is difficult to know what percentage of users would accept diversion in a particular context. Thus it is difficult to know from what percentage of vehicles equipped relative time savings become insignificant. Furthermore, some drivers may not know that diverting around an incident indeed did not save a significant amount of time. They may associate diversion with time savings, and then perceive some benefits whenever they divert.

2.4. OTHER CONDITIONS

2.4.1. Departure Time Change

The frequency of departure time changes is low and individual decisions do not affect travel times in the short run. Most drivers would change their departure time in order to avoid congestion (DT1, DT2, DT3, DT4). This would reduce travel times during peak hours. Hence, potential travel time savings from avoiding peak hours would be reduced.

But, as for recurrent conditions, users may make their own trade-off between departure time and trip time. Users can choose to leave at their preferred departure time, usually during peak hours, but will experience a longer trip time. On the other hand, they can choose to minimize their trip time, driving off peak hours, but will have to adapt their departure time to the traffic conditions. Like recurrent conditions, user satisfaction may remain good since users feel better informed than unequipped drivers.

2.4.2. Day-to-Day Variability

Day-today variability is defined as changes/alterations from the average value in travel times on alternate paths on a particular day. Possibly, users get information about traffic conditions just before starting their trip, and choose in consequence their route and adjust their departure time.

In terms of frequency of changes, day-today variability is somewhere in between recurrent conditions and incident conditions. The main difference with incident conditions is that the evolution is slower. Only a few commuters make their decision in a three-minute interval, while a significant percentage of them may make their decision in a three-minute interval under incident conditions. Hence, the uncertainty of the situation is reduced.

Another notable difference is that the commuters can take as much time as they want to make a decision, since it is usually made before their departure. Hence, more rationality from the users can be expected. Furthermore, the inconvenience of switching routes before a trip begins is less than for an in-route diversion. A higher propensity to switch routes is also expected.

It is likely that the day-today variability of travel times will be reduced, due to adaptation of equipped vehicles. Travel times for unequipped vehicles would be reduced and time savings for equipped vehicles are also likely to decrease. As for recurrent conditions, it is likely that some users will not bother changing their habits to save one or two minutes. Therefore, potential savings are likely to be small (only a few minutes) when a large percentage of users are equipped. Nevertheless, users might be satisfied if the navigation system allows them to know today's best route among the few routes they prefer, eliminating any sudden surprise from unexpected congestion (incident occurring during the trip excluded).

2.5. CONCLUSION

The percentage of vehicles equipped for which relative travel time savings between equipped and unequipped vehicles become insignificant depends on:

- The simulation approach - How behavior of unequipped vehicles is modeled;
- The network - Existence of alternate paths, bottlenecks;
- The incident characteristics - Position, length and severity of the incident;
- The congestion level - Existence of alternatives, congestion on main routes;
- User perceptions - Value of time savings for the user.

Nevertheless it seems that, in terms of relative travel times savings,

1) Savings will **decrease** but will be significant as long as there is a small percentage of vehicles equipped;
2) When a majority of vehicles are equipped, some users might perceive that **there** is no significant difference in travel times with unequipped vehicles.

The rate of equipping cars and trucks with an in-vehicle navigation system, although difficult to estimate, is very likely to be under a few percent per year in the near future. Hence, the 10% level of equipped vehicles will not happen soon. Furthermore, 10% of equipped vehicles does not mean that 100% of these vehicles are actually using their navigation systems. Indeed, some users might decide not to use the system at some particular time, if they do not feel it will be useful. Some drivers might refuse to change their habits and will not always react to real time information. Hence, 10% of equipped vehicles might correspond to only 5% of vehicles willing to divert. **Therefore,** relative time savings will remain significant in the short run, and real problems with user satisfaction will happen only in the long run.

Traffic demand increases 6% annually in California while congestion increases 15% annually. Hence, the percentage of vehicles equipped will most likely grow at a much slower rate than congestion in the near future. This study has considered the effect of the percentage of vehicles equipped on a network where traffic demand and congestion are steady. But in real life (during the **first** few years of implementation) this effect may be reversed by the influence of increasing traffic and congestion. Hence, potential benefits might in fact increase in the short run. But, as congestion increases, more and mom people will tend to buy a navigation system. It is likely that, in the long run, the rate of increase of congestion will be lower than the rate of equipping vehicles with navigation systems. Then, users will probably observe a decrease in time savings, due to the effects of an increasing percentage of vehicles equipped.

In terms of user satisfaction:

- Relative time savings can become insignificant, under recurrent conditions and day-today variability. However, there are some permanent savings for drivers who failed to fmd their best route, that the navigation system showed them.
- Under incident conditions, relative time savings will decrease both in **frequency** and amplitude. Rerouting will occur less often, and time savings will be smaller. Nevertheless, satisfaction may remain good since only part of the users would accept diversion.

