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Telematics and freight transport: a Dutch case study

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Abstract. Telematics applications have been introduced in the transport sector in order to improve the effective use of infrastructure networks, on the one hand, and to optimize the performance of the firm, on the other. In general, there is a lack of micro-based research in analyzing telematics applications. In this paper we study the familiarity, adoption, use, and investment plans of commercial freight transporters with respect to a number of these technologies, on the basis of a survey conducted in the Netherlands in 1994. Results show, amongst other things, that: (1) markets for the various technologies are far from saturated; (2) adoption follows usual innovation diffusion patterns, with large firms being the first adopters; (3) automatic vehicle location systems are used only in combination with mobile telecommunications technologies.

1 Introduction

The marriage between telematics and transport has given birth to an increasing number of children. All these offspring appear to have in common the fact that they originate from the need to improve the efficiency of the use of physical infrastructure and to reduce the deterioration of the environment, two phenomena which are closely related. The oldest child, or the one which first invoked interest among researchers and policymakers, is the option of telecommuting. Although initially there were great expectations of this child, on growing up it has proved to be somewhat disappointing (its potential has not been adequately exploited) (Mokhtarian and Salomon, 1994). A second chance came into being by the birth of telematics aimed at optimizing the use of various transport modes. Numerous telematics applications have been developed in this field. In the second section of this paper, we provide a typology of these applications. A subset of these is the subject of this paper; in particular, those that can be used to optimize the operations of freight transporters. We study them empirically, exploiting data from a survey conducted in 1994 among Dutch freight transport companies about the familiarity and use of telematics in freight operations. Our goal is to gain insight into the present level of adoption, use, and appreciation of the various types of telematics applications and to make inferences about the future course of adoption. In the background, as an implicit theoretical device, is the familiar innovation adoption theory (for example, see Davelaar, 1991).

In section 2 the general context of this study is described, and in section 3 we describe in more detail those telematics applications that are the subject of this paper. In section 4 we introduce and describe the survey and also present a descriptive analysis of the data, focusing our attention on the issues of usage, investment plans, etc. In section 5 we deal with a number of topics that are investigated more thoroughly on the basis of the data. Besides characterizing users and nonusers, we also seek to explain the differences between them, to address the topic of innovation diffusion, and to look for dependencies in the use of various sytems (complementarities or substitutabilities), etc. A general framework within which these findings can be placed is presented in section 6, which may serve to guide future research in this area.

2 Telematics in freight transport: setting the stage

The fundamental property of all telematics applications is the improvement of information provision. This improvement is of two types: the speed of information provision and the volume of the information provided. In the case of speed, the limit (real-time information) has been reached in many instances, for example, in route guidance systems. The scope for extending the volume of information is, however, practically unlimited, although bounds are set by the possibility of processing all the information supplied. Yet one should be aware of the fact that the volume of information might, in principle, easily be extended in a number of trivial instances. For example, radio broadcast information about traffic jams normally gives only the location (as exact as possible), the length of the queue, and incidentally the cause of the jam. However, this is basic information and hardly sufficient to make a decision whether or not to try an alternative route. Ideally, additional information is required and includes:

(1) the dynamic aspects of the queue—is it growing or shrinking, and at what rate;
(2) the average speed with which vehicles drive in the queue;
(3) the estimated time for which the queue exists;
(4) traffic intensities on the feeding routes;
(5) traffic intensities on the alternative routes.

All this, and perhaps more (also depending on personal circumstances), is required to arrive at a basically dichotomous decision: should I join the queue or try an alternative route. Theoretically this decision reduces to the question which option involves the least expected all-in costs (time, money, psychological costs, etc). Thus the information should lead to rational estimates of the costs resulting from the available options, which requires estimates of the various cost components and the associated probabilities.

Another point clarified by this example is that the volume of information has to be carefully and deliberately considered. Too much information, on the one hand, simply cannot be processed, with the result that a part of the information will not be used or that the decisionmaker gets too confused to make any decision at all. This is called saturation in the literature (Ben-Akiva et al, 1991). Too little information, on the other hand, does not lead to any changes in behaviour. An obvious, but at the same time very delicate, way to proceed is to supply information users with summary data. In the case of the above example, the provided information may be, for example, the expected time to go from point A to point B by route X is x minutes, and via route Y y minutes. The delicacy of this kind of information provision is again easily observed: how reliable is the information given in this format? Is the user also interested in estimated standard deviations.

