Research on the Manufacturing of DSRC Tags:
(Summary of Results for Publication)

by D W Tindall (TRL)

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TRL Limited

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RESEARCH ON THE MANUFACTURING OF DSRC TAGS:
(Summary of Results for Publication)

Version 1.0

by Dr. D W Tindall (TRL Limited)

Prepared for: **Project Record:** **Research on the Manufacturing of DSRC Tags**

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Project Manager	
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1 EXECUTIVE SUMMARY

The Dutch Ministry is giving serious consideration to the installation of a distance-based charging scheme for all vehicles and all roads which would be introduced in the coming years. This Kilometre Price (KMP) scheme would be the first of its kind and include over 8 million vehicles and a road network of more than 130,000 km. Since the complete KMP system as intended will take at least until 2012 to be implemented, the Ministry is currently investigating the possibilities for phased introduction of parts of the KMP system and functionality at a considerably earlier date. One potentially viable method is to equip all vehicles with microwave based (DSRC) tags and roadside detection and enforcement infrastructure in order to introduce road-charging on selected parts of the Dutch Road network as a first phase. The purpose of this research is to investigate the feasibility and risks of early introduction of a DSRC based approach from the point of view of volume tag manufacture, delivery and support.

Although this particular piece of research concentrates on the ability of suppliers to deliver the quantity of tags in the timescales required by the Ministry, it also considers some aspects of functionality and performance of tags, and the ways in which certain personalisation of the tags can be used as part of a systems design. This forms part of the intelligence gathering process. The report also highlights some of the discussions which have taken place during the factory visits relating to the system design aspects which are just as important as the tag sub-system.

After an initial survey and dialogue with likely candidate tag suppliers, six suppliers, which have a history of producing high volumes of tags and which were also prepared to sign up to a non-confidentiality agreement, were selected. These suppliers provided a completed questionnaire which covered a range of topics including supported charging schemes, current production capability and details of established tag products which would be appropriate to the KMP project. From this material, and some responses to further supplementary questions, three tag suppliers were down-selected for a factory visit. These visits provided a much better insight into the supplier's capabilities, especially the efficiency and quality of their production lines, and allowed better discussion on their ability to increase manufacture, in some cases significantly, to meet the Ministry's timescales.

The conclusions of this work can be summed up as follows.

There are a number of European tag suppliers who have demonstrated their current capability to produce high quality volume tag products but, with existing facilities, could not produce the volumes or meet the timescales which the Ministry would require to for their KMP timetable. Of those factories visited, it is clear that stable production line techniques are in place, which incorporate good automation and quality test processes and control and these could be replicated to provide the necessary volume. Some are already proposing to increase volume. However, such a large additional order from the Dutch Ministry would need to be serviced as well as any current and projected new project elsewhere in the world. In many cases the degree of replication would suggest a level of risk since, not only would there be a large number of additional lines to set up and put into volume production, but there would be the requirement for more trained staff to operate them. The skilled people to set up and test these additional production lines would be put on a very heavy schedule unless a phased introduction of lines (and a corresponding gradual ramp up of production) was exercised. One supplier will have to increase its production of relevant tags 10-fold to meet the full contract and this would be considered a risk. Another supplier would only need to replicate their production lines by 2 or 3 which is more realistic.

Interoperability does not appear to be a big issue compared to 5 years ago due to new European standards being developed and suppliers working together to meet operators need for multi-sourcing. Interoperability is not an issue between tag suppliers, although the use of different supplier tags on motorcycles which are being driven very close together is perhaps a scenario which has been little tested. The issue is more with interoperability with other supplier's roadside equipment. Depending on the policy for roadside equipment procurement, it is important to consider the effects of such procurement on the overall system performance, and to select operators which can prove interoperability with one or more such suppliers.

Given the above requirements for a step increase in production coupled with improved interoperability between DSRC suppliers equipment, it would suggest that the lowest risk of achieving the timescale and volume targets may be by dividing the contract between two suppliers such that each has to achieve a production of 4M in a 24 month period from award in Q2 2008 to start of Q2 2010. This would leave sufficient time for Interoperability tests in 2009, full operational tests in Q2 and Q3 of 2010 and some additional margin.

Refurbishment of tags was an issue which became more relevant during the factory visits. Depending on the charging policy and contractual arrangements with users, there may be a significant number of tags which require refurbishment each year. The policy on reuse of tags will be very important in determining the level of refurbishment which takes place. If there are any methods, other than tag failure, which causes them to be sent back to the supplier for refurbishment and redistribution, this could add a large additional workload on a supplier. For example, one supplier, which is supporting a population of 5 Million tags, is refurbishing 400 thousand tags per annum. Should there be a mechanism for a user to have a short contract (say 12 months), a tag which functions perfectly could be sent back to the factory for refurbishment quite frequently.

There is significant flexibility in the way tags are programmed for use in a scheme. Many of the suppliers claim to have delivered partially or wholly programmed product and some with individual user details. The recommendation is that, if user specific data is to be programmed by the factory, then individual packaging and shipment from the factory is the easiest approach.

Nearly all the suppliers contacted could provide a tag which would allow on-board funds to be credited via some form of pre-pay mechanism. The actual mechanism for doing this is outside the scope of this research but is nevertheless a very important element of the overall scheme. Current thinking of the Ministry is also to retain a transaction log on the tag which can be interrogated by the user. This can also be compared with a shadow account which maintains a copy of charges incurred and allows back office processes to audit the payment for road use. No supplier offers a significantly large on-board memory for storing more than a few tens of transactions. Any tag development would increase the risk of delivery of the scheme. Development of a new ASIC (the main functional device within the tag) would take too long and adding additional memory to an existing device would require testing and validating. Since none of the suppliers questioned provided an integrated display in their low cost, battery powered tags, viewing of the transaction log would require access to some form of reader. This may be located at a service provider's premises or locations where the on-board purse of the tag can be credited with funds. The tags are equipped with a buzzer and some simple indicators which can warn of low funds or tag errors.

