

**ROAD MARKINGS TO INCREASE ROUNDABOUT  
LANE UTILIZATION AND SAFETY IN CYPRUS**

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## **ABSTRACT**

The main focus of this paper is to examine the introduction of road markings and signage at multi-lane roundabouts in Cyprus as a measure to improve safety. Successful applications from other countries prove that lane separating markings inside the circle of a roundabout can improve safety and increase the flow of traffic through the roundabout. Road markings increase the utilization of available road space at a roundabout and can also improve driver behavior. Over the past few years in Cyprus, many rear-end and side-to-side collisions have been reported at two and three lane roundabouts with the Ministry of Communications and Works and the Police seeking solutions to improve the situation and better manage the rising traffic levels at roundabouts.

A pilot scheme introducing road markings at a small roundabout yielded positive results and a minor decrease in collisions which encouraged the authorities to widen the scheme to cover larger roundabouts with two and three lanes. Current standards for road markings at roundabouts in the United Kingdom, New Zealand and The Netherlands are being used as a guideline in developing local standards according to driver behavior and traffic patterns. The possibility of using the 'Alberta' method of marking multi-lane roundabouts in Cyprus will also be examined in this study as well. Further research is recommended to determine whether the planned road markings and signage is easily comprehended by the drivers. Safety results after the markings have been implemented will also help to assess the benefits of road markings and signage introduced.

## INTRODUCTION

Roundabouts have been introduced on a wider scale in Cyprus since the early 1960's with great success (mostly single-lane roundabouts in the beginning) and they constantly multiply in numbers as they are seen as an effective type of junction for its many benefits and advantages. Multi-lane roundabouts are also very common and are very common on the road network, with more than 25 in place around the island.

With a population of more than 800,000 people, over 2 million tourists per year, a road network of more than 7,750 km (4,815 miles) of paved roads and nearly 600,000 registered vehicles, the island is facing a challenging situation when it comes to keeping traffic moving safely and efficiently. In addition to the growing traffic, Cyprus' road safety record is one of the worst within the European Union 27 Member States.

The sudden increase of multi-lane roundabouts on the network along with the poor safety record, especially at roundabouts of a larger scale, created a big challenge for the road authorities and the Police. Also the lack of adequate driver education and publicity on how motorists can use such roundabouts efficiently added to the problem. Driver behavior and culture is the main cause of most accidents in Cyprus. A recent study examining accident black spots on the road network identified some multi-lane roundabouts with a high number of accidents (injury and damage accidents, side-to-side collisions), prompting the authorities to examine ways to improve the situation in addition to the driver behavior issues mentioned above. It was decided that a combination of measures will need to be in place in order to achieve the best results and improve safety and throughput at roundabouts. Such measures included:

- Researching and literature review (best practice) of applications in other countries
- Examining the possibility of introducing additional lane markings and road signs on the approach and within the inside circle of roundabouts
- Educational campaign by the Police and other agencies on how motorists can efficiently and safely use all types of roundabouts

Road markings can be used to channelize traffic and indicate specific lane use as well as benefit the efficient operation of a roundabout by ensuring maximum use of the road space. They can also improve safety by assisting in the reduction of certain types of accidents such as side-to-side, rear-end or collisions between vehicles inside the circle and others entering. Additionally, the use of road markings improves the gap acceptance which leads to more efficient operations at a roundabout. Care has to be taken in order to avoid confusing the motorists with unnecessary markings and signage. If a specific roundabout (or intersection) operates at a safe and efficient level sometimes additional measures including markings might affect efficient operations.

## **BEST PRACTICE/APPLICATIONS IN OTHER COUNTRIES**

In order to look at best practice in other countries with similar driving patterns or experiences like Cyprus, applications in places such as the United Kingdom, New Zealand and The Netherlands were investigated further. Research is not limited to these particular countries but extends to include others such as the United States, Australia and of course other European Countries.

### **Best Practice in the United Kingdom**

The Cyprus standards for signing and marking (1) are mostly based on the UK standards. Cyprus was a British Colony and motorists drive on the left side of the road as in the UK, New Zealand and other countries. For this reason, the current UK standards of the Department for Transport (DfT) and the Highways Agency were used as a guideline for roundabout markings.

The Cyprus Technical Committee for Examining Traffic and Road Safety Problems/Issues (members include the Public Works Department, the Town Planning and Housing Department, Local Authorities and the Police) in a recent meeting decided to implement, on a pilot basis, some of the markings that are proposed in the Design Manual for Roads and Bridges of the UK Highways Agency (2). Traffic Advisory TA 78/97 (Design of Road Markings at Roundabouts) was used and the guidelines described below were selected for implementation but not all have been implemented yet. As mentioned in the Traffic Advisory document, due to the varied geometrical and operational characteristics of each roundabout there is no standard layout for roundabout markings. It was also noted at the meeting that the driver behavior and enforcement in the UK is a lot different than in Cyprus.

#### *Concentric Markings*

These markings as described in the TA 78/97 are similar to the ones already in place at the Limassol Roundabout in Cyprus which is described later in this paper. Such markings are shown in FIGURE 1. They basically follow a path along the lane dividing axis of the inside circle of a roundabout. Concentric multi-lane roundabouts seem to be the exception in Cyprus therefore this type of marking proved more challenging for implementation in order to avoid further confusion to the motorists. A second roundabout in the coastal town of Paphos has been selected for placing concentric markings.

