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Comparison between Surrogate Safety Assessment Models (SSAM) and Accident Models on Unconventional Roundabouts

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IN SUPREMÆ DIGNITATIS 1343 UNIVERSITÀ DI PISA

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Resume of the Presenter

***Antonio Pratelli** is professor of Transport ant Traffic Studies at the School of Engineering of the University of Pisa. His main research activity has addressed in the field of transportation networks planning and design. Author of more than one hundred and thirty papers published in major national and international journals, book chapters and conference proceedings.*

In the past and as host professor, he also held courses of transport and traffic engineering at the University of Florence, and at the University of Siena. As academic fellow, he held lectures at the Iowa State University, University of Kentucky, University of Bahrein, and University of Zagreb. Actually, he is the scientific director of LOGITLab, a research lab in transport and logistics. For five years, he was the director of the master course in "Logistics System Management" at the University of Pisa. Professor Pratelli also acts as a Consulting Engineer for large Italian firms on accessibility, trip generation forecasts, road networks management and control, design of intersection and parking facilities. During the last two decades, he has designed a number of roundabouts, which today, for the large part, are in operations in several cities both in Tuscany and in other parts of Italy. In 2011 June he was awarded the WIT Eminent Scientist medal by the board of directors of the Wessex Institute of Technology (United Kingdom) "for his outstanding contribution to transport engineering". In 2019 he was awarded the Promet30 prize by the Faculty of Transport and Traffic Sciences, University of Zagreb (HR).

Currently, professor Pratelli is the director in chief of the research team working at the University of Pisa on two different European H2020 research projects, dealing with UAV drones applied to urban logistics (i.e. "Aurora", H2020-MG-2018-2019-2020) and bio-plastic waste management (i.e. "Recover", H2020-GA-88764820).

Research Task

- This paper describes the comparison between the **Surrogate Safety Assessment Model** (**SSAM**) of the Federal Highway Administration (**FHWA**) and the predicted number of accidents calculated through analytical models, regarding Unconventional Roundabouts.
- The novelty of this comparison lies precisely in the fact that the 3 roundabouts analyzed fall into the category of so-called **Unconventional Roundabouts**, i.e., arrangements with "roundabout circulation", which do not fall within the types listed in the Italian Legislation (Ministerial Decree 19-04-2006).
- In particular, the conflicts type "*Approach*" for the **Maycock & Hall** model and the conflict type "*Rear end*" for the **Arndt & Troutbeck** model were taken into consideration. Furthermore, possible points of conflict (of the same category, i.e., "**Rear end**") were evaluated using dynamic simulation models. In detail,
- In detail it was decided to use the **Aimsun™** dynamic simulation software to obtain the necessary inputs for the surrogate safety assessment carried out through SSAM.

Outline

INTRODUCTION

ITALIAN UNCONVENTIONAL ROUNDABOUTS

Unconventional Roundabouts Theory and Italian Legislation

Territorial framework and O/D Matrices of the 3 identified Roundabouts

SSAM APPROACH FROM FHWA

EXISTING ROUNDABOUTS ACCIDENT MODELS

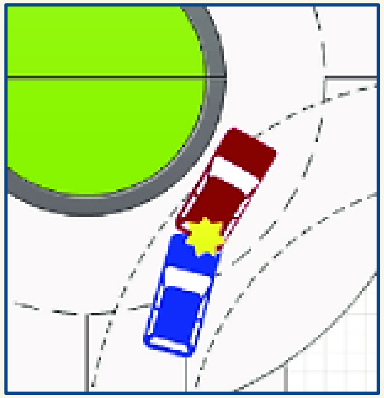
COMPARISON OF THE TWO APPROACHES

CONCLUSIONS AND FUTURE RESEARCH WORK

Introduction

U.S. Department of Transportation
Federal Highway Administration

- This work describes the comparison between **SSAM** software of the **FHWA** and the predicted number of accidents calculated through analytical models, regarding the so-called **Unconventional Roundabouts** (particular roundabouts with shapes and dimensions that are out of the ordinary concept).
- The "*Approach*" type conflict formulas are used for the **Maycock & Hall model** and the "*Rear end*" type conflict formulas for the **Arndt & Troutbeck model**. As far as the surrogate safety evaluation is concerned, it was carried out using **SSAM**, through the trajectory files generated by the dynamic simulation software **Aimsun™**.



- The points of conflict that have been taken into account, both regarding the models and SSAM, are the "**Rear end**" type.
- To improve the visualization style of the points of conflict extrapolated from SSAM, it was decided to use the Quantum Geographic Information System software (**QGIS**).

Italian Unconventional Roundabouts (1)

Unconventional Roundabouts Theory and Italian Legislation

- In the **Italian legislation** there can be three basic types of roundabouts: Conventional, Compact and Mini Roundabouts (function of Diameter [m]). For arrangements with "roundabout circulation", which do not fall within the above typologies, we, therefore, speak of **Unconventional Roundabouts** and for them, the geometric dimensioning and verification must be adapted.