The Ministry's policy on charge differentiation between motorcycles, cars, trucks of various sizes and trailer may affect the design of tag enclosures for the KMP scheme. For example, if trucks must declare their axle count, as is required on the Austrian truck charging scheme, then a simple button and display may be required on a tag intended for a truck. Cars will not

have such a declaration to make and so this functionality would not be visible on the tag enclosure. The more complex the user interface on a tag, the greater the likely cost and power consumption of the tag. The general opinion is that the successful delivery of such a large scheme will rely on keeping it as simple as possible.

The use of tag with motorcycles is claimed to be possible but no evidence of performance was obtained during the research. This is viewed as a risk until such time as a successful demonstration is provided by one or more candidate suppliers.

In large volumes, the suppliers which offered an opinion thought that a tag price of around €15 could be met. This would be reviewed if the total requirement was split between suppliers. Despite the necessary increase in production facilities to meet this contract, and the lack of any guarantees that the production lines would be used for further contracts, the suppliers still believe that the above price is realistic. Only if complex charging strategies require additional functions within the tag will this price be at risk.

A number of issues for further work is highlighted by this research, which has been carried out in relative isolation from the overall design of the DSRC based KMP scheme. All suppliers contacted have emphasised the fact that a much better response can be given when certain scheme parameters have been agreed, in particular the following.

- The level of personalisation which the scheme requires. The simpler the requirement, the easier it is to provide high volume product.
- The method(s) for distribution to users. Individual tag delivery by post is practical but requires accurate data to be passed to the tag suppliers.
- How to handle individuals with failed tags
- How to inform users that their tag is not functioning
- The contract policy with users and the ability to change agent or service provider. If users return tags when they change providers then there could be a large percentage of tags returned for refurbishment.
- Whether trucks and/or trailers require differentiation for charging purpose.
- The security policy which is adopted.
- Whether multiple sourcing of roadside equipments is mandated.
- The physical roadside equipment structures so that maximum speed requirements can be investigated

There are a number of open issues with the suppliers which should be addressed to keep the information contained in this research up to date. Not only do the detailed operational requirements affect the tag design, but also there is on-going development at all suppliers. One supplier, for example, suggested both a new product which would be ready very close to contract award, and the possibility of a hybrid solution in which the old product was fitted with a new processor in order to meet the transaction log requirement. If the on-board pre-pay purse option is definitely required, this supplier may have one of the few solutions which could meet the timescale, albeit with increased risk due to the changes which will have to take place.

A watching eye on progress with new tag products leading up to the award of contract would be beneficial to the Ministry in keeping it informed of the latest and best products and likely risks.

This document has been created from a larger unpublished project report which was delivered to the Dutch ministry at the conclusion of the research. Here, the findings of the research are summarised, but the reader cannot associate details with any particular tag

supplier. The Dutch Ministry and TRL entered into a non-disclosure agreement with all the participating tag suppliers, so that as much intelligence as possible could be gathered on which the Ministry could make decisions on future planning for the KMP scheme. The identity of the tag suppliers taking part in the research will remain anonymous and all sensitive information provided to TRL regarding products, manufacturing processes and future development plans have been removed from this publication to preserve confidentiality.

2   INTRODUCTION

The Dutch Ministry is giving serious consideration to the installation of a distance-based charging scheme for all vehicles and all roads which would be introduced in the coming years. This Kilometre Price (KMP) scheme would be the first of its kind and include over 8 million vehicles and a road network of more than 130,000 km. Since the complete KMP system as intended will take at least until 2012 to be implemented, the Ministry is currently investigating the possibilities for phased introduction of parts of the KMP system and functionality at a considerably earlier date. One potentially viable method is to equip all vehicles with microwave based (DSRC) tags and roadside detection and enforcement infrastructure in order to introduce road-charging on selected parts of the Dutch Road network as a first phase. The purpose of this research is to investigate the feasibility and risks of early introduction of a DSRC based approach from the point of view of volume tag manufacture, delivery and support.

Although this particular piece of research concentrates on the ability of suppliers to deliver the quantity of tags in the timescales required by the Ministry, it also considers some aspects of functionality and performance of tags, and the ways in which certain personalisation of the tags can be used as part of a systems design. This forms part of the intelligence gathering process. The report also highlights some of the discussions which have taken place during the factory visits relating to the system design aspects which are just as important as the tag sub-system.

In section 3, the method used to conduct this research is described, from the initial award of contract through to the production of this document.

In section 4, the overall conclusions of the research are presented. Section 5 provides a summary of the areas of risk which have been identified in the research. Section 6 provides a list of outstanding issues and areas for further work. Since the tag production cannot be isolated completely from the overall system design, there remain some areas for which tag suppliers can provide better answers when certain operational and functional details of the system design are settled. There is also the need to keep this information current as tag suppliers move forward with new products or variants on a current product which may more closely meet the requirements of the Ministry.

In Appendix A, a copy of the blank questionnaire, as send to the suppliers which agreed to contribute to the research, can be found.

All the information contained in this report is based on written documents and emails provided by the tag suppliers, conversations with employees of the suppliers and visits to selected tag supplier factories. Based on this evidence, the author has used his own judgement to draw a number of conclusions relating to the risks associated with the delivery of volume tag product within the Ministry's required timescales. TRL has only made judgements based on the evidence presented during this research project and assumes the integrity of the data provided at the time and the knowledge of the persons contacted within the organisations.