Concentric markings can be easily implemented around Cyprus at various roundabouts with similar geometry (concentric). However, a roundabout that is considered to be operating at satisfactory levels will not necessarily need additional markings.

### *Partial Concentric Markings*

As mentioned above, the lack of driver education in regards to driving behavior in roundabouts called for the introduction of other measures in order to improve the safety conditions and prevent driver confusion and aggressiveness. From various traffic surveys and studies conducted by the Traffic Section of the Public Works Department it was observed that drivers did not seem to follow the correct entry lane path according to where they wanted to exit once they were inside the circle. Additionally, further confusion and problematic operation occurs within the circle with many near-collisions observed. For this reason, the partial concentric markings as presented in FIGURE 2 were selected (Case 1 and 2). Two multi-lane roundabouts in the capital of Cyprus were selected for implementing this measure of broken concentric markings which are adjacent to the entries and/or exits of the roundabouts.

Once implemented, a before and after study will be executed in order to assess the impact of the markings on safety and efficiency. The Police and other stakeholders involved plan to proceed with an education/informational campaign (such as issuing a leaflet and TV advertisement campaigns) in order to ensure better use of the roundabouts by motorists.

### **Best Practice in New Zealand**

Like with the UK standards, due to the similarities in the driving patterns of Cyprus and New Zealand the document published by Land Transport New Zealand called “Guidelines for Marking Multi-lane Roundabouts” in 2005 was used (3). More particularly because the guidelines focus on marking multi-lane roundabouts the possibility of using the ‘Alberta Method’ of marking multi-lane roundabouts is further examined in this paper.

As described in the above document, the ‘Alberta Method’ involves the placement of exit lane pavement markings within the circulating carriageway of a roundabout to separate vehicles and guide drivers through the intersection. ‘Alberta’ exit lane pavement markings combined with clearly marked approach lanes, direction arrows and appropriate signage used on multi-lane roundabouts will give motorists every opportunity to negotiate these roundabouts without conflicting with other circulating traffic. It is recommended they be used on all multi-lane roundabouts. Such markings are used in Australia and New Zealand and consist of a 3 meter stripe of 100mm width and a gap of 3 meters.

The Alberta method is presented in FIGURE 3 and could be possibly used in Cyprus due to the confusion that appears to occur inside the circle from motorists not following the correct path to exit the roundabout. It must be noted that the markings in New Zealand are combined with other measures such as the use of give way symbols and lane use arrows which appears to be consistent with some of the UK and Dutch guidelines. In addition, the use of appropriate road signs is recommended.

## **Best Practice in The Netherlands**

The Netherlands have one of the best road safety records in Europe. Over the past three decades, the annual number of traffic fatalities has declined by 75 percent from 3,200 to 800. Today, The Netherlands has one of the lowest per capita traffic fatality rates in the world. New techniques and guidelines utilizing road markings and signage have been introduced over the past few years with great success. As presented in this paper, Cyprus has already adopted the use of lane arrows as a good example from The Netherlands. During recent road safety seminars and presentations given in Cyprus from experts of the Dutch Ministry of Transport (Ministerie van Verkeer en Waterstaat) and Dutch Consultants it was mentioned that driver behavior in The Netherlands has significantly improved by targeting human behavior that trigger collisions in the first place, through educational campaigns, major improvements on the road network and enforcement.

As presented in FIGURE 4, concentric markings at two lane roundabouts in The Netherlands as recommended by Fortuijn and Carton (4) are similar to the UK and New Zealand markings (the roundabout presented in FIGURE 4 appears to have no flared entries which reflects recent design changes in The Netherlands). However, in addition to driver confusion within the circle, it appears to be misunderstood as to which lane the drivers need to follow in order to enter the roundabout and exit safely. To combat the problem FIGURE 5 includes photos from some of the lane arrows used in The Netherlands that are now used in Cyprus as well but in a slightly different way. They are described in the next section of this paper.

Recent research from experts in The Netherlands showed that the use of arrows in the center of the entry lanes (called HART RIJSTROOK in Dutch which refers to the center of the traffic lane) can be beneficial when used at Turbo Roundabouts as presented in FIGURE 6. Unique features include the repeated use of sets of arrow markings as well as the yield marking just before the entry to the roundabout. Bicycle crossings also appear frequently at roundabouts in The Netherlands and special care is taken to incorporate those in the road marking design.

## **ROUNDABOUT MARKINGS AT ROUNDABOUTS IN CYPRUS**

Several efforts to improve driver behavior and operations at roundabouts in Cyprus initiated nearly 5 years ago but the need for a wider scale approach is now evident for the reasons explained in the introduction. Some of the applications in place on the Cyprus road network are presented below in an attempt to examine their effect and look into further improvements.

## **Pilot Scheme with Road Markings in Limassol**

An attempt to introduce road markings at roundabouts in Cyprus began in 2004 with a pilot scheme that called for the introduction of concentric road markings at a two-lane roundabout in the city of Limassol (second largest city in Cyprus). The scheme included a typical RM (Road Marking) Line which consisted of a 3 meter stripe with a 1 meter gap.