Ministero delle infrastrutture e dei trasporti

(Ministerial Decree 19-04-2006)

- In Italy, there are many Unconventional Roundabouts, both because in terms of space there is the need to adopt solutions that are not conventional, and because for the moment there are always obsolete roundabouts on the national territory which have not been adapted and which in fact are often poor in **terms of safety** (there are no in-depth studies on this matter).

Italian Unconventional Roundabouts (2)

Territorial framework and O/D Matrices of the 3 identified Roundabouts (1)

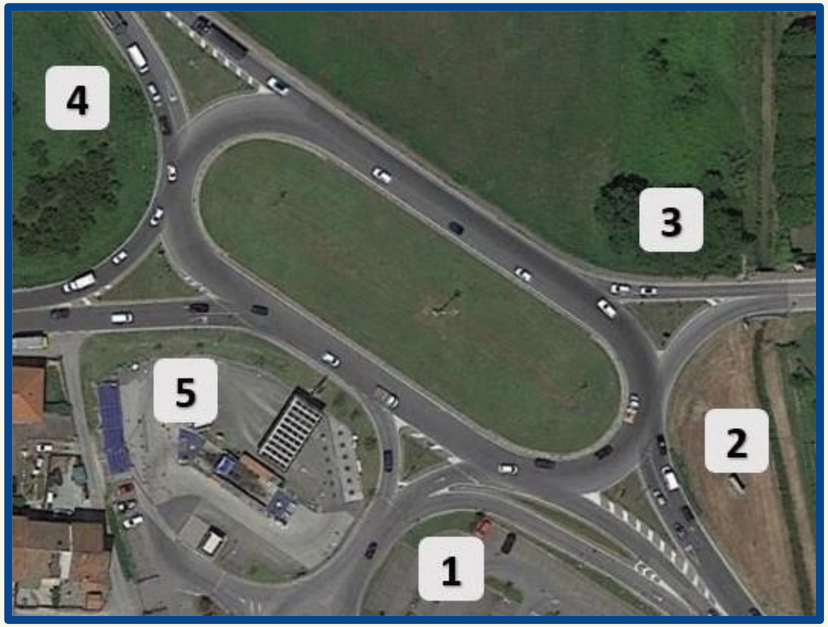
- In the next slides the **3 Unconventional Roundabouts** analyzed by the authors are illustrated. All 3 roundabouts are situated in Italy, in the **Tuscany** region and are located in urban areas, therefore the speed referred to during the calculations is equal to **50 km/h**.

- In particular, in the next figures the 3 **aerial images** extracted from Google Earth and the progressive numbers of the branches of the roundabouts are reported. Reference is made to them for the reconstruction of the **Origin/Destination (O/D) matrices**, reported in turn in the next corresponding Tables.

- These matrices were elaborated starting from the data **surveys** carried out on the 3 roundabouts through the use of Sony DCR-SX34 **digital cameras**, positioned at specific points of the intersections, during the peak periods of the week.

Italian Unconventional Roundabouts (3)

Territorial framework and O/D Matrices of the 3 identified Roundabouts (2)



Territorial framework of the 1st Unconventional Roundabout located on SP61-Lucchese-Romana in Lucca, Tuscany, Italy

Roundabout 1 - SP61 Lucchese-Romana (Lucca, Tuscany, Italy)						
Matrice O/D	1	2	3	4	5	TOT
1	0	142	60	36	72	310
2	36	0	140	346	812	1334
3	44	204	0	114	76	438
4	58	320	56	0	280	714
5	58	794	184	372	0	1408
TOT	196	1460	440	868	1240	4204

Italian Unconventional Roundabouts (4)

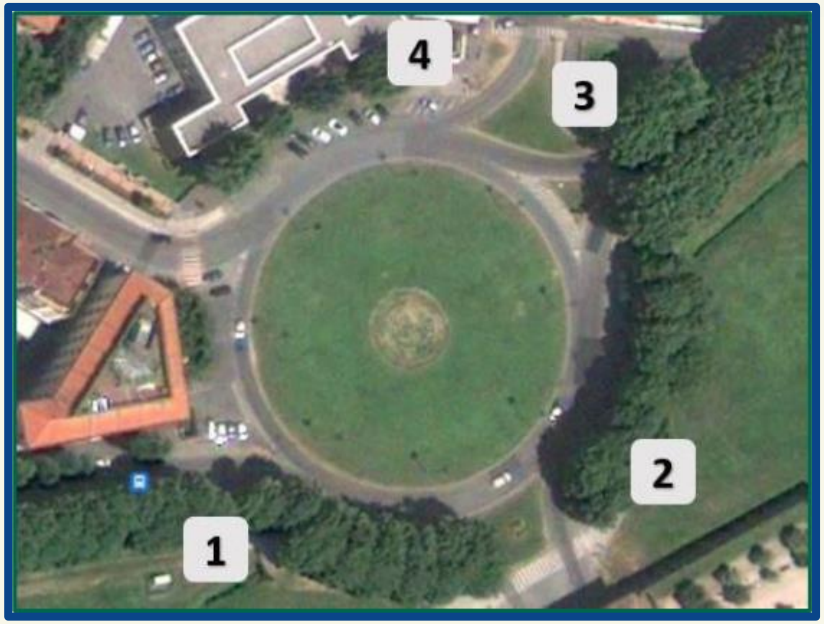
Territorial framework and O/D Matrices of the 3 identified Roundabouts (3)