In this paper we restrict ourselves to the use of telematics in the transport sector. In this sector, a variety of telematics applications can be found. These applications can be classified according to two criteria (see figure 1). The first criterion is whether the information which is generated by means of the telematics application is of a general kind, or restricted to a specific aim. We call this general use versus specific use. The second criterion is whether the information generated is publicly or privately available. Examples of telematics applications are given in each of the four cells of figure 1. This scheme also reveals that one can associate with each cell a typical kind of information dissemination pattern. An example of general and

Also, the specific applications have the advantage that their use is restricted to the specific information that is provided; hence all redundant and superfluous information can be removed. Consequently, the general types of informaton have to lead to a significant efficiency effect in order to be of interest to the user. A similar comment holds for the relationship between public and private applications. Again, the private ones have to generate an important efficiency gain to be relevant to the potential user.

In this paper we will study the application of private telematics in freight transport (for studies on two public-specific applications, see Emmerink et al, 1996; and Ouwersloot et al, 1996). The telematics applications which are under study here are: mobile telephony (MT); automatic vehicle location systems (AVL); satellite communication systems (SC); and on-board navigation systems (NS). Besides these applications we also discuss electronic data interchange (EDI) which is the transmittance of freight-accompanying documents by electronic means. In some respects, EDI is different from the other telematics applications mentioned above, in particular, as its primary aim is not to support the driver in making decisions. Yet there are two reasons for including EDI technology in this study on a comparable basis: first, EDI is a true telematics application, that is, an offspring from the marriage between telecommunications and computer technology; second, like the others, EDI is aimed at reducing operating costs. Moreover, as a telematics application it is of the private and specific type. Nevertheless, the specific nature of EDI has to be taken into account in interpreting the results in the remainder of this study.

3 Potential benefits of telematics

Innovations will be adopted when the benefits outweigh the associated costs. These benefits depend on the extent to which the characteristics of the innovations correspond to the needs of the firm. Therefore, to answer questions on the adoption pattern of innovation it is necessary to get a clear insight into their potential benefits. For each of the telematics applications under study here, we will discuss briefly these benefits.

Mobile telephony offers the possibility for the home office and the driver to be in permanent contact. This implies, in the first place, that all relevant information can be exchanged instantaneously, so that both the driver and the office can be provided with sufficient and up-to-date information. This information is useful only if decisions—or adjustments therein—are likely to be made during the trip. There are several relevant situations in which this may be the case:

(a) the driver has to pass some highly congested routes, for which alternatives are available;

(b) the complete route (in particular the return trip) is not fixed beforehand;

(c) there is a high probability that situations arise in which the driver needs office information or guidance, for example, conflicts with controls or receivers, emergency situations, etc.

A second consequence of MT is that the driver loses some part of his or her autonomy when driving the truck or, in other words, that the home office gains control over the driver. It may be hypothesized that this is in the interest of firms that want to have a structured control over their drivers, for example, because of the lack of informal links. Hence, it seems plausible that large firms are more intensive users of MT.

Automatic vehicle location systems are at first sight exclusively in the interest of the home office. It is, however, difficult to think of any benefits to the firm when AVL is used without a means of communicating with the driver. Thus it seems logical that AVL will almost exclusively be used in combination with interactive communication media such as MT or SC (see below). An exception may be those firms with drivers plying routes on which they make frequent stops where they can be called, for instance, in a densely populated area. In any case, AVL will be useful when routes are to some extent not fixed.

Satellite communication systems are similar in their benefits to MT but may be assumed to have a larger operating radius. An important shortcoming of MT is its dependence on local telecommunications systems. With SC this can largely be overcome. Hence compared with MT, SC will most likely be used by operating firms internationally. A further advantage of SC is the digital technique on which it is based. This means that information transfer is much more reliable, which may be important when data transmission is involved. It is important to note, however, that the introduction of digital MT systems—which occurred after the survey on which this study is based was held—and particularly those systems based on the so-called GSM technology (global system for mobile telecommunications) have made SC largely redundant. GSM is a digital system which has been adopted in a number of important European countries, and functions more or less as a European standard. Hence, both advantages of SC—digital technology and Europe-wide use—have practically been met, whereas the disadvantages of SC, in particular its relatively high costs, have remained.