Unfortunately a before and after study was not officially initiated to examine the effects of the markings but from a preliminary examination of the accident data for the year before the markings were introduced and a full year after the markings were introduced, it was shown that there were 30% less accidents at this particular roundabout. This roundabout is in the center of town linking the touristy seafront Avenue with the commercial center and the Courthouse that is adjacent to the roundabout. It has four arms and carries a substantial volume of traffic throughout the day due to its central location. The preliminary results did not indicate whether the markings improved safety conditions at this roundabout therefore a more detailed study is needed before accurate conclusions can be drawn.

The upcoming implementation of road markings inside the circle of roundabouts as per the UK, New Zealand and Dutch guidelines is anticipated to result in more efficient use and increased safety of multi-lane roundabouts.

## **Entry Markings – Directional Arrows at the Ayia Napa Roundabout**

The introduction of entry markings with the use of directional arrows was recently implemented at a relatively busy two-lane roundabout in the beach resort of Ayia Napa, as presented in FIGURE 7. This particular roundabout has several problems with its geometry and layout, mainly at the main approach to the circle which was chosen for using the entry markings in an effort to maximize the road space and ensure adequate lane utilization due to the unique geometry and significant grade difference between the arms and the inside circle. Speeding is also an issue at this roundabout and several traffic calming measures are in place (yellow bar markings, special road signs, and raised plateau) and other measures such as the installation of a speed camera are planned.

Based on several applications from The Netherlands, lane arrows were designed for use at this particular roundabout as indicated in the details presented in FIGURE 8. The arrows were placed in two sets with the first being placed 20 meters from the entry line and the second set a further 50 meters back. Due to the fact that the grade at the approach is nearly 10% the distances that the arrows were placed did not appear to be adequate and it was observed that either they had to be moved in the future or made wider and more evident as can be seen from the photos presented in FIGURE 9. The lane arrows were designed based on existing marking guidelines (left turn, right turn or straight path arrows) for speeds under 60 km/hr.

A detailed study to examine the extent of the benefits caused by the arrows installed and additional signage has not yet been completed but early results and feedback given by local motorists as well as the District Engineer who implemented them are very positive. It must be noted that many tourists and non-Cypriots use this roundabout especially during the summer months, so markings and signage are necessary in order for a motorist who is not familiar with the directions and the roundabout itself to understand which lane they should be in. When observing the traffic for a consecutive period of time one can easily see that the majority of motorists use the inside lane (far right) that leads into the town of Ayia Napa and move in the correct direction according to the arrows. A recommendation is to install the arrows at all entries to this roundabout after the pilot phase is completed.

The details of the arrows planned for use in The Netherlands as presented in FIGURE 10 indicate some of the similarities with the markings already implemented in Cyprus with the main differences being the total length and the elliptical shape of the circles.

## **SIGNAGE**

In addition to the road markings at roundabouts, road signs are very important in order to warn the motorist first that they are approaching a roundabout and then which lane they need to be in so they can enter and exit the roundabout in a safe and efficient way. Warning and regulatory signs are commonly used in Cyprus but the need for additional signage is imperative given the fact that the road markings themselves are not always adequate and driver understanding of how to move through a roundabout is not sufficient. In certain cases it might be more appropriate to use more road signs than markings or vice versa. A balance of the two appears to be the ideal situation as seen in FIGURE 11 which presents road signs at turbo roundabouts in The Netherlands (5). A similar sign is intended for use in Cyprus after the road markings pilot phase has been completed. The road marking width is the same as the one used at the Ayia Napa roundabout.

## **CONCLUSIONS**

The road marking proposals presented in this paper are mainly designed to reduce the types of collisions that occur at multi-lane roundabouts and also provide for more efficient operations. The main principle is to encourage vehicles to approach roundabouts in the lane appropriate to their desired exit with the use of road markings/arrows. Road signs can also assist in advising the drivers for the correct lane they need to be in for each approach/arm. Road markings inside the circle of a roundabout can provide additional capacity, improve driver behavior and increase the utilization of the available road space. Also, they seem to reduce weaving and potentially dangerous movements by drivers.

The possibility of using the Alberta Method of road marking at roundabouts in Cyprus was briefly described and it is recommended for further analysis as one of the key problems that drivers face when driving through roundabouts in Cyprus is exiting.

Following the improvements that have taken place so far at two locations in Cyprus which are described in this paper, motorists appear to have a clearer indication of the approach lane they must be in to take any of the exits. The positive feedback from the initial efforts is encouraging and should prompt the authorities to realize the plans for a wider scale implementation.