3 METHOD

This section describes the starting point for this research and the approach taken to achieve the objectives. The basic question is easy to post but the answers will inevitably be more complex. The Ministry wishes to know the answer to the following question.

"What is a realistic production period for the amount of DSRC tags needed for KMP, under what additional assumptions and what are the main risks".

Section 3.1 expands this basic question by way of additional questions and assumptions which the Ministry have provided as input to the work.

3.1 Areas for investigation and basic assumptions made by the Ministry

The expansion of the fundamental question leads to the following sub-questions which comprise the material for detailed discussions with tag suppliers.

1. From the award of a contract, in what timeframe could a supplier manufacture and deliver 8.5 million tags to the Ministry. There would be a lead time during which new production lines must be assembled and tested and critical components procured. Given the constraints of the investment in new manufacturing facilities, what maximum rate of manufacture would a supplier consider? How many could they manufacture within 12 months of award of contract? How many could be manufactured in 24 months from award of contract? These questions will investigate whether any supplier can deliver the whole contract in the required timescales or whether multiple suppliers would be necessary, thereby increasing risk of interoperability but ensuring the benefits of multi-sourced supply.
2. How would a supplier propose to increase their manufacturing base? Would it be accommodated internally or would existing or new external sub-contractors be necessary? Where would this manufacture take place?
3. What are the risks to cost, quality, delivery and all-of-life support relating to this manufacturing approach?
4. Would the complexity of the tag, particularly in the level of personalisation required for the proposed KMP scheme affect the production time compared to a very basic tag configuration? This will help to assess whether a simple tag with minimum personalisation will reduce the risks of meeting a system start-up date at the expense of possible increased flexibility in charging policies.
5. How is the price of a tag affected by having extended functionality in comparison to a tag with basic functionality, if the contract is for up to 8M tags?
6. Given such a large order, are additional expenses to be expected for realisation of the additional manufacturing capacity (for the production of 8.5 mil within 1 year and within 2 years), or will this cost be amortised over the production run?
7. To what extend is the CEN TC 278 set of standards a guarantee for interoperability (given a multi vendor strategy i.e. tags and beacons produced by different vendors)? What evidence of interoperability can be verified with the suppliers?
8. What information can the suppliers provide relating to the lifecycle of a tag? What arrangements for refurbishment can they offer?
9. What additional findings and remarks can be gathered by TRL from the suppliers which are relevant to the overall system design, especially the operational aspects and charging policies?

In addition to the above questions, the Ministry wishes to impose a number of constraints and assumptions on any tag technology which may be considered for the supply of DSRC tags to the KMP scheme:

1. All discussions, calculations and assumptions have to be done assuming a DSRC-tags offered by a supplier is stable and has been commercially available for some time. In addition, Suppliers are encouraged to give information on tags that are not yet commercial available in Q3 2007 but are expected to be commercially available before tender awarding.
2. Tags should be easy to install, preferably by the driver, or alternatively by an agent or at a garage.

3.2 The approach

This section describes the approach taken by TRL. Approval was sought from the Ministry at each step of this approach, before moving to the next.

Our first step was to develop and seek Ministry approval of a set of technical and commercial requirements for the DSRC based system and how a tag must operate to meet these requirements. This resulted in requirements documentation being delivered to TRL by the Ministry and this in turn assisted in the development by TRL of a questionnaire to suppliers.

The following lists the minimum (mandatory) requirements set by the Ministry for a tag which would be suitable for the KMP scheme.

1. A unique tag identifier shall be stored in the tag and never alterable
2. Tags shall be protected against fraudulent use and altering of information stored in the tag by unauthorized means
3. Tags shall be configurable to be used in either pre-pay of post-pay operating mode
4. Tags are owned by the buyer/vehicle owner, who is responsible for recharging and performing test on operational availability
5. Vehicle characteristics and operating mode shall be stored in the tag upon tag purchase/delivery and may be altered by an authorized body e.g. when tag owner changes his driving behaviour considerably or needs tag for another vehicle
6. Tags shall operates in free flow condition within speed range of 0 km/h to 250 km/h
7. Interoperability with beacons from several suppliers must be proven in practical use by an authorised body
8. For a tag operating in pre-pay mode, the (re)charging date, time, location and id of recharging is considered to be a transaction and stored on tag
9. Tag operating in pre-pay mode produces a warning for the vehicle driver when less than <amount to be decided> Euros is remaining. The <amount to be decided> will be fixed during further specification and will be the same for all pre paid users. The delivery of this warning is considered a transaction.
10. The following minimum transaction information shall be stored on tag:
    - date, time, id and location of road side equipment,
    - date, time and result (OK/NOK) from self-tests
11. In case of lack of storage capacity on the tag, information about passing roadside equipment may be removed according to the FIFO principle
12. Information not concerning passing roadside equipment shall not be removed, not even in case of lack of storage capacity on tag

13. The transaction history stored on the tag shall be accessible to the vehicle driver
14. Tags should have a memory capable of storing a minimum of 500 transactions for a shadow account
15. The tender for producing of tags is expected to be awarded in Q2 2008
16. Interoperability tests are expected in 2009. Suppliers must be able to support these tests on demand
17. Delivery and installation of tags should start in August 2009 and should be finished October 2010
18. A full operational test is expected in Q2 and Q3 of 2010. The amount of tags produced, delivered and installed by the beginning Q2 should be adequate for these operational tests which should be approximately one third of the total order.

The following additional information was provided by the Ministry about the likely roadside infrastructure but which is not directly related to the research topic.