Relative time savings &creases as the percentage of vehicles equipped increases, and absolute time savings also decreases, to a lesser extent. Hence, some users might perceive this decrease in absolute time savings, and feel that the navigation system "does not work as well as it did previously."

When there is a majority of equipped vehicles, relative time savings may not justify buying or using a navigation system. But user satisfaction may remain high if services other than travel time savings are provided, like information about travel times on alternate paths or congestion avoidance.

It seems necessary to identify some other services which can be provided by navigation systems. It is important to provide a high level of service, such that a majority of users would actually use their navigation system during their commute, and would not restrict its use to guidance within unfamiliar destinations. The more equipped drivers actually using the system, the more influence over traffic is provided, depending on the type of information provided, active or passive. The next section of this report will focus on the identification of other possible services which a navigation system can provide.

3. SOME OTHER POTENTIAL BENEFITS

3.1. INTRODUCTION

This section examines how people feel and what they perceive during their trips. Obviously, these factors are much more difficult to measure than travel time or distance. But these factors are believed to have a major impact on satisfaction. Hence, they must be taken into consideration.

Some preliminary results from the LISB Route Guidance and Information System Berlin (Al 1) report that the highest rated perceived benefit by users is "less stress." Nevertheless, surveys and experiments not ma& in the U.S. should be interpreted with extreme caution. In terms of behavior and attitudes, it is difficult to distinguish between:

- essential human behavior (similar in the U.S)
- behavior influenced by the culture (not similar in the U.S.).

A reasonable approach would be to compare all the surveys and experiments, and to extract the common results. Unfortunately, this is very difficult at this point since there is only a small number of surveys and experiments, which use different approaches and different contexts. Hence, performing direct comparison is difficult. Furthermore, results obtained also depend on the network. For example, there are fewer urban freeways and a higher level of congestion in Europe than in the U.S. This parameter may have an influence on driver behavior and attitude.

Also, surveys usually take a sample representative of the whole population. Thus, they reflect opinions and attitudes of the average driver. Results may be different if the sample represents the potential first buyers of navigation systems. Hence, conclusions based on survey results should be considered with caution.

The first part focuses on driving stress and its effects on commute satisfaction. Route choice is then examined in order to understand what kind of services the navigation system can provide. Then pre-trip information is emphasized, since it may provide some additional valuable benefits.

3.2. STRESS

3.2.1. Introduction

Generally, stress might be expressed by:

- an emotional response (anxiety)
- a physiological response (heart rate)
- a behavioral response (aggressiveness)

From a review of the relevant research, it appears that:

- the emotional response has a major influence on satisfaction,
- the physiological response has a significant influence on satisfaction,
- the behavioral response has a negligible influence on satisfaction.

A high level of **stress** is experienced during the commute, according to experiments made recently in Irvine, California **(S1,** S3, S4, **S5,** S6, S7). Gulian et al., in a study made in the U.K. in 1988 **(S21),** report that driving is often associated with anxiety, bad mood and frustration. In this study, the 97 respondents were mostly **males,** mostly commuters with flexible hours. Campbell et al., in a study made in the **U.S.** in 1956 **(RU1),** found that less strain, annoyance and frustration was perceived as being a major advantage of expressway driving. **Michaels (S9)** thinks that total stress in driving is a mom important determinant of route choice than operating cost or travel time.

Perceptions of stress seem to vary a lot among drivers. Gulian et al., in a study made in the **U.K.** in 1988 **(S21),** report that, to the question, "In general, **based** upon your entire driving experience, do you consider that driving is a stressful activity?", driver **responses** had a mean of 54 and a standard deviation of 26 on a scale from 2 to 100. Some people feel very little stress, while some people feel a high stress. The 97 respondents of this survey were from the same area, mostly males, drove more than 20,000 miles a year, and had flexible hours. However, it is not clear whether they drove on similar or on significantly different type of roads. The same study reports that, in a traffic jam, about half of the drivers feel strain and anxiety, while the other half remain relaxed. Similarly, a huge variability in amplitudes of reactions on physiological stress among drivers has been reported **(S1,** S4, **S5,** S6, S12, S13). This is supported by Lazarus (S14). **He says** that a particular environmental condition is likely to prompt diverse reactions among different persons &pending on their respective perceptions of the threat posed by the condition and their resources for coping with it. Therefore, one should resist the temptation to **generalize** and say "driving on urban streets is more stressful than driving on freeways." **A more** realistic approach would be to identify some cluster of stress reactions.

From the literature on driving stress and route choice, four major components of driving stress have been identified, **labelled** by a state of mind description.