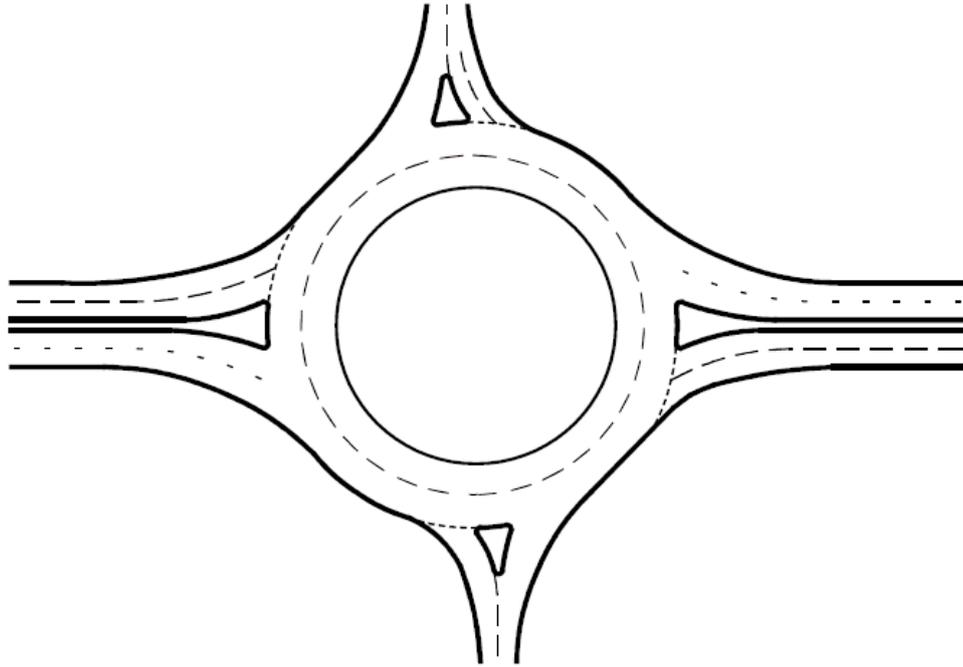
Finally, the use of appropriate road signs in conjunction with the proposed road markings maximizes the benefits gained and should be further examined. Research should also focus on the issue of an updated version of the highway/road code of Cyprus to include all necessary details for educating drivers on how to drive through roundabouts safely and efficiently.

## REFERENCES

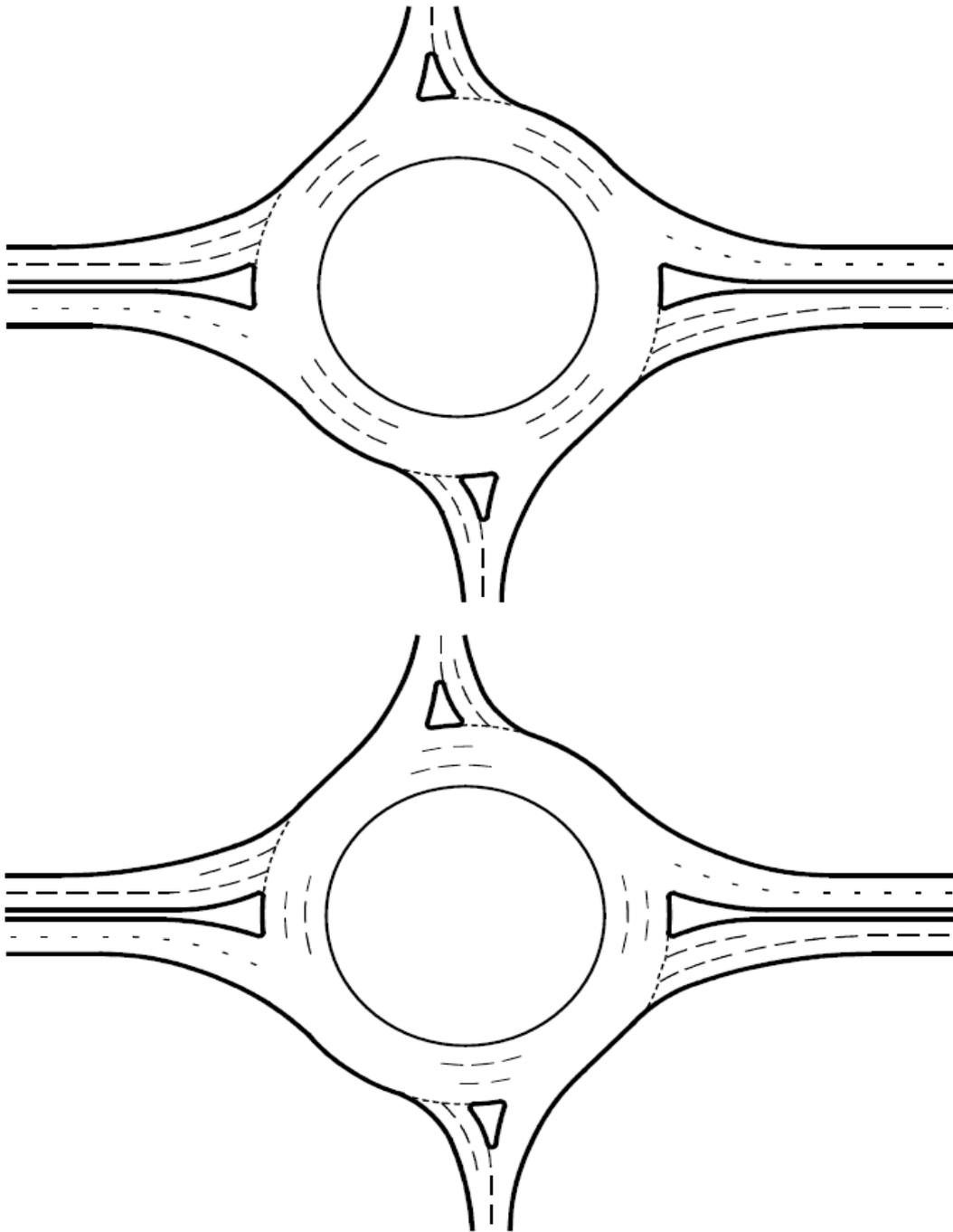
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5. Royal Haskoning Consultants, Holland. Presentations, Note Materials and Research/Knowledge Transfer from the *Safe Road Design Seminars* held in the Republic of Cyprus (2005-2007) by the Dutch Ministry of Transport (Ministerie van Verkeer en Waterstaat), Royal Haskoning and DHV Consultants.