On-board navigation systems are clearly of direct benefit only to the drivers and not to the home office, especially when the driver has to find his way in new situations. Such new situations may relate to a congested route or to an entirely new route. NS will therefore most likely be used by firms with predominantly stand-alone contracts, but also by firms which operate on a large spatial scale, as drivers tend to be familiar with the road network only when they drive in a relatively limited geographical area. It should be noted that for NS both real-time and stand-alone systems exist. Clearly, real-time systems are far more adequate and can therefore have a different impact. The distinction was not made in the survey, however, and hence we will not use it. Moreover, the distinction between real-time and stand-alone systems makes no difference from the point of view of typology: in both cases the application is of the general and private type.

The benefits of EDI are of two kinds. First, guaranteeing that the freight-accompanying documents arrive at the locations where they are needed (delivery points, but also national borders) before the truck arrives means that the control at these points can be prepared in advance, and can therefore be carried out much more efficiently. This will reduce waiting time for the drivers. A second advantage of EDI, but also a precondition for its use, is that standard formats are used and hence the chances of errors and interpretation difficulties are reduced to an absolute minimum. Consequently, as standard formats are particularly useful in communications between partners who are familiar with each other, EDI may be expected to be used more often by firms that work predominantly with a more or less constant set of trade partners, for example, on a contracting base. It should be noted that EDI is typically a network technology. This means that adopting EDI is useful only when other actors, in particular the trade partners of the firm and the regulatory authorities, also adopt EDI. This is another distinctive feature of EDI, in relation to the other applications. These other applications can be used perfectly by firms on their own, as they do not refer to communications with actors external to the firm, but are all directed to intrafirm information exchange.

4 A survey on the use of telematics among commercial fleet operators in the Netherlands

In this section we will describe in brief the elements of a survey focused on the adoption of telematics technologies by truck operators in the Netherlands. The survey was organized in the framework of a broader empirical research project on the market potential of telematics, coined MARTA (Monitoring Attitudes towards Road Transport Automation). This project was undertaken as part of the EC DRIVE II programme on telematics in transport. Its aim was to survey the "ATT requirements and responses of inter-urban fleet operators in the Netherlands", where ATT stands for advanced transport telematics. A questionnaire was composed which gathered background data on the characteristics of the firms—namely, firm size, geographic orientation, dominant type of freight, dominant type of orders—and a number of issues related to the telematics application, namely, knowledge, actual use, experience and satisfaction levels, intended use, ideas about the level of investments, perception of advantages, and reasons for nonadoption.[1]

The questionnaire was sent to a stratified sample of 1172 Dutch goods transport companies. The sample was stratified so as to include a sufficient number of medium-size and large firms which are usually market leaders and whose absence might not have provided sufficiently interesting insights into the developments of the sector concerned. In addition, large firms were expected to be the more intensive users of the above technologies and thus more interesting for our investigation.

Table 1. Characteristics of the sample.

	Sample	Population
Firm size (number of vehicles)		
1-4		6566 (65%)
5-9		1338 (13%)
1-10	31 (10%)	
10-19		1063 (11%)
11-20	94 (30%)	
20-49		770 (8%)
21-30	73 (23%)	
31-40	37 (12%)	
⩾41	79 (25%)	
⩾50		346 (3%)
Spatial orientation		
Regional	17 (5%)	
National	69 (22%)	
West Europe	182 (57%)	
'World'	47 (15%)	
Dominant contract type		
Fixed	170 (53%)	
Mixed	115 (36%)	
Stand alone	32 (10%)	
Automated activities		
Fleet trip planning	44 (14%)	
Route planning	15 (5%)	
Both	34 (11%)	
Neither	221 (70%)	

[1] For interested readers the questionnaire is available on request from the authors.

The response rate was 27% (n = 320) which—compared with similar surveys—may be considered to be satisfactory. The distribution of firms by firm size measured in vehicles, for both the sample and the population, is given in table 1. The overrepresentation of large firms is evident and should be taken into account where relevant. Some other sample statistics are also given in table 1, notably those related to the geographical orientation of the firm, the type of contract most often used, and the present practice of automation in the firm.