- congestion - ***frustrated***
- lateness - anxious
- task load - ***overloaded***
- uncertainty - ***worry***

3.2.2. Congestion

Congestion is not easy to define since for some drivers it may mean heavy traffic moving at 45 mph on the freeway, while for others it may mean stop and go traffic. Nevertheless, it is likely that a minority of drivers perceive congestion in heavy traffic moving at 45 mph, while a majority perceive congestion in stop and go traffic. Most people dislike congestion, but they also react very differently to it. Gulian et al., in a study made in the U.K. in 1988 **(S21),** found that, when in a traffic jam, 45% of drivers show some passive coping (wait, relax, think about something else), 43% of drivers show some level of strain and anxiety, and 12% of drivers show some active coping (try to cut in **front** of other cars or to get out). Hence, congestion may be an important stress factor for some drivers, while it may not bother other drivers.

Stokols et al. **(S5)** report that perceived severity of traffic congestion influences commuting stress. Novaco et al. (S4) found that subjective congestion, "traffic congestion as a frequent inconvenience," and a lower satisfaction with the commute increase as the distance and time of the commute increase. Both studies were made in Irvine, California, in 1982 and 1978, with 100 commuters. It may reflect that not only the level of congestion is important, but its duration **affects** satisfaction directly.

Hence, congestion causes stress and reduces commute satisfaction for some drivers. Furthermore, congestion significantly affects commuter behavior, as studies about route choice report.

In terms of route choice, it seems difficult to distinguish between avoiding congestion and saving time, since they are correlated. Carpenter, in a study made in the U.K. in 1979 **(R4),** report that drivers who placed most emphasis on avoiding congestion were generally trying to minimize the time spent and/or the frustration caused by sitting in a **traffic** jam. Hence, it appears that some drivers associate avoiding congestion with saving time. Wachs, in a study made in the U.S. in 1967 **(RU8),** report that many drivers associate trip time with trip distance and congestion. Nevertheless, these two are distinguished in this report since they reflect fundamentally different behaviors, either an attempt to save time, or an attempt or relieve stress, or both. In some cases, it is possible that some drivers avoid congestion and loose time, but that they feel satisfied since they believe they gain some time. Indeed, for the driver, congestion is systematically **perceived,** while travel time has to be measured.

Congestion is a major factor **affècting** route choice **(R1,** R3, R4, **R5,** R6, R8, **R1** 1, R12, RU6, **RU8). Heywood,** in a study made in the U.K. in 1985 **(R8),** interviewed four commuters in a congested urban area. He reports that all respondents chose routes specifically to avoid congestion. Carpenter, in a study made in the U.K. in 1979 **(R4),** reports that some drivers increase their distance up to **100%,** avoiding congested junctions, in an attempt to save time. **Orman,** in a study ma& in the U.S. in 1966 **(RU6),** reports that congestion is quoted as the second reason for route choice, after travel time. Wachs, in a study made in the U.S. in 1967 **(RU8),** reports that "less congestion and strain" is the second parameter in order of preference, after access controlled routes.

Some en route changes are ma& to avoid congestion. **Heywood,** in a study made in the U.K. in 1985 **(R8),** found that about 80% of en route changes were ma& to avoid congestion. Carpenter, in a study made in the U.K. in 1979 **(R4),** reports that when reaching unexpected congestion, some drivers would divert apparently more to relieve frustration and tension than in the hope of saving much time. Huchingson et al., in a study made in the U.S. in 1977 **(RU4),** report that 48% of drivers say they divert to avoid congestion, while 27% say they divert to save time.

Identification of information needs from commuters in a traffic jam, indicated that the information most wanted by drivers in the U.S. is the location and degree of congestion, which seems to be more important than recommended alternate routes or estimates of travel time **(SU1,** SU2, SU3, SU4, Al). This may reflect the fact that the decision to divert is based on congestion avoidance ("How serious is the congestion?") rather than on travel time savings ("How much time would I save?"). In the U.S., the desire to avoid congestion is often a reason for arrival time shifts away from the peak period **(DT1, DT2,** DT3, DT4).

In conclusion, congestion is a major stress factor for some drivers. Avoiding congestion is a major factor that influences driver behavior. It is possible that some drivers would try to use their navigation system in order to avoid congestion. Therefore, it is important that navigation systems enable them to do so.

3.2.3. Lateness

It should be noted here that a navigation system can provide the user with some valuable service, although there is no savings in terms of travel time. For example, if the driver is just on time on his commute, he might be very anxious during his trip. He does not know whether there is any congestion ahead, and may be afraid of being late and of its consequences. A navigation system can tell him that his planned route is not congested at the beginning of his trip. He can then infer that he will be there on time and be more relaxed during the trip.

There has been a lot of research investigating commuters' departure time decisions. The most important result is that arrival time seems to be more important than travel time for some commuters. Chang et al., in a study made in the U.S. in 1987 **(DT5),** found that the most accurate model according to experiments was a model where the commuter always tried to achieve the **preferred** arrival time. Paine et al., in a study made in the U.S. in 1976 **(DT13),** found that arriving at the intended time is considered more important than average trip time and cost.