19. With the introduction of KMP only on dual carriage highways there will be approximately 750 locations*2 driving direction*4 beacons per location=> 6000 beacons. Adding the complete main road network (Hoofdwegennet) adds approx. 1200 beacons

In additional to the above minimum requirements, the following desirable requirements have been proposed. If these additional requirements are met by a supplier, then any differences in production costs, timescales or risks associated with production of tags meeting the minimum requirements should be stated.

1. Vehicle characteristics can be changed during life cycle of tag
2. Operating mode of tag can be changed after purchase
3. Tag might preferably be able to store 1000 transactions, this is still under discussion, it might be a huge amount
4. If interoperability with beacons from several suppliers cannot be proven in practical use than is must be proven by an independent authority
5. Tag might give information to the vehicle driver when a technical problem/malfunction is detected. This is also considered as a stored transaction
6. Tag produces a signal (light, beep etc) when a correct transaction is recorded
7. Transactions stored on a tag can be accessed by the vehicle driver by means of a display

The next step was to compile a list of tag suppliers which are likely to be capable of meeting the tag volume and delivery schedule. The review of the supplier's websites suggested that many of them claim to have produced tags in volume for other road charging schemes around the world. This list was created from those proposed by the Ministry and TRL's knowledge of the players in the DSRC market. An internet search was undertaken to research the proposed potential suppliers to get as much background information on past contracts and capabilities as possible. As well as European candidates, one American and one Japanese supplier were identified. Unfortunately, the Japanese company failed to respond to the email request for information and a suitable contact point. The American company confirmed that they manufactured tags but did not comply with any of the European standards and would therefore be non-interoperable with any other supplier.

Once verbal contact was made with a supplier, the willingness to participate was confirmed and a suitable single point of contact established. From past experience, it has been

advantageous to put in place a confidentiality agreement with any supplier who is willing to take part in the research. This became one of our conditions for participation in the research and for receipt by the supplier of the questionnaire. The list of candidate European suppliers was contacted to:

- determine a single point of contact,
- send an overview document based on the Ministry memo "Research on Manufacturing possibilities of DSRC-tags for Dutch Road Pricing System",
- obtain their willingness to participate in the research
- send a confidentiality agreement for joint signature by TRL and the supplier.

A questionnaire was created, based on the Ministry requirements specified above. This was reviewed by the Ministry and, after some additional comments were incorporated, was approved for circulation. The aim of the questionnaire was to investigate in detail the products and production capabilities of all suppliers willing to participate in the research. A copy of the blank questionnaire is provided in this document as Appendix A.

After receipt of a signed confidentiality agreement, a copy was countersigned by TRL and returned to the supplier with a blank copy of the questionnaire for completion. A deadline was set for return of completed questionnaire, but due to some delays and non-availability of staff at both TRL and certain suppliers, the deadline was extended by 2 days. Some supplementary questions were also asked of the respondents to clarify points in their questionnaire.

Following evaluation of the contents of the completed questionnaires and with the agreement of the Ministry, three companies were down-selected for further investigation, including a visit by a TRL consultant. In particular, a condition of the visit was to ensure that a suitable manufacturing plant could be visited to see evidence of manufacturing volumes and standards of quality and control.

The visits would involve both technical and commercial discussions to explore the evidence of technical functionality to meet the requirements and to understand how the supplier might ramp up production to meet the tag delivery volume, despite having an existing customer base. Documentary evidence was requested prior to a meeting so that we could determine the "reality" of what was claimed. Proof of testing, compliance with standards, evidence of interoperability with other suppliers or schemes and contact names or references from prior installations was sought, since all of these should be available for a mature product.

Over the course of the visit, each supplier would be asked to respond to the same set of core questions, based on the Ministry's research objectives and assumptions. The challenge would be to collate the findings from three different suppliers into a harmonised set of conclusions which could then be added to the results of the questionnaire. Further supplementary questions were asked during the visit to support the written responses.

All of the evidence collected via the questionnaire responses and the three visits has been collated into this written report and delivered for approval by the Ministry. A final meeting, held at the Ministry, to discuss the contents of the draft Final Report, resulted in a small number of clarification questions which were asked of all participating tag suppliers. The responses were included in the Final Report and concluded the research.

4 CONCLUSIONS

This piece of research has achieved it's objectives as set out in the project plan. It required a very strict timetable to obtain all the information included in this report and a willingness by the suppliers to provide resources at very short notice to complete the questionnaire, and in three cases, suitable staff and their time to permit a visit to their offices and factories. The following broad conclusions can be made.

1. There are a number of European tag suppliers who have demonstrated their current capability to produce high quality volume tag products but with existing facilities could not produce the volumes or meet the timescales which the Ministry would require to meet their KMP timetable.

2. Of those factories visited, it is clear that stable production line techniques are in place which could be replicated to provide the necessary volume.

3. The proposed methods for upgrading or replicating their current production lines suggest that a number of the tag suppliers are capable of delivering a major part of the volume of tags in the timescale required. The timescale needed to upgrade is on average 9 months from award of contract. Given what was seen at the three supplier sites visited, this would not appear to be unreasonable.

4. In many cases the level of replication would suggest a level of risk since, not only would there be a large number of additional lines to set up and put into volume production, but there would be the requirement for more trained staff to operate them. The skilled people to set up, and test these additional production lines would be put on a very heavy schedule unless a phased introduction of lines (and a corresponding gradual ramp up of production) was implemented.

5. This large step-up in capacity suggests that the lower risk of achieving the goals may be by not giving one supplier the whole contract but instead dividing the contract between two suppliers such that each had to achieve a production of 4M in a 24 month period from award in Q2 2008 to start of Q2 2010. This would leave sufficient time for Interoperability tests in 2009, full operational tests in Q2 and Q3 of 2010 and so additional margin.