The stratification implies that sample results have to be weighted for statements about the population. This calculation of the weights, which is not straightforward owing to the different categories, is explained in the appendix. The weighting factors thus determined are given in table 2. Further information on other details of the survey can be found in Nijkamp and Pepping (1995).

We already note that the data with respect to SC should be considered carefully. As mentioned above, during the period of the survey SC was challenged by the introduction of the GSM mobile telephony, making SC systems suddenly almost redundant. Hence data related to SC in the past have a different context compared with those related to the future. For example, if we find that companies had significant investment plans for SC at the time of the survey, this does not imply that they still have these plans, as they would probably prefer to invest in GSM mobile telephony nowadays. This may complicate the interpretation of the results.

Table 2. Weighting factors.

Firm size	Sample	Weight	Sample estimated
1-10	31	5.52	171 (54%)
11-21	94	0.83	78 (25%)
21-30	73	0.49	35 (11%)
31-40	37	0.44	16 (5%)
⩾41	79	0.17	13 (4%)

5 Analysis and discussion

In this section we will present and interpret various empirical results from the survey. In the subsequent analysis we will treat the data related to EDI separately, given its somewhat different character (see section 2).

5.1 Electronic data interchange

EDI was introduced in the Netherlands about a decade ago. At present, about 61.3% of the firms in our sample seem to be quite familiar with EDI, although only 15% of the companies surveyed appear to use EDI. A proper weighting of these figures leads to national estimates of 34.0% for familiarity and 8.7% for use. The fact that just about a third of the firms are familiar with EDI, and that only a quarter of these actually use it, indicates that the EDI market is far from saturated.

From the description given in section 3 we expect that EDI will more often be used by:

(a) firms with predominantly fixed contracts, opposed to stand-alone contracts;

(b) firms facing more control points, that is, international transport companies.

In addition, with reference to conventional diffusion theory it seems plausible that large firms are more frequent adopters of EDI. These hypotheses were investigated by estimating a logit model, with EDI adoption as the endogenous variable and the above-mentioned variables as the explanatory variables (see table 3, see over). The results show that the dominant type of contract has the a priori expected effect on

EDI adoption. Also, firms operating worldwide, as well as firms from the largest size category are more frequently users of EDI. However, estimates for the other categories are less in line with our prior expectations, but it should be recognized that these estimates are also not significant. So in general we may conclude that some support for our hypotheses is found in this estimation.

Table 3. Logit estimation of EDI adoption (dependent variable: has the firm adopted EDI).

Variable	Estimate	Standard error
Contract type		
fixed	1.01	0.40*
stand alone	−0.25	0.83
(mixed	0.0)	
Spatial orientation		
(regional	0.0)	
national	0.61	1.15
West Europe	−0.16	1.14
World	1.22	1.17
Firm size		
(1–10	0.0)	
11–20	−0.09	0.88
21–30	0.77	0.86
31–40	−0.09	0.99
⩾41	1.78	0.84*
Constant	−3.42	1.19*
Number of observations	313	
Log likelihood (base model)	−132.40	
Log likelihood (full model)	−110.99	
Likelihood ratio test (9 df)	42.82*	

Note: EDI, electronic data interchange; df, degrees of freedom.
* Significant at 5% level.

Next, users of EDI appear to be overwhelmingly *satisfied* with this technology. Only one out of the 48 users indicated to be unsatisfied, and five were indifferent. This appears to be very encouraging for EDI manufacturers, although two remarks are in order here. First, statements about satisfaction through the adoption of a technology should always be read with great care, as entrepreneurs may not be eager to admit that they are disappointed about their innovation. Additional objective information (for example, the share of EDI in the information-processing activities of the firm) is therefore preferable. Second, there may be some influence of stratification at this point, because only those firms which presently use EDI responded to this item. In particular, those firms that previously used EDI, but have stopped using it because they were unsatisfied, are badly missed in this respect. In the same context, it may also be indicative that just about 20% of the users are *very* satisfied with EDI.