Bates et al., in a study made in the U.K. in 1988 **(DT12),** report that drivers are not much aware of their travel time, but much more about the feeling of being on time or late. Most drivers interviewed said that they pay little attention to their travel time, except when it seems unexpectedly higher than usual or when the next event is important (no lateness tolerated). Bates et al. also report that some drivers know that leaving earlier or later would reduce their travel time, but they are not willing to change departure time. It may reflect the fact that travel time is considered less important than departure time and/or arrival time. Drivers concerned with arrival time are probably those having a fixed schedule and no lateness tolerance. In the U.S., they account for about 50% of commuters **(DT15,** DT17, **DT20).**

The challenge of this research is to understand the process commuters use to set their departure time. It is a decision made under high uncertainty, since commuters lack the information necessary to predict their travel time. The decision ma& by a commuter depends on:

- the ability to predict travel time
- the trade-offs among departure time, travel time, arrival time, average earliness and risk of lateness.

Although most researchers attempt to build a model to predict departure time, none of it is very accurate in reproducing actual choice. This may be due to the fact that the models assume that drivers make a lot of computations and maximize their utility. Simon **(U8)** thinks that people behave like utility maximizers when the situation is simple, but that in complex situations, they become less consistent. Chang et al., in a study made in the U.S. in 1989 **(DT10),** think that the commuter will not optimize his arrival time, but will try to **find** a satisfactory one. According to their model, the commuter adjusts his departure time until his schedule delay (the difference between work start time and arrival time) is smaller than an indifference band, which depends on the commuter idiosyncrasies. They found that the utility maximization model does not work, but that the satisfying model works better. They concluded their research by suggesting that different commuters use different decision rules.

For drivers without lateness tolerance, some stress stems from the uncertainty of travel times. **Golob** et al., in a study made in the U.S. in 1970 **(DT14),** report that the greatest concern among bus users is service unreliability. The usual reaction is to leave earlier to compensate for variability. Mahmassani et al., in a survey made in the U.S. in 1988 **(DT15),** report that commuters prefer to arrive 14 minutes early on the average. Drivers with an important lateness tolerance preferred to arrive 10 minutes early on **average,** while drivers with almost no lateness tolerance preferred to arrive 17 minutes early. They also found that drivers with no lateness tolerance change their departure time more often, suggesting that their behavior is influenced by fear of lateness. In the morning commute, most of these drivers listen to radio traffic reports. It may **reflect** a need to **reduce** the uncertainty of their travel time, which seems to cause some anxiety. Therefore, there may exist some significant benefits from the reduction of variability in travel times. Bates **(DT12)** identifies three types of variability:

- between vehicles making the same trip
- between the period between 7a.m. and 8a.m.
- between day-today variability

A navigation system can reduce variability by showing some alternate route when the usual route is unexpectedly congested or rerouting in case of a incident.

A notable fact is that early arrival seem to be almost as important as late arrival. **Pells,** in a study ma& in the U.K. in 1988 **(DT11),** reports that 8% of commuters reject early **arrival** at all cost, while 16% reject late arrival at all cost. Chang et al., in a study made in the U.S. in 1987 **(DT5),** report that unacceptable early arrival seems to be more important than unacceptable late arrival. But the fear of being late should not be confounded with the dislike of being too early on average. Most likely, the **first** affects immediate satisfaction while the second affects satisfaction in the long run. This may reflect the attempt to be on time and the importance of reducing uncertainty in work trip travel times.

In conclusion, fear of lateness seem to have a major influence on commuter behavior. Unpredictability of travel times causes stress for commuters, who react by leaving earlier. It is possible that some drivers expect that the navigation system would reduce their uncertainty of travel time and their risk of being late, which affects them during the trip.

3.2.4. Task Load

Task load is defined as the level of attention required by the driving task. It is strongly correlated with the subjective complexity of the driving task. It is likely that subjective complexity of the driving task is only slightly correlated with the objective complexity of the driving task, since it depends on the **driver** experience and skills. Michaels, in two studies made in the U.S. in 1960 and 1962, reports that there are considerable differences in tension response among drivers, both on urban streets **(S10),** and on freeways **(S8).** Some of these differences come from physiological characteristics, but it is likely that they do not explain all the differences.

Michaels, in a study made in the U.S. in 1962 **(S8),** identified two kinds of interferences causing tension:

- **traffic** interferences (other vehicles)
- &sign interferences (road characteristics)

He used the galvanic skin response to measure tension. He found that frequency of interference grows proportionally with traffic volume. Tension response increased linearly with volume until a certain threshold in volume was reached. Then tension increased very rapidly. He interprets that this threshold is the point where the information load becomes excessive and the traffic situation becomes unpredictable.