6. The policy on reuse of tags will be very important in determining the level of refurbishment which takes place. If there are any reasons, other than tag failure, which causes tags to be sent back to the supplier for refurbishment and redistribution, this could add a large additional workload on a supplier. For example, one supplier is supporting a population of 5 Million tags and has a refurbishment production line which handles 400 thousand per annum. Due to the ability to have short contracts (say 12 months), a tag which functions perfectly could be sent back to the factory for refurbishment at this point.

7. Interoperability does not appear to be a big issue compared to 5 years ago. A number of new European standards, combined with operators insisting on multiple sourcing has made suppliers work closely together to iron out interoperability problems experienced in the past. Therefore, placing contracts with selected vendors is not as high a risk as it used to be. Interoperability is not an issue between tag suppliers, although the use of different supplier's tags on motorcycles which may be

very close together on the road is perhaps a scenario which has not been tested adequately. The issue is more with interoperability with other supplier's roadside equipment. Depending on the policy for roadside equipment procurement, it is important to select operators which can prove interoperability with one or more such suppliers.

8. There is significant flexibility in the way tags are programmed for use in the scheme. Many of the suppliers claim to have delivered partially or wholly programmed product and some with individual user details. The recommendation is that if individual tags are being programmed for specific customers at the factory, then individual packaging and shipment from the factory is the easiest approach.

9. Products with the ability to have an on-board purse and shadow account arrangements are well supported by the suppliers contacted. The ability to accept the DEBIT and CREDIT commands (part of the CEN TC278 standard command set) is universal, so an on-board purse is feasible. Alternatively, using the attribute PAN allows an off-board (Back Office) account to be used in either pre-pay or post-pay modes. For shadow accounting, the same off-board transaction would be used to notify the back office of transactions which have debited the on-board purse, thereby allowing tracking of road usage.

10. The requirement to have a large transaction log (500 with desirable of 1000) in the tag, to provide the user with an audit trail of road charges, has not been required before and there is a risk in adopting this. Typically, suppliers claim they can support a few tens of transactions but this is not proven. There is certainly no general support for hundreds of historic transaction log entries. For security reasons, the memory is often placed with the tag functionality within an ASIC. Designing and producing an ASIC with increased memory capacity is not a short term fix. It may take up to 1 year to produce a new stable ASIC. This is clearly putting the required KMP timescales at great risk.

11. There is no evidence of low cost displays in the current tag production. Displays tend to be provided on more expensive GNSS devices. One supplier does offer a display attachment option to their tag, but this would need to be connected to the vehicles power supply and therefore become more costly and more difficult to install. If the user wishes to view the transaction log then the only practical way to do this would be to visit either an agent or perhaps a garage where methods for downloading the log were available. This would require any terminal to function as both a log reader and, if pre-pay is required and permitted at such locations, a means to add credit to a tag. The general recommendation from most of the tag suppliers was to keep things as simple as possible, especially with such a large scheme and a rapid introduction of tags.

12. The standard ReceiptData as defined in the CEN TC278 standards defines the structure of any historical transaction and test log. By using short log entries for transactions (comprising date, time, and road side equipment location and ID), funds recharging (if operating in pre pay mode (re)charging date, time, location and id of recharging) and self test (comprising date, time and result (OK/NOK)) it may be possible to store more history. However, this will require software changes to the tags, thereby increasing the risks on tag delivery.

13. Tag identification is programmed into the tag in two ways. Firstly a unique supplier ID can be entered using secure keys which do not leave the factory. Personalising the tag with an account ID (Personal Address Number – PAN) and other user specific

attributes (Vehicle Registration Mark – VRM) can be done at the factory or by a trusted agent who will be using a different secure key. Depending on the scheme tag reuse policy, it would be possible to change user specific attributes (PAN or VRM, if used) within a tag at a trusted agent without having to send it off for reprogramming at the factory.

14. Improvements to the transactions standards in recent years have removed a loophole relating to the possibility of multiple transactions when stationary or slow moving under roadside equipment. In the past, some suppliers have allowed further transactions to occur once every 255 seconds. This is no longer possible and tags will only transact as soon as the microwave path is first established. Thereafter, no further transactions can take place until the tag has left the footprint of the particular beacon which first established contact. As a further protection, the roadside equipment could also prevent multiple transactions with the same tag ID.

15. All tags are equipped with a buzzer and therefore, if a tag is operated in pre-pay on-board mode, a warning of low funds can be implemented.

16. All suppliers contacted were manufacturing tags to a single functional specification. If there are variations required for the car, motorcycle and truck communities then this would add to the complexity and hence costs and timescale to deliver the volume of tags required.

17. Manufacture of a low cost, stable product at the volume required by the Dutch Ministry should be possible at a unit cost of €15. Such a device will at most have a buzzer and perhaps one or two LED indicators showing declared vehicle classification. Any further complexity would increase the risks of rapid deployment to a large population and require considerably more customer support.

5   AREAS OF RISK

During the course of the research, a number of risk areas have been identified. This section brings together these risk areas.

1. Large step in production

It is clear from the research that no tag supplier currently has the spare capacity to deliver the volume of tags in the timescale required by the Ministry. All suppliers will need to replicate their production line facilities to meet the demand. There is a risk in deploying the expertise required to set up the lines, training staff, procuring new production line equipment and procuring additional volumes of time critical components and equipment to meet the timescale for completion of such a large order. Dividing the total requirement between 2 or 3 suppliers will limit the risk but increase the level of interoperability testing which should be done. Nevertheless, some suppliers will be replicating their facilities by 2 or 3 times which is not unreasonable. Those suppliers which need to replicate their facilities more times than this would be considered a high risk option.