## LIST OF FIGURES

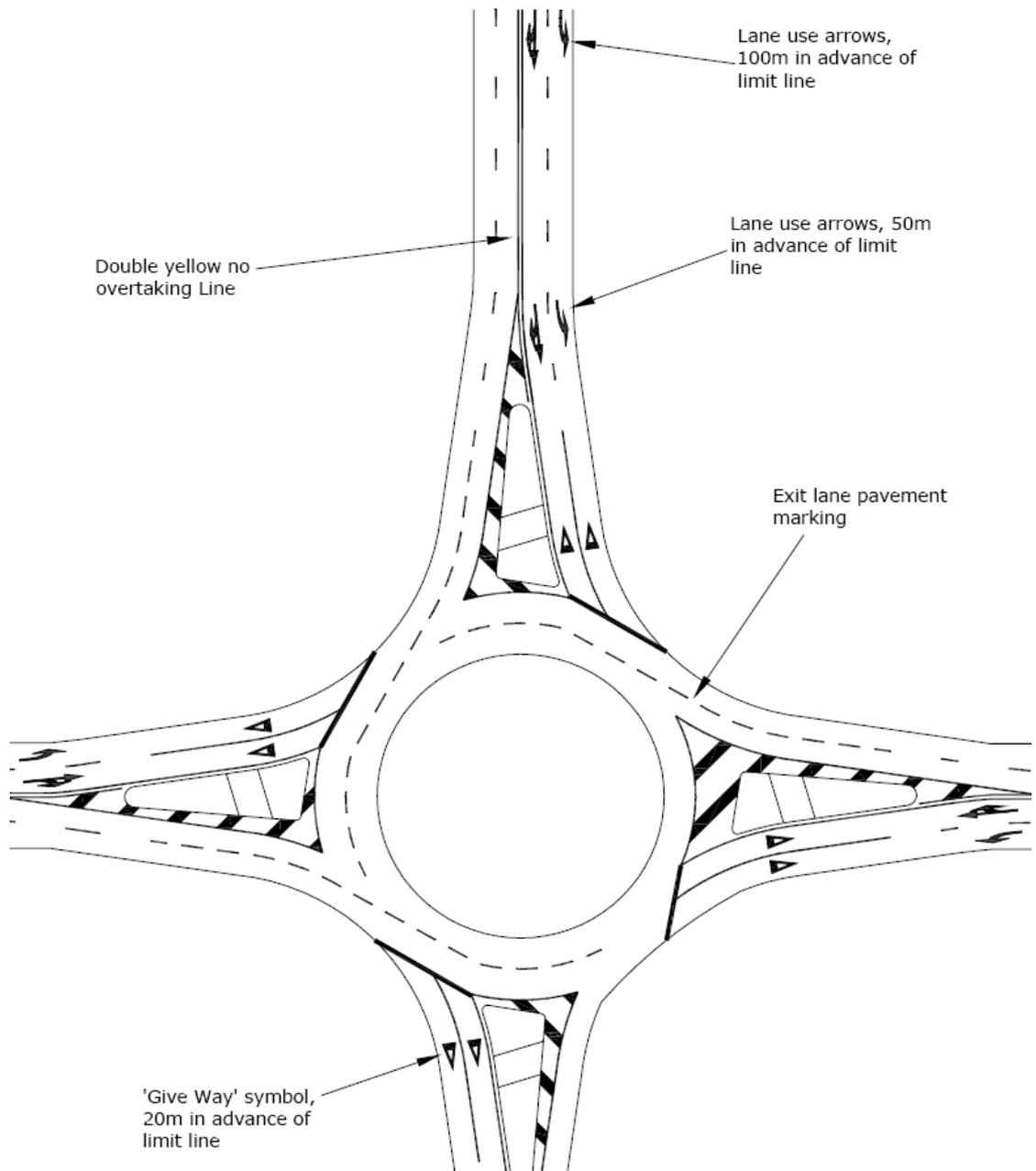
<b>Figure</b>	<b>Title</b>	<b>Page</b>
<b>Figure 1:</b>	Concentric Roundabout Markings (UK).....	11
<b>Figure 2:</b>	Partial Concentric Roundabout Markings (UK).....	12
<b>Figure 3:</b>	Typical Multi-lane Roundabout with 2-lane Approaches (NZ)...	13
<b>Figure 4:</b>	Two Lane Roundabout with Concentric Markings (NL).....	14
<b>Figure 5:</b>	Lane Use Arrows in The Netherlands (NL).....	15
<b>Figure 6:</b>	Lane Use Arrows at Turbo Roundabouts (NL).....	16
<b>Figure 7:</b>	Lane Arrows at Ayia Napa Roundabout in Cyprus (Drawing)....	17
<b>Figure 8:</b>	Lane Arrows at Ayia Napa Roundabout in Cyprus (Detail).....	18
<b>Figure 9:</b>	Lane Arrows at Ayia Napa Roundabout in Cyprus (Photos).....	19
<b>Figure 10:</b>	Detail of Lane Arrow Markings in The Netherlands (NL).....	20
<b>Figure 11:</b>	Road Signs to Assist Entry Lanes at Roundabouts (NL).....	21