Instream vehicles and curvatures accounted for most of the interference. Traffic interference caused much more tension than road interference. Rural interstate freeways experienced fewer traffic interference than urban freeways. Considering only traffic interference, Michaels found that an uncontrolled primary road generated about 1.75 times more tension than a controlled access freeway, and an urban arterial generated about 3.34 times more tension than a controlled access freeway. In terms of satisfaction, he reports that dislike of a route **increased** more rapidly than tension increased

He interprets the results by stating than one of the basic determinants of driver tension is the degree of predictability that exists in the driving environment. He defmes comfort as the predictability of interference and convenience as the freedom in setting the level of performance. He thinks that drivers adapt their speed to the perceived complexity of the driving situation and tend to adopt some kind of critical level of tension while driving.

This last statement is supported by Janssen (S12) who thinks that stress depends mostly on driver characteristics. He noted that, under the same driving environment, drivers can have a high control over their task load. For example, on a slightly congested freeway, a driver can stay in the same lane or constantly change lanes.

However, in some situations the driver cannot set his task load to his desired level. He may be restricted by speed limits and **instream** traffic. It may also be possible that some drivers are involved in other activities like talking to passengers, listening to the radio or tapes, or using their cellular phone. These drivers may want to minimize their task load, rather than setting it to a certain level. For example, driving in the left lane at the same **speed as the speed limit can be interpreted as an attempt to minimize task load.**

Michaels, in a study made in the U.S. in 1960 **(S10),** also investigated driving stress on urban streets, using the galvanic skin response technique. A notable finding is that a traffic event does not systematically arouse a response from the driver. About 15% of traffic events aroused no response. Two routes were **compared;** a major arterial with heavy traffic, including commercial traffic and an alternate route passing through a residential **area** having light traffic. The major arterial generated 45% more tension than the alternate route. The events causing the higher magnitude in tension response were diverging vehicles, merging and crossing vehicles, traffic signals, and **instream** pedestrians.

Michaels, in a study made in the U.S. in 1966 **(S9),** compared tension response on two roads having a comparable traffic volume. He found that the high access control highway generated on the average 46% less tension among drivers than the road without access control. Rutley et al., in a study made in the U.S. in 1970 **(S13),** report that heart rate was significantly higher in roundabouts and freeway on-ramps than in freeway **off-**ramps and normal freeway driving.

Stokols et al. (S5) found that many researchers report a significant, positive correlation between traffic volume and increased level of heart rate, blood pressure and electrocardiogram irregularities. They also noted that highly complex traffic situations have been found to be associated with increased heart rate and blood pressure.

Therefore, it is clear that traffic volume and complexity of the situation affect stress. However, how it relates to satisfaction is not clear. A closer look at studies about route choice gives a better idea on the correlation.

Base of driving seems to be an important factor affecting route choice. **Heywood,** in a study made in the U.K. in 1985 **(R8),** reports that the main reason to change from the usual route, after the implementation of a bus lane on a highway, is the perception that it is the easiest route. From four interviews, he found that some drivers were reluctant to use shortcuts because of the difficulty of rejoining the main traffic stream. **Carpenter** (R4) interviewed 32 commuters in the U.K. in 1979 and found that most of them avoid minor roads. For them, the concept of "easiness of route" seemed to be a combination of task load items (number of left turns, number of junctions, simple to follow from map) and other stress components (familiarity with route, avoiding heavy traffic). Wachs, in a study made in the U.S. in 1967 **(RU8),** found that the most important factor affecting route choice was the preference for access controlled routes. Al-Deek et al., in a study made in the U.S. in 1988 **(B1),** report that route choice for commuters in Los Angeles is freeway biased. It may reflect a preference for ease of driving. However, this behavior may also reflect an attempt to save time for some drivers.

The number of stops and signals is an important factor affecting route choice **(R1,** R2, R3, **R5,** RU4, RU5, **SU6). Trayford** et al., in a study made in Australia in 1988 **(SU6),** report that the first preference in terms of driving objectives was comfortable speed or saving stops (64%). versus saving time or gas (36%). Some researchers **(R3, RU8),** report a preference for a controlled access road. Huchingson et al., in a study made in the U.S. in 1977 **(RU4),** where 215 drivers were interviewed at rest stops, report convenience as the major reason given for route choice.

In these surveys, the importance of ease of driving may be understated since drivers do not base their response on all available routes, but on the few obvious alternatives they know. These alternatives were found when they discovered the network. Shraagen has made a review of the literature investigating unfamiliar trips **(U6).** He reports that drivers prefer to stay on the major roads as long as possible, and only move to local road types when absolutely necessary. He writes that drivers know that main roads are generally faster and less stressful. Another possible explanation is that they are afraid to get lost on minor roads, since there are fewer signposts. However, it is likely that the few alternatives the commuter knows are easy routes, and this factor does not appear in their stated criteria.