2. Pre-pay on-board purse

The general advice from those suppliers visited is that a simple approach to scheme design should be adopted, at least for the initial start up solution. Although technically possible, the use of pre-paid on-board accounts compared to pre or post paid central accounts is viewed as a bigger risk. The complexity of any reconciliation process involving differences between the balance in the on-board account and the balance in a Back Office shadow account will inevitably cause a level of human interaction to resolve disputes over charges. There are also concerns over the maximum size an historic transaction log can be on the tag. To date, there has not been a requirement for such a large log by any other scheme operator using simple low cost DSRC tags. Since displays are not fitted to such tags it is also difficult for the user to view the evidence of past transactions. They would need to visit an agent's or service provider's premises to view the log. Loading of the purse with additional funds would also require a visit to the same (or similar) locations.

3. Motorcycles

Although some suppliers claimed to have used tags on motorcycles and one supplier provided photographs as evidence, there was no evidence of performance compared to standard 4 wheeled vehicles. This should be considered a risk until evidence of good DSRC performance can be obtained either from existing operators or from the tag suppliers themselves.

4. Differentiation in charging – tag variants

The design of the tag will depend on the methods by which charges are levied on different classes of vehicle and the use of trailers on any vehicle. If a user must declare certain parameters, for example, the number of load-bearing wheel axles for trucks, then a simple user interface (button(s) and/or lights) will be necessary. This may lead to multiple designs of

tag enclosure and tag build processes, thereby adding to additional manufacturing complexity.

5. Level of refurbishment

The policy for issue, contract options and level of potential competition between multiple service providers will influence the number of tags which are sent back to a supplier for refurbishment. At one extreme, there is no competition in the market place and every user obtains a tag from the only service provider. The only reason to replace a tag is if it develops a fault or the policy for changing vehicles requires a new tag to be issued and the old one returned. At the other extreme, there could be many competitor service providers each trying to attract customers with short term deals. If after the contract, (say for example 6 months or 1 year) the user decides to change service provider, then the old tag will be returned for refurbishment. The level of risk will depend on the policy adopted.

6. Level of personalisation

This factor is also influenced by the policy adopted. If batches of tags are made to a similar personalisation specification, they will only be differentiable via the unique identifiers programmed into them at manufacture. The Personal Account Number (PAN) can be associated with a users account in a similar way to a credit or debit card. If the tag fails, a new one can be issued and the only change is in the Back Office where the new PAN is associated with the Users account and the old PAN added to a black list as a precaution against fraudulent use of the old tag. Theoretically, the same tag could be moved between a number of declared vehicles and the owner of the Back Office account would pay for all charges. If the user bought a new car, this could replace one on the Back Office list and the tag simply moved to the new car (they may be a need to obtain another tag holder if the new car is not fitted with one or a holder of the correct design.

If the VRM attribute is used, then the tag is effectively tied to a particular vehicle and can be used as a security feature (random checking of the declared VRM against an image taken of the vehicle in which it was fitted and the VRM read manually or using ANPR techniques). In addition, it permits a more robust solution by integrating the enforcement camera system with the tag reading system. If a tag has failed and the VRM is read from the enforcement image, the Back Office will be able to check whether the vehicle is equipped and invite the user to replace the tag. It does however complicate the process when vehicles change ownership and prevents the use of one tag with multiple vehicles.

7. Interoperability – RSE procurement policy

Unless all tags and all roadside equipments are procured from one supplier, it is inevitable that some form of interoperability testing will be required at a very early stage to verify correct operation. The more suppliers involved, the more complex the combinations will become. The general feeling is that interoperability, certainly amongst the larger suppliers of tags and roadside equipments has improved in recent years due to tighter specifications from operators and better test procedures and standards. This risk should be assessed by gathering evidence of interoperability of the currently available tag designs with various roadside equipments deployed around the world.

8. Product cost

The general feeling is that, with such volumes, the tag cost should reduce to between €12 and €20. Having determined that suppliers will need to set up and operate completely new facilities just for this project, and with no guarantee of them being required after the delivery is complete, there must be a risk in keeping this cost down. Further analysis of this issue is recommended.

9. Product evolution

All major suppliers of tags have ongoing development of their product(s). At least one supplier is planning a new product to be in volume production within the timescales of this project. Despite the condition that any tag considered for this project should be stable and in long term volume production, it is worth following progress on any new product to determine whether the risk of introducing it as part of a phased delivery can be done with an acceptable level of risk.

6 OUTSTANDING ISSUES, AND AREAS FOR FURTHER RESEARCH

1. This piece of research has been carried out in relative isolation from the overall design of the DSRC based KMP scheme. All suppliers contacted have emphasised the fact that a much better response can be given when certain scheme parameters have been agreed, in particular

   - The level of personalisation which the scheme requires. The simpler the requirement, the easier it is to provide high volume product.
   - The method(s) for distribution to users. Individual tag delivery by post is practical but requires accurate data to be passed to the suppliers.
   - How to handle individuals with failed tags
   - How to inform users that their tag is not functioning
   - The contract policy with users and the ability to change agent or service provider. If users return tags when they change providers then there could be a large percentage of tags returned for refurbishment.
   - Whether trucks and/or trailers require differentiation for charging purpose.
   - The security policy to be adopted.
   - Whether multiple sourcing of roadside equipments is mandated.
   - The physical roadside equipment structures so that maximum speed requirements can be investigated

2. At the time of writing this report, the Dutch Ministry requires tags to be used on motorcycles. This area is a lot less proven compared to the use on vehicles with 4 or more wheels where the microwave path is relatively predictable. Suppliers A, B, and D claim to have delivered tags which were intended for use with motorcycles. This particular requirement should be investigated further, preferably as early as possible.