Perhaps most interesting is the question of *investment* plans. Again we have used a logit model to investigate the determinants of investment plans. The explanatory variables are the same as in the estimation of the use of EDI, but in addition this use of EDI was included here. The results are given in table 4. Clearly, the current use of EDI and the existence of investment plans are strongly related. Apparently firms are truly satisfied with EDI and therefore foresee an expansion of its use. The other explanatory variables tell a more or less similar story as in table 3, but with a different emphasis. The spatial scope of the activities of the firm appears to be a reasonable explanatory variable, in that it supports the hypothesis that firms operating internationally are relatively more interested in EDI. Also the size of the firm gives the a priori expected result. The dominant type of contract, however, does not lead to the expected outcomes, which is less easy to understand. A possible reason may be that fixed contract firms have reached their saturation level of EDI investments in contrast to other groups, as they were the first to adopt the technology, and may also be expected to have completely installed their equipment first in this sector.

It is interesting to note at this stage that it is really the actual use of EDI that counts in explaining investment plans, not the reported level of satisfaction. When this latter variable is used (by means of two dummy variables, one for firms which are very satisfied and a second one for 'normally' satisfied firms), instead of the EDI use, the estimation leads to statistically inferior results, despite the increased number of explanatory variables![(2)]

The (tentative) conclusion that can be drawn from this analysis is that firms tend to adopt EDI in the predicted way (that is, they appear to adopt it rationally) and that the adopters are almost unequivocally satisfied with the technology, even to

Table 4. Logit estimation of EDI investment plans (dependent variable: does the firm have plans to invest in EDI).

Variable	Coefficient	Standard error
EDI use	2.39	0.41*
Contract type		
fixed	0.12	0.38
stand alone	0.67	0.57
(mixed	0.0)	
Spatial orientation		
(regional	0.0)	
national	0.45	0.98
West Europe	0.42	0.95
World	0.74	1.01
Firm size		
(1-10	0.0)	
11-20	−0.49	0.86
21-30	0.68	0.81
31-40	0.68	0.87
⩾41	1.93	0.78*
Constant	−3.24	0.90*
Number of observations	314	
Log likelihood (base model)	−162.78	
Log likelihood (full model)	−115.85	
Likelihood ratio test (0 df)	93.86*	

Note: EDI, electronic data interchange; df, degrees of freedom.
* Significant at 5% level.

(2) This observation allows an interesting methodological remark. Both use and level of satisfaction can be interpreted as variables indicating that the (perceived) benefits are greater than the (expected) cost. However, in such a context the use variable would act as a revealed preference, and satisfaction as a stated preference. The observation then shows that the revealed preference statistically outperforms the stated preference approach. Note that this similarity in the background is a reason for not including both variables in one estimation.

such extent that users have a strong incentive to make further investments. The analysis suggests that firms working predominantly with fixed contracts have not only adopted EDI first, but also completed their investments earlier.

5.2 Mobile telephony, automatic vehicle location, satellite communication, and on-board navigation systems

Next we will turn to the broad category of telematics systems outside the EDI realm. Table 5 gives some basic statistics on this group of telematics applications in the transport sector. With the exception of MT, the adoption rates are very low, although the familiarity is reasonable for all applications. This means either that firms are not convinced of their usefulness and hence will not use them in the near future too, or that there is a large potential market which just has to be developed.

Table 5. Basic statistics of advanced telematics applications (in percentages).

	Unweighted	Weighted
Use		
MT	23	21
AVL	3	1
SC	5	2
NS	0	0
Familiarity		
AVL		
very familiar	9	5
quite familiar	48	33
SC		
very familiar	9	4
quite familiar	49	41
NS		
very familiar	3	2
quite familiar	41	30

Note: MT, mobile telephony; AVL, automatic vehicle location systems; SC, satellite communication systems; NS, on-board navigation systems.

In section 2 it was argued that AVL is *used* most probably in combination with MT or SC. This is confirmed by the data, as indeed all nine AVL users also use MT or SC. On the contrary, MT and SC are not considered as complementary systems because eleven firms report the use of both technologies. It may be seriously questioned, however, whether these firms view the two technologies as distinct, or rather think that MT use is based on satellite technology. It was also argued that firm size is the most important characteristic that may discriminate in the adoption of MT or SC. This argument hinges on the increased control for which the demand may be greater in large firms, and the investment argument may also play a role (as for all new technologies, larger firms may be assumed to be better able to raise the necessary capital for the investment). Estimation of a logit model explaining the adoption of MT or SC by firm size and the other firm characteristics gives some support to this hypothesis, as it is especially the large firms which are much more likely to be users of MT or SC (see table 6; note that all size categories are insignificant, but the largest category is the only one with the correct sign).