**FIGURE 1** Concentric Roundabout Markings in the UK  
(clockwise traffic)

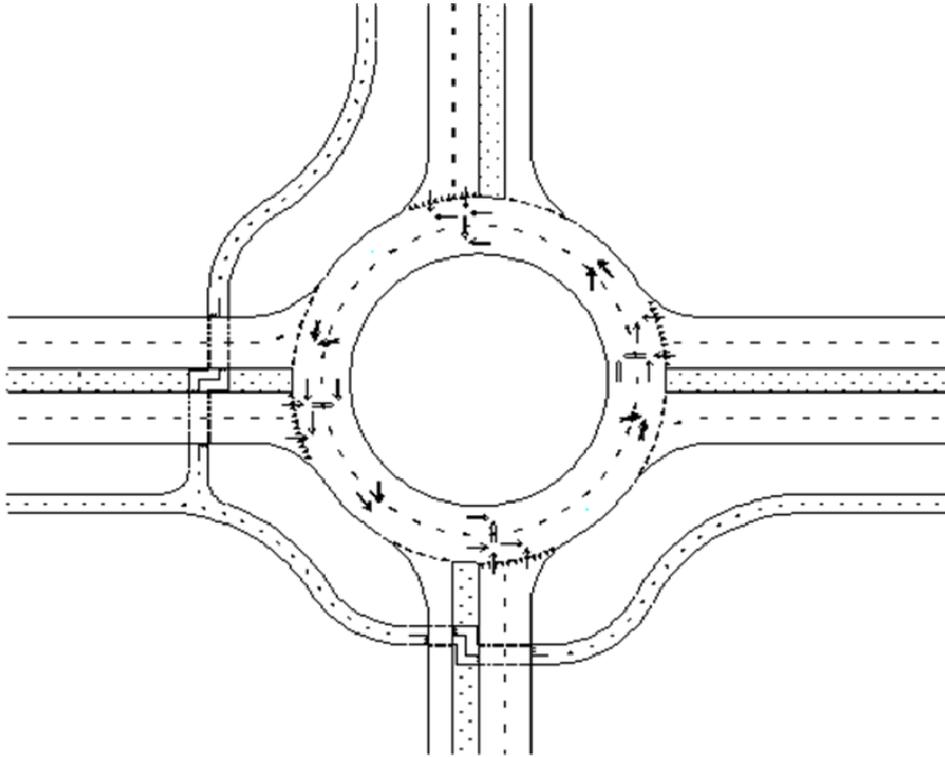


**FIGURE 2** Partial Concentric Roundabout Markings in the UK  
(Case 1 and 2) - (clockwise traffic)



**FIGURE 3** Typical multi-lane roundabout in New Zealand with 2-lane approaches (one featuring an exclusive right turn lane), three 3-lane exits and a 1-lane exit