3. The use of an on-board purse is considered to increase the risk of successful deployment of a nationwide scheme. The fact that one supplier involved in the research does not support a transaction log, three other suppliers support 30 – 50 entries and one supplier supports 128 (256 on request) suggests that the methods of payment may need to be reconsidered if it is important for users to be able to view charges for their road use. Any upgrade to this facility would at least require a redesign of the pcb to accommodate more external memory or at worst, the redesign of an ASIC. The strategy for methods of payment and user facilities should be considered in the light of this information.

4. The Charging policy for trucks should be considered with regards to tag variants which may be required. The charging policy for trucks can be based on axle count, weight or on other attributes such as level of pollution. All of these attributes are part of the standard CEN TC278 transaction structure and could be used by the Dutch Ministry to differentiate charges. Tags made by two suppliers involved in the research are exclusively for use in charging for trucks and require the user to declare the number of axles in use. This would be unnecessary for cars and light vehicles, unless vehicles towing trailers are to be differentiated for charging purpose. Once this policy is determined, the tag suppliers will be able to comment on the need to deliver more than one variant of a tag design.

5. Interoperability with roadside equipments is very important and investigation of tags alone does not address this issue. There is an increased risk if the roadside supplier is not the same as (one of) the tag suppliers, and a higher risk if no tag is manufactured by the chosen roadside equipment supplier(s). At an early stage, the candidate tags should be tested at speeds ranging from stationary to as high as practically possible at roadside equipment suppliers test or on-road sites. The upper speed limit (requirement states 250km per hour) will be a challenge for any roadside equipment supplier to demonstrate.

6. If an on-board transaction log of a minimum 500 entries and preferably 1000 entries is still seen as a mandatory requirement, it will be necessary to explore this topic in greater detail, perhaps with further tag suppliers to determine whether anything can be provided at low risk within the timescales.

7. The Dutch Ministry should be aware of the latest developments in the DSRC based functional and test standards which have been issued in recent years. In particular, the work done by ETSI ERM TG37 has produced specifications in the last 3 years including test specs for layers 2 and 7 of the DSRC transaction between the tag and the roadside equipment. Documents TS102486-1 -1,2,3 and TS102486-2- 1,2,3 (amongst others) should be bought, studied and advice fed back to the Ministry which will influence the design of the scheme. It would also be useful to understand the relevance of documents produced by certain scheme operators relating to threat analysis which would assist in developing the security policy. In particular, schemes which have produced a number of relevant specifications include the Chilean MOPT interoperability scheme, the TIS systems in France, NORITS in Scandinavia, and the work of CEN/TC278 in the production on EN15509 and EG11 to support the European Commission.

8. There are a number of open issues with the suppliers which should be addressed to keep the information contained in this research up to date. Not only do the detailed operational requirements affect the tag design, but also there is on-going development at all suppliers. One supplier, for example, suggested both a new product which would be ready very close to contract award, and the possibility of a hybrid solution in which the old product was fitted with a new ASIC in order to meet the transaction log requirement. If the on-board pre-pay purse option is definitely required, only one supplier involved in the research may have a solution which could meet the timescale, albeit with increased risk due to the changes which will have to take place. One supplier will have to increase its production of relevant tags 10-fold to meet the full contract which would appear to be very risky. Other suppliers would only need to replicate their production lines by 2 or 3. Due to the speed with which this research was conducted, some tag suppliers were unable to respond by the deadline. For completeness, it would be advantageous to add information from such suppliers, possibly by way of the same questionnaire as sent out to those involved in this research.

9. A watching eye on progress with new products leading up to award of contract would keep the Ministry informed of the latest situation with regard to best products and likely risks.

ACKNOWLEDGEMENTS

GLOSSARY

This is a table which defines terms used throughout this report.

Term	Definition
ABvM	Anders Betalen voor Mobiliteit ("Paying differently for Mobility")
ASIC	Application Specific Integrated Circuit
BST	Beacon Service Table (part of a CEN TC278 compliant transaction from the RSE to the tag)
CEN	The European Committee for Standardization (Comitée Européen de Normalisation)
DSRC	Dedicated Short range Communications, a short range wireless protocol designed for automotive use
GPRS	General Packet Radio Service
GPS	Global Positioning System
ICC	Integrated Circuit Card (also called a Smart Card)
KMP	KiloMetre Pricing
OBU	On Board Unit. For this research this is synonymous with "tag"
PAN	Personal Account Number
pcb	Printed circuit board
ReceiptData	A type of message defined in the CEN TC278 standards which is 28 octets in length
RSE	RoadSide Equipment
TC278	The Technical committee of CEN charged with Road Transport and Traffic Telematics
TfL	Transport for London
VRM	Vehicle Registration Mark

Annex A : Questionnaire sent to DSRC Tag Suppliers

Below is a blank copy of the Questionnaire sent to the DSRC Tag Vendors.

Questionnaire to Tag Supplier

Instructions for Completion

All information will be treated in the strictest confidence.

Deadline for submission is: 13:00hrs GMT - Monday 10th September 2007

The questionnaire allows free text to be provided.

The questionnaire is designed to be variable in length according to the number of schemes for which you have supplied tags in volume, and the number of different tags which you are currently manufacturing in volume. Also, each response to questions is unrestricted in length so please include any information which you feel is relevant.