Adoption levels of the other technologies are too low to investigate this further meaningfully. Instead we will turn our attention now to such aspects as familiarity and intentions for *investments* for these three technologies (investment plans for MT

Table 6. Logit estimation of adoption of mobile telecommunications technologies (dependent variable: adoption of mobile telephony and/or satellite communication systems).

Variable	Coefficient	Standard error
Contract type		
fixed	−0.25	0.30
stand alone	−0.48	0.53
(mixed	0.0)	
Spatial orientation		
(regional	0.0)	
national	−0.07	0.70
West Europe	−0.64	0.68
World	0.96	0.73
Firm size		
(1−10	0.0)	
11−20	−0.08	0.55
21−30	−0.24	0.58
31−40	−0.75	0.69
⩾41	0.64	0.55
Constant	−0.82	0.65
Number of observations	313	
Log likelihood (base model)	−173.45	
Log likelihood (full model)	−157.07	
Likelihood ratio test (9 df)	32.85*	

Note: df, degrees of freedom.
* Significant at 5% level.

were not surveyed). We recognise that the discussion below is severely restricted by data limitations. Investment plans will probably depend critically on past investments, both in the dimensions of amounts and in the timing. However, information on these variables was not available to us.

First of all, we find that all adopters of AVL and SC report to be very familiar with the technology concerned[(3)], and in addition that they are all (very) satisfied with it (recall that there are no users of NS yet). Moreover, a majority of the current AVL and SC users have plans for further investments in the applications. The maximum amount that these firms are willing to invest per vehicle for these technologies is more or less uniformly distributed over the categories 1000−2500, 2500−5000, 5000−7500, and above 7500, although it is noteworthy that for SC the more expensive categories accounted for more responses.[(4)] The maximum amount for office equipment is below 50000 (with an equal share between the categories 0−15000 and 15000−50000) for all but one respondents. Finally, it is remarkable that almost all AVL users have plans to invest in SC, but that SC users are more hesitant to invest in AVL. This is in line with the previous observations that AVL is particularly useful in combination with (advanced) telecommunications devices, whereas these latter can be used perfectly as stand-alone devices.

Next, we concentrate on firms which are not yet users of specific technologies. It seems reasonable to expect that intended investments are positively related to the degree of familiarity with the technical possibilities of the technology concerned.

(3) Except for two SC users who report to be only 'quite familiar', perhaps because of its recent introduction.

(4) Amounts in Dutch guilders. The first category listed was 500−1000 guilders.

The data show that this indeed holds for AVL and SC, but for NS the opposite holds: seven firms report investment plans, five of which admit that they are unfamiliar with the technology. This unfamiliarity with the technologies also explains the relatively large difference in the indicated investment amounts per vehicle which the firms are willing to pay. That is, nonusers that have investment plans typically report much lower amounts. For example, none of the users indicated a maximum amount per vehicle below 1000 guilders, whereas 10% (AVL) and 6% (SC) of the nonusers are in this range. This may be interpreted as a clear underestimation of the required investments in the technology owing to unfamiliarity. However, the observation that SC is perceived as more expensive, made when discussing the investment plans for users, is confirmed, as the average amount for this technology is expected to be higher. Moreover, the willingness to pay for NS appears to be in the same order of magnitude as for AVL. This suggests that these two technologies are perceived as equally useful. Figure 2 shows a Venn diagram that illustrates the finding that firms tend to combine technologies. Each subset consists of those respondents with a positive intention to invest in any of the technologies, and the intersections of the subsets thus show the number of firms that intend to invest in two or even all three technologies. The figure suggests that firms tend to adopt technologies in combination, in particular by combining the standalone applications AVL and NS with an interactive application such as SC, apparently expecting the synergy effects that we pointed out in section 3.