**(clockwise traffic)**

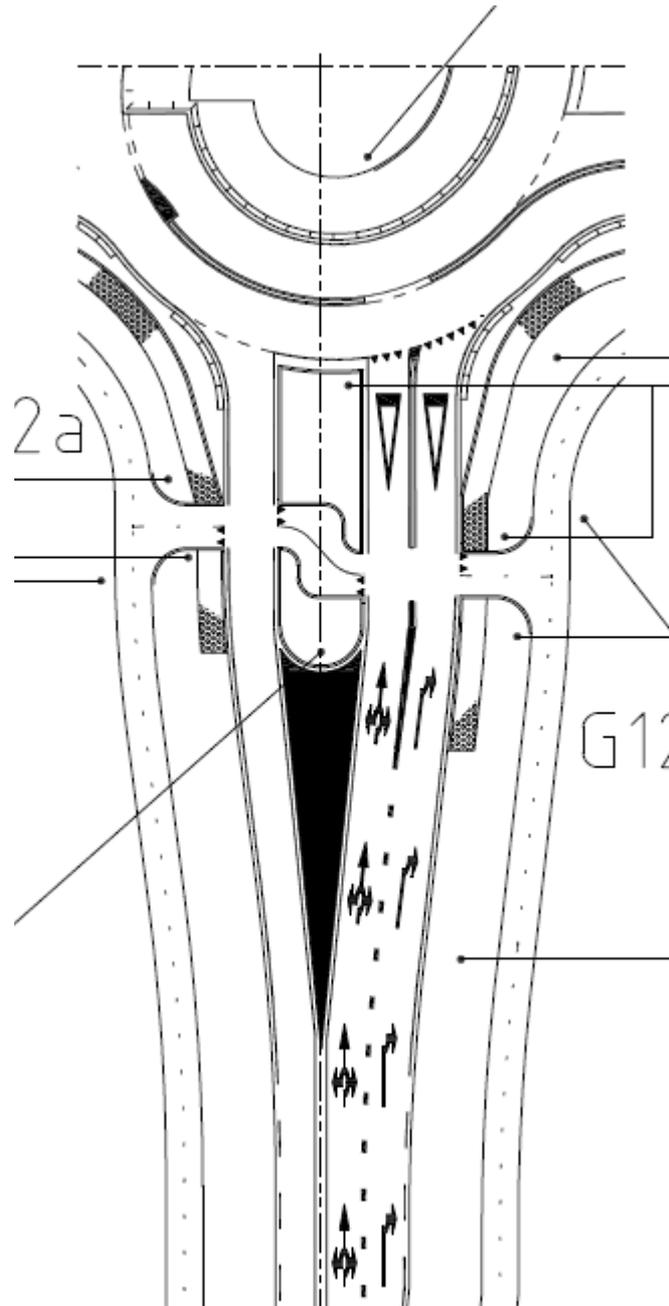


**FIGURE 4** Two lane roundabout with concentric markings in The Netherlands  
(Note 1: The arrows inside the circle indicate potential conflict points)  
(Note 2: Notice the roundabout has no flared entries reflecting new designs implemented in The Netherlands)