In conclusion, a high task load may arouse physiological stress and affects route choice for some drivers. However, how it relates to user satisfaction with navigation systems is unclear. Nevertheless, it is possible that some drivers try to use their navigation systems in order to set their desired task load and to reduce some uncertainties about the driving environment they might encounter. Furthermore, navigation systems may reduce the task load in itself, since it can relieve the effort to follow a route.

According to **Averill** (S **15),** many psychologists believe that control over aversive stimuli helps reduce stress reactions. Although he acknowledges there is no simple relationship between personal control and stress, he believes that reduction of uncertainties has more potential than personal control to relieve stress. In terms of route choice, the commuter might set his task load relatively low for his everyday commute trip. However, he might accept a higher task load if he is under time constraints. For recreational trips, the driver might wish to minimize his task load. Conversely, if the actual task load on the route suggested by the navigation system is very different from the driver's expectations, he might react with a strong dislike of the navigation system.

3.2.5. Uncertainty

This last component includes all other identified stress factors which are related to uncertainty. The rationale is that decisions under uncertainty usually induce risk taking and/or a huge effort to process information. Both are likely to be potential stressors. Uncertainty is also strongly **correlated** with unpredictability of the situation and with feeling out of control of the situation, which are recognized as influencing stress.

Michaels, in a study made in the U.S. in **1962 (S8),** concluded that one of the determinants of driver tension is the degree of predictability that exists in the driving environment. In a study on urban streets made in the U.S. in 1960 **(S10),** he reports that the arterial with higher traffic and more pedestrians generates much more tension than an alternate route in residential areas. **Averill** (S 15) believes that there is no simple relationship between personal control and stress. He says it depends on the stress response and on the context.

Reduction of uncertainty seems to be a significant motivation for commuters to get traffic information. About 75% of commuters in the U.S. (SU4, SU5) say that they **would** use a telephone service which provides information about travel time on their alternate routes. For some drivers, it may be correlated with the fear of being late. Some drivers dislike unprotected left turns, at least according to studies made in the Netherlands **(R1,** R7). It may reflect an aversion to the delay involved in waiting for a break in **traffic** for some drivers, or a fear of accident for some others. Other topics related to uncertainty while **driving** include familiarity with route, fear of being lost and fear of accident.

Familiarity with a route usually implies greater comfort and lesser tension. Indeed, after driving more than a hundred times on the same route, the driver may know better the route, all exits and entry points, and where other vehicles may merge or suddenly brake. He may have a better knowledge of travel times, and may know how long they **are** likely to wait at each bottleneck. He also may know about the route ahead and the level of **traffic** they can expect on each part of the route. Nevertheless, driver reactions are likely to be affected by their experience with driving on unfamiliar roads. However, overall the situation is more predictable for **some drivers,** which may be reflected by a significantly higher commute satisfaction for some drivers. Carpenter, in a study made in the U.K. in 1979 **(R4),** reports that 9 out of 32 drivers interviewed preferred to use routes they knew. Further research is needed to know whether familiarity with a route has a strong impact on the driver's feeling of comfort and satisfaction. This is important since a navigation system will be likely to incite users to change route more often. How it **affects** perceived comfort is impoltant.

The fear of getting lost seems to significantly influence driver behavior. Carpenter, in a study ma& in the U.K. in 1979 **(R4),** reports that drivers without a good sense of direction "hate getting lost" and tend to follow the route they knew, even though the road scenery may be particularly unpleasant. Huchingson, in a study made in the U.S. in 1977 **(RU4),** found that the main reason why drivers did not divert around an incident was that they **were** unfamiliar with the area.

Perception of safety **(R1,** R3, **RU1,** RU7, **RU8)** seems to be a major factor influencing route choice. In particular, it is often a reason to reject a route, but seldom to select a route. For example, the major disadvantage of expressway driving is that it is perceived as unsafe, according to study ma& in the U.S. in 1956 **(RU1).** Although probably most drivers give little thought to safety on their commute, the few who do will attempt to increase their perceived safety. It is important to note that the fear of being involved in an accident, the uncertainty about other vehicles' behavior and the dislike of driving in certain environments generates high emotional reactions. Hence, it significantly influences satisfaction.

Uncertainty about finding a parking place may also be important, especially for unfamiliar drivers. It may be frustrating to drive around a destination without finding a parking place. Similarly, the fear of running out of gas may be a cause for worry.

In conclusion, familiarity with the road, fear of getting lost, parking information, and fear of accident may have some influence on driving comfort. Obviously, assisting drivers to find their way will increase their satisfaction. But also enabling them to choose their degree of familiarity with the road and their perceived safety may have some impact on satisfaction.

3.3. ROUTE CHOICE

It is obvious that research about route choice provides a lot of interesting facts. Unfortunately, the amount of research devoted to it has not permitted full understanding of why a driver chooses a particular route for his commute.