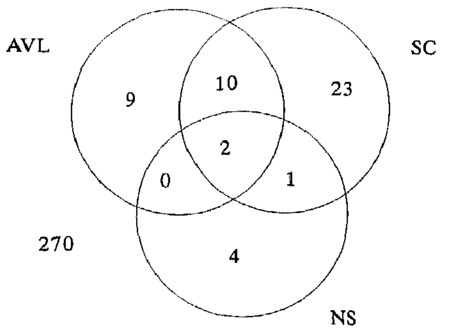

Figure 2. Number of respondents that have intentions to invest in (combinations of) technologies (note: AVL, automatic vehicle location systems; SC, satellite communication systems; NS, on-board navigation systems).

Finally, we investigate whether the above findings may be explained by the perceived benefits that the firms have mentioned. Respondents were presented a short list of possible advantages[5] that may be obtained by using any of the three technologies AVL, SC, or NS. For each of them the firm could indicate whether they considered the mentioned benefit as a reason to adopt any of the three telematics applications. In doing so, the firms were not restricted to indicate only one benefit, but could choose any number of benefits. Unfortunately, in answering this question, firms were not asked to specify which specific benefit was related to which technology (in case they had investment plans for more than one technology, which is a common occurrence). Moreover, for practical reasons only those firms were interrogated that

[5] The seven suggested benefits are: strategic company position; information supply to forwarders and receivers; speed and punctuality of delivery times; efficiency/load ratios of the vehicles; control in case of traffic congestion; reduction in driven kilometres; coordination in case of trouble or monitoring of dangerous goods.

had indicated to have at last some intention to invest. It would of course also have been interesting to observe what possible benefits firms expect from these technologies, even if they do not intend to adopt them shortly. The possible benefits that were suggested in the questionnaire and to which the respondents mainly adhered, as could be expected, can be aggregated in three groups with increasing degree of concreteness: strategic aspects (strategic company position); concrete quality improvements (information supply to forwarders and receivers, speed and punctuality of delivery times, control in case of traffic congestion, coordination in case of trouble or monitoring of dangerous goods); and contribution to cost reduction (efficiency/ load ratios of vehicles, reduction in driven kilometres).

The analysis of the questions related to this aspect are very revealing. Figure 3, comparable with figure 2, shows the number of times a firm mentions at least one of the reasons under the headings strategic, quality, or cost as a perceived benefit of telematics applications. The figure shows that firms tend to concentrate on the quality and cost benefits. The number of firms mentioning strategic benefits is substantial, but they always mention at least one of the other benefits too. Indeed, quality or cost benefits are hardly ever mentioned alone as the reason to consider new investments. Table 7 relates the familiarity of the technology to the perceived benefits. The table shows that familiarity leads to higher expectations concerning the strategic and quality benefits, but shows no impact on the expected cost benefit. Also note that the absolute percentages for each potential benefit do not differ dramatically between familiar and nonfamiliar firms or across technologies, particularly for the qualitative and cost benefits. Hence it can be concluded that familiarity

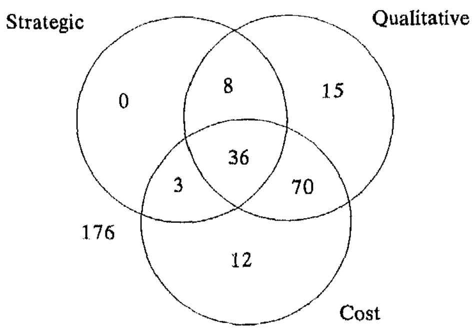

Figure 3. Number of firms that expect or perceive various types of benefits.

Table 7. Relation between familiarity with respective technologies and types of perceived benefits (in percentages).

	Benefits		
	strategic	qualitative	cost
Automatic vehicle location systems			
very or quite familiar	37	92	82
not familiar	24	88	88
Satellite communication systems			
very or quite familiar	34	93	86
not familiar	30	81	81
On-board navigation systems			
very or quite familiar	39	95	84
not familiar	29	86	86

leads to increased expectations concerning the less concrete benefits such as strategic and quality aspects, and also that the perception of benefits does not depend on which technologies the firms are familiar with.