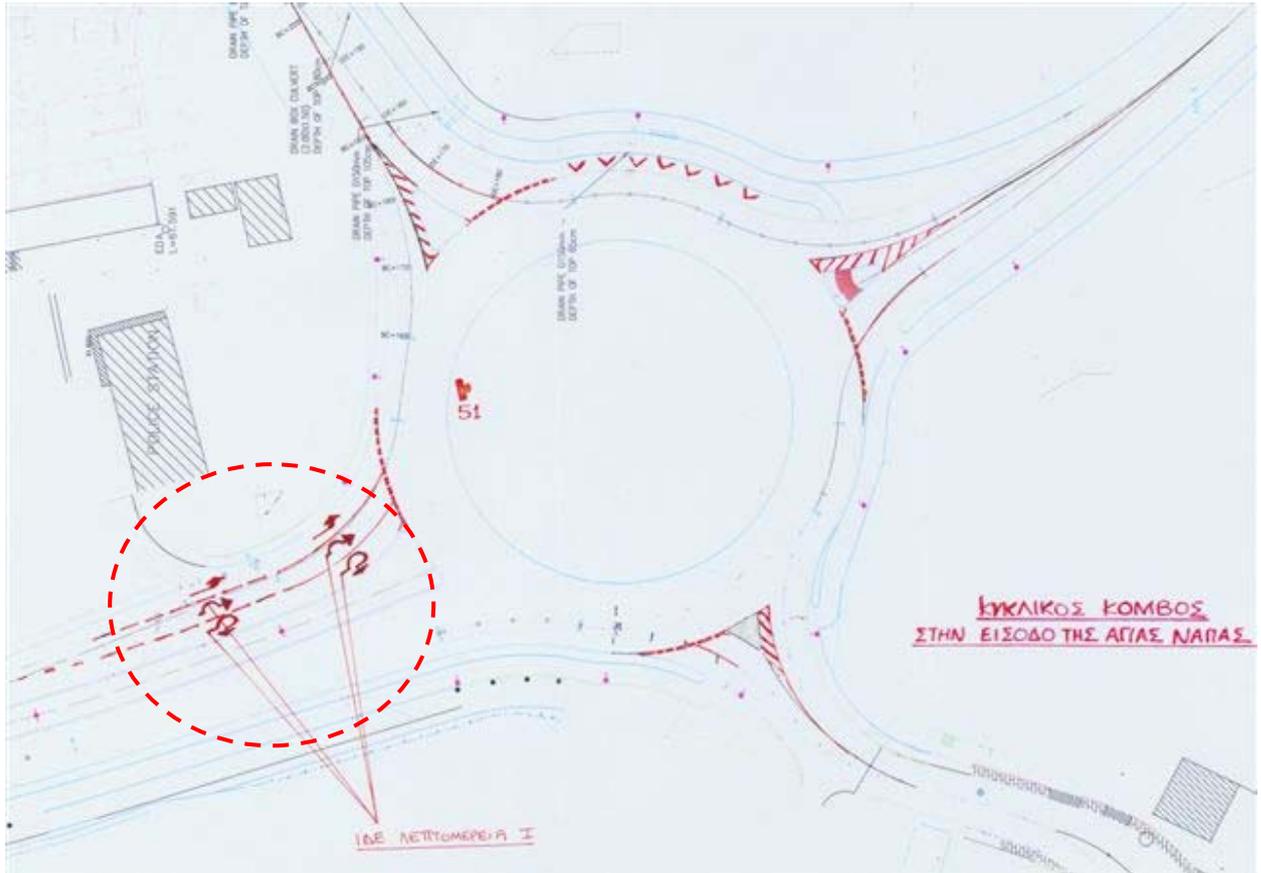
**(counter-clockwise traffic)**



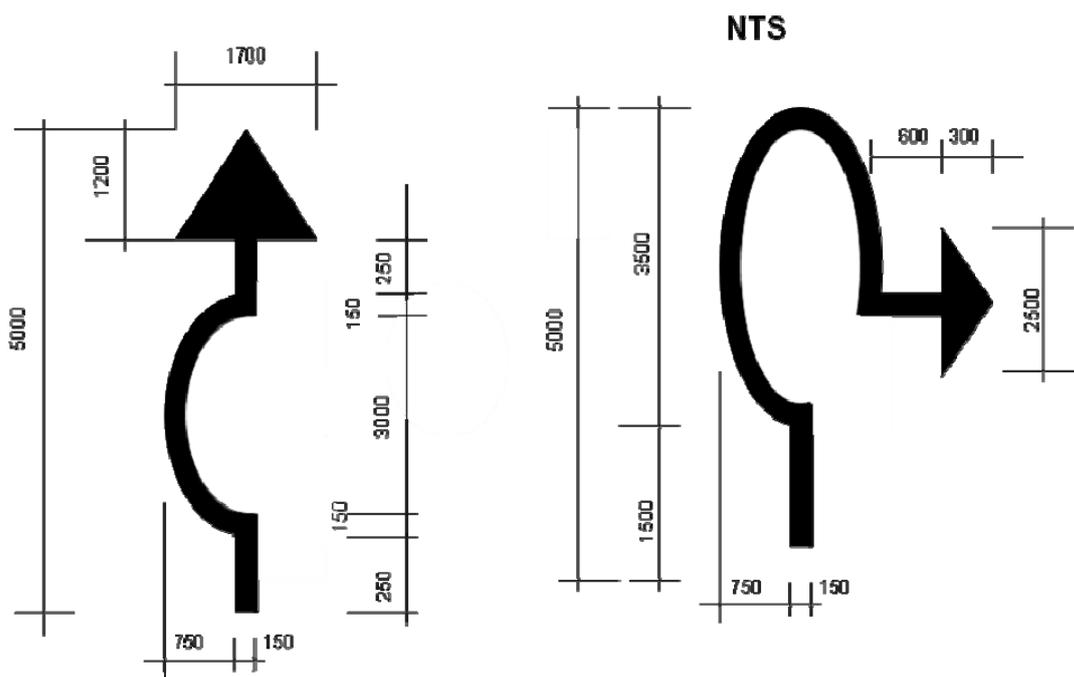
**FIGURE 5** Lane Use Arrows in The Netherlands  
(counter-clockwise traffic)



**FIGURE 6** Lane Use Arrows at Turbo Roundabouts (The Netherlands)  
**(counter-clockwise traffic)**



**FIGURE 7** Lane Arrows at Ayia Napa Roundabout in Cyprus (Drawing)  
**(clockwise traffic)**

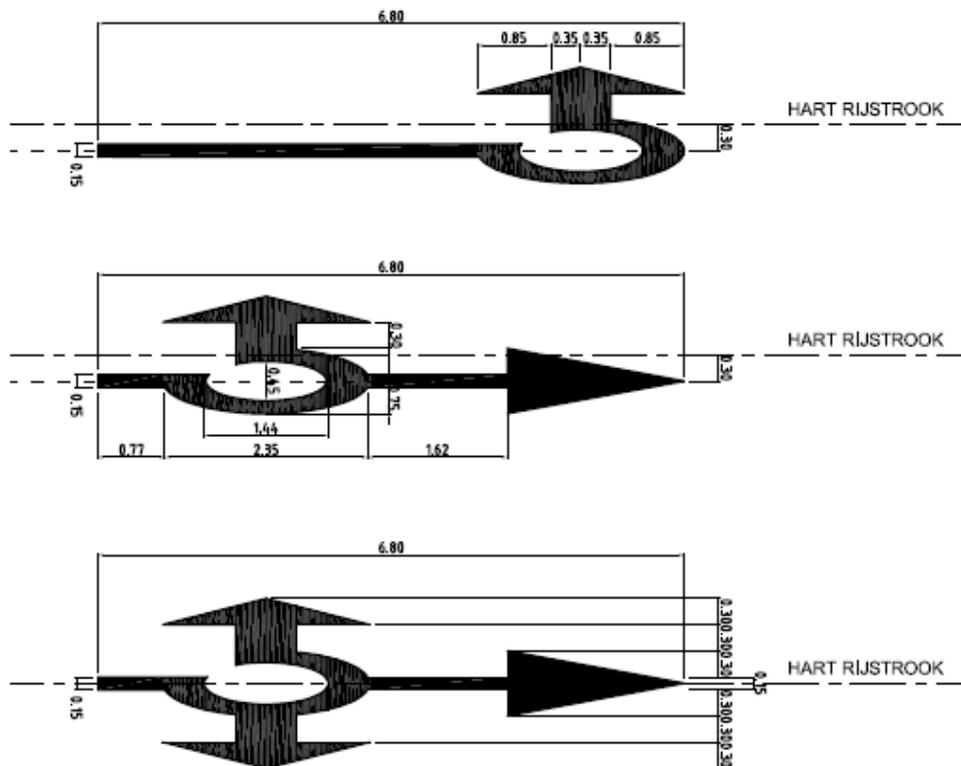


**FIGURE 8** Lane Arrows at Ayia Napa Roundabout in Cyprus (Detail)  
Dimensions are in millimeters

**(clockwise traffic)**



**FIGURE 9** Lane Arrows at Ayia Napa Roundabout in Cyprus (Photos)  
**(clockwise traffic)**



**FIGURE 10** Detail of Lane Arrow Markings in The Netherlands  
(not officially implemented yet)

**(counter-clockwise traffic)**



**FIGURE 11** Road Signs to assist entry lanes at roundabouts in The Netherlands (note: image is reversed)

**(counter-clockwise traffic)**