1. Please provide answers to all questions. If you have no relevant response to make to a question please state "No information" or "Not applicable" to show you have answered the question.

2. Ensure you return your submission with a filename which includes the company name or identifier.

3. Please do not in any way change the format of the document or change the wording of the questions. There is a section at the end for adding any further information which you think is relevant.

4. Finally email the completed questionnaire(s) to: abvm@trl.co.uk . TRL will acknowledge receipt of your submission via an email.

Thank you for taking the time to complete this questionnaire.

1. Company Details

1.1	Tag Supplier's Name	
1.2	Primary Contact	
1.3	Primary Contact Tel.	
1.4	Primary Contact Mobile	
1.5	Primary Contact email address	
1.6	Supplier Address	
1.7	Supplier Postcode	
1.8	Supplier Region/County	
1.9	Supplier Country	

2. Evidence of previous volume production of tags

2.1	How long have you been producing 5.8GHz DSRC tags in volume?	

2.2 For each Road User Charging (RUC) scheme you have provided 5.8GHz DSRC tags, please copy the table below and complete with the following information. Number each individual table as 2.2.1, 2.2.2, 2.2.3 etc

2.2.1	Scheme Name	
2.2.1.1	Tag model/identifier of tag(s) used in this scheme (use same model/identifier description as used in table 3 below)	
2.2.1.2	Start of tag delivery	
2.2.1.3	End of tag delivery	
2.2.1.4	What total volumes of tags did you deliver?	
2.2.1.5	What rate of volume delivery did you meet? (maximum rate)	
2.2.1.6	What level of configuration/personalisation did you provide?	
2.2.1.7	What level of service have you provided during the whole operational lifecycle of the tags?	
2.2.1.8	Have you some points of contact where we can obtain client feedback on the tag delivery/performance/reliability/service? Please provide contact details.	
2.2.1.9	If other manufacturers tags used on this scheme, what evidence of interoperability can you provide?	
2.1.1.10	What evidence of tag reliability can you provide for this scheme?	

3. Current products

3.1 **For each 5.8GHz DSRC tag which is currently in volume production, please copy the table below and complete with the following information. Number each individual table as 3.1.1, 3.1.2, 3.1.3 etc**

3.1.1	Tag model/identifier	
3.1.1.1	How long has the product been in production?	
3.1.1.2	Is the hardware stable? When was the last change or upgrade?	
3.1.1.3	Is the software stable? When was the last change or upgrade?	
3.1.1.4	What functions are available for supporting central account?	
3.1.1.5	Does the product support on-board purse either as a monolithic device or with smart card?	
3.1.1.6	What audible/visual devices doe the tag contain?	
3.1.1.7	Please specify what transaction standard(s) the product supports (TC 278 compliant, A1,CARDME,Pista,DCAS,IAP, other)?	
3.1.1.8	What personalisation attributes does the tag support?	
3.1.1.9	Does the product support Access Credentials security?	
3.1.1.10	Does the product support exemptions?	
3.1.1.11	Where would you manufacture such volumes of product?	
3.1.1.12	Would you employ a sub-contracting of manufacture? Where would this be? Have you used them before or would need to find new sources?	
3.1.1.13	How long from start of contract to delivery of first batch of	

	product? (award of contract will be Q2 2008)	
3.1.1.14	Once in volume production, what rate of delivery can you achieve?	
3.1.1.15	What testing procedures would you apply to volume production prior to shipment?	
3.1.1.16	What additional quality control measures do you employ?	
3.1.1.17	Can you provide an indicative unit price for such volumes in the given timescales?	
3.1.1.18	If smaller volumes were requested, can you provide an indicative price against volume ?	
3.1.1.19	Can you supply appropriate programming equipment (including software) for personalisation by the Ministry or its agents?	
3.1.1.20	What programming must be done in the factory and what can be done by the Ministry or their agents?	
3.1.1.21	Can personalisation data (attributes) be altered once programmed? If so, which ones and how?	
3.1.1.22	What security is built into the tag to ensure attributes cannot be altered once programmed?	
3.1.1.23	What options can you offer for delivery of pre-programmed/boxed products suitable for directly delivering to agents, garages or users?	
3.1.1.24	What services can you provide for full-life support of a large volume of tags in use by customers?	
3.1.1.25	What is the typical battery life of the tag design?	
3.1.1.26	What evidence have you of interoperability of this tag product with other manufacturers Roadside Equipments (RSEs) or specific manufacturers beacon designs? Which	

	other RSE manufacturers have you worked with to achieve this?	
3.1.1.27	What is the typical transaction time for the tag?	
3.1.1.28	Can you provide evidence of correct functioning of the tag in the whole vehicle speed range from 0kmph to 250 kmph? If no evidence available, what part of this speed range is the tag designed to operate over?	
3.1.1.29	If On-board account is available, can the tag warn of low funds?	
3.1.1.30	What number of historical transactions can you store in the tag?	
3.1.1.31	What methods do you employ to access this historical log, either by the operator or the user?	

4. New products

4.1	What new DSRC tag product(s) are in the pipeline?	
4.2	What advantage do they have over current product?	
4.3	When can volume production be expected?	
4.4	If the KMP project has specific functionality which is not in a current product, is the supplier willing to develop their product to meet this requirement?	

5. Other Issues

5.1	Given such a volume of tags and a corresponding infrastructure which requires between 6000 and 7200 beacons, do you have any comment on the risk associated with the delivery of such an infrastructure?	
5.2	Are there any other comments or suggestions you would like to include at this point which will assist TRL in their research objectives? If so, either write them here or provide an additional attachment or file.	
5.3	Is there any other electronic document based evidence which you would like TRL to consider? If so, please include with your submission.	