Another aspect which may be related to perceived benefits is the level of intended investments. An ad hoc reasoning would suggest that the more benefits a firm perceives, the higher the intended investments, and it also seems plausible that the more concrete these benefits are, the higher the investments. However, applying a linear regression to explain the maximum amount per vehicle that the firm is willing to invest with the three benefit variables defined above reveals that these benefits play no significant role whatsoever. On the contrary, the fact that a firm is already a user of the respective technologies is by far the most important factor explaining differences in the level of the investment plans. This is quite surprising, as it was observed above that familiarity with the relevant technologies made firms somewhat unsure about the expected cost benefits. Apparently, firm-specific and site-specific experience brings them to higher investments. The picture that emerges from this discussion is that firms do not have a clear idea of what benefits telematics applications can bring to them. They suspect that there are benefits, but are unable to indicate clearly where they can be found. Consequently, the answers to the investments lack any structure, and are presumably driven by other considerations than a cost-benefit evaluation.

The overall suggestion that comes to the fore is that firms which have invested in telematics technology start to learn about it and find that it is not as cost reducing as they had thought. Yet, at the same time, they find that the quality and strategic benefits are more important than they had expected. This inspires the firms that already adopted the technology to raise the investment levels. Moreover, as the experienced firms have better (that is, higher) cost estimates of the required investments than uninformed firms, the former ceteris paribus report higher expected investment levels.

6 Synthesis

The adoption and successful market penetration of new technologies normally follows a logistic growth curve, starting with a hesitant use in the initial stages followed by accelerated market coverage up to a stage of gradual saturation (for example, see Bertuglia et al, 1995). The trajectory of telematics systems in the commercial trucking sector seems to follow largely this standard picture. However, there are—as usual—early adopters and late adapters. In this paper we have tried to identify the nature of the various transport firms in terms of their willingness to use telematics as an integral part of their activities.

In the empirical analysis, a distinction has been made between EDI and other telematics applications (notably mobile telephony, automatic vehicle location, satellite communication, and on-board navigation). So far as EDI is concerned, it appears that firm size plays a dominant role in the use of EDI, whereas the nature of contracts of carriers (in particular, fixed contracts versus stand-alone contracts) and their international orientation are other major explanatory factors. For the remaining types of telematics systems, it once again appears that firm size is a critical variable. Also, it turns out that familiarity with new telematics systems and investment plans is not uniformly distributed among firms, but is related to the perceived or expected benefits of telematics.

On the basis of such findings, one may try to draw some inferences for the future trajectory of telematics applications in the freight transport sector. First, the use of telematics is still in its infancy and there is a wide scope for much broader market coverage. Second, the market of telematics users is segmented, so that it seems plausible that telematics applications will have various appearances, depending on specific firm needs and characteristics.

In the case of EDI it appears that so far the critical mass for its use has not yet been reached, so that one may expect that this network technology will generate a much higher share in all segments, as soon as the externalities of the technology lead to a significant rise in the benefits for all actors involved. For the other telematics technologies, such network considerations are not relevant. They may simply be assumed to follow the typical logistic adoption curve applicable to innovations in general. The results of the present analysis do not point to any other adoption patterns because the most fundamental hypothesis involved in the general diffusion theory—large firms adopt first—is confirmed. However, an exception should be made for satellite communications systems. The technical advantages of this technology have been nullified by simple mobile telephony with the introduction of GSM, which is at the same time much cheaper. Hence, despite the relatively encouraging results of the analysis with respect to satellite communication, because of the techno-economic dominance of GSM we expect that SC technology will not develop much further, and may eventually—perhaps even quite soon—become obsolete.

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APPENDIX

Calculation of the sample weights

As the categories for firm size, measured in number of vehicles, are not identical for the sample and the information for the population, calculating weights is not straightforward. Instead we adopted the following approach. We assume that the distribution of firm size is negative exponential. The five numbers for the sample in table 1 are used to estimate this curve. This estimation is carried out by transforming the curve into a linear curve, and applying the ordinary least squares method. Thus let the fraction of firms that fall in the category 1 - 4 cars be p_1. Then

$$p_1 = \int_0^4 \lambda \exp(-\lambda x) \mathrm{d}x = 1 - \exp(-4\lambda) , \qquad \text{(A1)}$$

which can be linearized as

$$\ln(1-p_1) = 4\lambda .$$

The estimate of λ was 0.0787 (standard error 0.013 significant at 1%, $R^2 = 0.90$). This is then used in equation (A1) to find the estimated number of firms in the size categories as generated by the sample. These estimated numbers are then used to determine the weight factors for each category, as given in table 2.