Many researchers assume that drivers select their routes on a time/distance/cost criterion. They succeed in predicting about 60% of the commuting trips (R2, R3, R4, R6, R8, R 10, R 11, R12, RU5, RU7, RU8). Many other researchers have identified some other relevant factors (convenience, comfort, safety, congestion, number of stops, ease of driving). But it is difficult to measure the relative weight of these correlated parameters.

A review of the literature has been made by van Winsum (R1). The next section focuses on a few facts which permit better understanding of how drivers perceive the network, try to process information, and answer questions about route choice. This would give an idea about what kind of improvements navigation systems can provide in perceptions and ability to process information.

1) Correlated parameters

Distance is correlated with time. Hence, when people say they minimize distance, it may mean that they minimize time also because they believe the two are proportional. Mcdonald, in a study made in the U.K. in 1989 (R14), tested this hypothesis. After interviewing subjects who spontaneously stated travel time minimizations as the most important route choice criterion, he found that other motives were very important, especially congestion avoidance.

It may reflect the fact that, when asked about their reasons, travel time is most commonly named. However, the actual choice is based on several important criteria. It is a well-known fact from communication research that what people say is not what they mean. The answers seem to be an oversimplification of the decision process.

2) Unlimited number of parameters

More than 50 different parameters have been identified. Nevertheless, nobody can be sure that all parameters have been identified, since parameters such as the presence of children in the car or road lighting at night may be very important for some drivers. It seems that each driver has his own road characteristics he focuses on in order to select his route. The identification of each driver's most important characteristic may be difficult.

3) Limited knowledge of the network

From research conducted independently in Europe and in the U.S., it appears that drivers know two or **three** routes for their commute, and 70% do not know more than three **(R1, R5,** RU8, SU7). Similarly, it appears that many drivers fail to optimize their stated criteria **(B5,** R2, R5, R8, **R10, R1** 1, R13, RU6). It may be explained by the fact that some drivers do not correctly perceive the actual road characteristics **(R9),** or that some of them do not know the fastest route. It is possible that some commuters know only one route, but know everything they need to know to find the fastest route. Nevertheless, a navigation system may help some drivers to know the network better, and information about alternate routes may be of some value for them.

4) Erroneous perceptions

Road characteristics are not measured accurately by drivers **(2.2.2.),** especially travel time (R7, RU2, **RU8,** U4). Not only do drivers perceive inaccurately absolute value road characteristics, but also they have difficulty evaluating relative values of road characteristics. Many drivers make mistakes when ranking two roads.

Bonsall et al., in a study made in the U.K. in 1986 **(R3),** noted that several drivers who claimed to be seeking the least congested or quickest route actually used significantly different routes. Although congestion is a subjective factor, and origins and destinations were slightly different, Bonsall and May believe that such reasons explain only a small proportion of the anomalies.

Campbell et al., in a study made in the U.S. in 1956 **(RU1),** found that, in comparing two routes they sometimes used'

- only 68% of drivers were able to rank them correctly for distance
- only 63% of drivers were able to rank them correctly for time
- only 38% of drivers were able to rank them correctly for distance and time.

Furthermore, 25% of the drivers who lost time on the freeway believed that it was quicker: 70% of the drivers who lost distance on the **freeway** compared to the other route sometimes used, believed that they had gained distance.

It is possible that these results are not caused by a lack of ability to measure the characteristics, but by a lack of effort spent in comparing the routes. At the time of this study, there was not much congestion. It is possible that some drivers did not care enough about travel time and distance to spend the effort to accurately compare the routes. A navigation system which provides drivers with accurate road characteristics may be of some value for these drivers.

5) Strive to give rational answers

It is a well-known fact from sociology that society encourages rational, serious, businesslike behavior. Although sometimes decisions are based on emotions, most people will strive to justify them afterwards by logical reasons. For example, if you ask your neighbor why he bought a Mercedes, he will not say "I'm so proud to be able to afford one," you will rather hear something like "It's such a well-built, reliable car." In terms of route choice, it means that drivers tend not to say "I just like this route, it satisfies me" but rather, "It's the fastest route," especially if they believe that it is the fastest among the few they know. Hence, answers given are more rational than actual reasons.

Schoppert et al., in a study ma& in the U.S. in 1960 **(RU10),** investigated how drivers plan a route to an unfamiliar destination. There were large differences between actual and stated planning. Burrel, in a study ma& in Germany in 1968 **(R15),** found strong evidence that respondents overstate regularity in their behavior. Benshoof, in a study ma& in the U.K. in 1970 **(R5),** explained results found by suggesting that route selection is a largely irrational process for many drivers, who may indicate certain reasons in the questionnaire for the sake of filling space.

6) Network dependency and context

Reasons for route choice depend on differences in characteristics among the available routes on the network. For example, if all the known routes require the same level of task load, then task load is not quoted as a reason for route choice, although it may be very important for the driver.

Each network and origin-destination trip offers some specific trade-offs for the commuter: time vs. distance, congestion vs. distance, congestion vs. task load. The answers given by the respondent may be based on personal trade-offs on the commute, or on the interview words and choices offered, but not always on preferences about routes in general.

Furthermore, navigation systems will probably change the context dramatically. From information about a few routes, drivers will get comprehensive, reliable information about many alternatives, depending on the navigation system. It might change the trade-offs offered, their stated preferences, and hence their behavior. You might hear something like, "When I didn't have a navigation system, I always took the same route. Now I can choose the fastest, the easiest, or the least congested route, depending on **traffic** conditions, time constraints, and my mood."

In conclusion, route choice research is still in its infancy. It appears that route choice, for most drivers is a trade-off between objective, rational criteria (time, distance, cost), and subjective, emotional criteria (congestion, **stress,** task load, scenery). Although one has a tendency to believe that it is based on objective and rational criteria, it seems **more** and more clear from research that emotional criteria have a dominant role. It is likely that each driver has his own perception (way to select, organize, and interpret information), preferences and dislikes, and ability to assimilate information. Hence it may be very difficult to predict what a particular driver desires.

3.4. PRE-TRIP INFORMATION

Here, **pre-trip** information does not mean information about recurrent congestion. It means any predictable congestion at the moment when the trip begins. At this moment, all incidents which occurred previously are known. An incident that occurred 15 minutes ago causes congestion for an hour. Its effect on traffic could be forecasted, assuming the existence of an efficient prediction tool, and its consequences included in the information given. Hence, uncertainty during the trip could be reduced to the lack of precision of traffic predictions, and from incidents **occurring** during the trip, which is typically in the order of 30 minutes.

Providing information before the trip begins, either within the car, at home, or in the office may be very valuable for some drivers. The driver can assimilate and analyze the information, and decide on departure time and route before beginning the trip. About 90% of the drivers choose their routes before starting, according to research conducted in the

U.K. (R3, R5). In fact, pre-trip information may relieve most of the stress due to uncertainty about how long the trip is going to be, is there some congestion ahead, where there are available parking places, which route is the best today. About 75% of the commuters in the U.S. (SU4, SU5) say that they would use a telephone service which provides travel times for their alternate routes.

Pm-trip information may also assist the commuter to compare objectively the road characteristics of the available alternatives. Mahmassani et al., in a study made in the U.S. in 1987 **(DT16),** have examined the effect of availability of full information when commuters experience the network. Actual commuters interacted with a simulated commuting system. Every day for seven weeks they were informed about their travel time the previous **day** and they chose their departure time and route choice for the same day, depending on their previous experience and the information available. One group of commuters had no more information than their previous experience. The other group had full information, including travel time estimates on each route, depending on departure time.

After 30 days, about 10% of the people switched route or departure time, compared to about 80% at the beginning of the experiment. Hence, the situation was almost stable. Travel times of people having full information was then 19% shorter than travel times of people having limited information. Furthermore, people with full information needed to switch less and reached their stability faster. That means that the task was much more easy and convenient for them.

Therefore, it is possible that providing information before the trip begins would provide some valuable information for some drivers.

3.5. CONCLUSION

This part has attempted to identify some other services that can be provided by navigation systems. From the literature, it appears that drivers have different expectations, and that perceived benefits may vary a lot among individuals. The notion of perceived benefits is particularly important. Although navigation systems are designed and sold as travel time savers,

some people may want to use them to avoid congestions;
some people may want to use them to reduce their risk of being hate;
some people may want to use them to save time;
some people may want to use them to set their driving task load;
some people may want to use them to compare objectively the road characteristics of the available alternatives;
some people may want to use them to reduce some uncertainties about the trip before it actually begins;
some people may feel proud to have the high-tech equipment in their cars.

In fact, most people will probably want to make their trade-off among these objectives. For each of these people, the perceived benefits are very different. Some preliminary results from the LISB Route Guidance and Information System Berlin (A 11) report that about half of the users perceive travel time savings always or almost always, while the other half perceive travel time savings seldom or never. How many drivers try to avoid congestion, save time, or reduce uncertainty does not affect satisfaction. The essential fact is that a huge majority of drivers actually perceive some benefits.

Hence, it may be important that a navigation system provides a lot of services other than time savings, since it may enlarge significantly the potential market for navigation systems.

4. CONCLUSION

Relative travel time using equipped and unequipped vehicles decreases as the percentage of vehicles increases, such that relative time savings may appear insignificant far some users when a majority of vehicles are equipped.

From the literature, it appears that driver behavior reflects not only a willingness to save time, but also to avoid congestion, avoid being late, set the driving task load, and reduce uncertainty. Some of these factors are correlated but they reflect different trends among drivers.

Therefore, navigation systems might consider stress-relieving factors among the benefits from the user point of view. Furthermore, providing some information before the trip begins may provide some additional valuable benefits. Thus, providing many services in addition to time savings may expand significantly the potential market of navigation systems.

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