Territorial framework of the 2nd Unconventional Roundabout located on Viale Nazario Sauro in Livorno, Tuscany, Italy

Roundabout 2 - Viale Nazario Sauro (Livorno, Tuscany, Italy)				
Matrice O/D	1	2	3	TOT
1	0	390	517	907
2	443	0	691	1134
3	476	541	0	1017
TOT	919	931	1208	3058

Italian Unconventional Roundabouts (5)

Territorial framework and O/D Matrices of the 3 identified Roundabouts (4)



Territorial framework of the 3rd Unconventional Roundabout located on Porta Santa Maria in Lucca, Tuscany, Italy

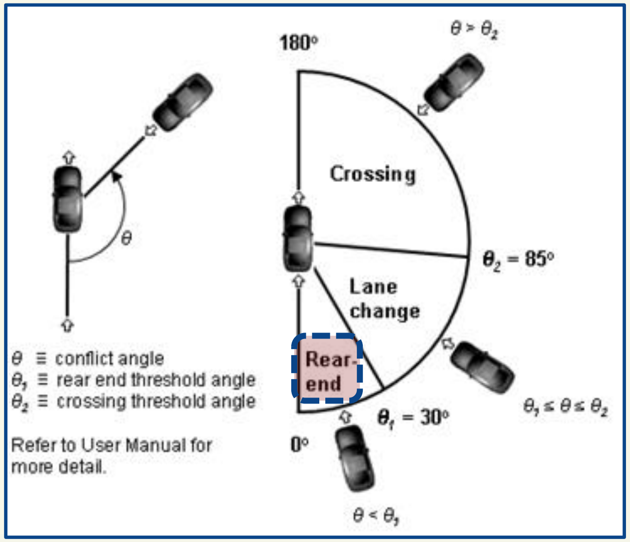
Roundabout 3 - Porta Santa Maria (Lucca, Tuscany, Italy)					
Matrice O/D	1	2	3	4	TOT
1	181	299	1749	0	2229
2	253	0	195	0	448
3	951	52	12	0	1015
4	263	51	12	0	326
TOT	1648	402	1968	0	4018

SSAM Approach from FHWA

- The concept of **surrogate safety** derives from the desire to develop alternative tools to the existing ones to evaluate the accident frequency of road infrastructure: in particular, while the ordinary methods derive from statistical evaluations based on accidents that have occurred, the surrogate safety methods are instead based on factors that do **not require years of accident statistics**.

- The **SSAM** program elaborates the trajectory files (**.trj files**) obtained from output from a dynamic simulation program (in the case of the present research, Aimsun™).

- In detail, SSAM evaluates every single vehicle-vehicle interaction according to criteria with which it can establish whether there is a point of conflict and to which category it belongs. The program contemplates four types of conflicts: **Rear end** (considered in this work), Lane changing, Crossing and Unclassified. The unit of measurement is expressed in **conflicts/day**.



Existing Roundabouts Accident Models

- To study the safety characteristics of the elements of the road system, there are several models for predicting accidents. The authors have decided to use two of the most used models: **Maycock & Hall model** and **Arndt & Troutbeck model**. They were chosen because they take into account the traffic demand, geometric and dynamic characteristics of the intersection.

- With these models, it is possible to calculate various types of accidents, but clearly, as explained above, it was decided to use the formulas of the Conflicts Type "Approach" for the *Maycock & Hall model* (A_2) and those of the Conflict Types "Rear end" for the *Arndt & Troutbeck model* (A_r), which indicate precisely rear-end collisions. The unit of measurement is expressed in **accidents/years**.

$$A_2 = 0.0057 \times Q_e^{1.7} \times \exp(20C_e - 0.1e)$$

$$A_r = C_1 \times Q_a^x \times Q_c^y \times S_a^z + C_2$$

- The **coefficients** of these formulas are the standard ones calibrated for conventional roundabouts. So, another of the interesting aspects of this research was precisely that of verifying whether these coefficients could also work for **Unconventional Roundabouts**.

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Comparison of the Two Approaches (1)

- A **summary table** of the calculations carried out is shown which served to reconstruct the graphs on which most of the considerations will be made.

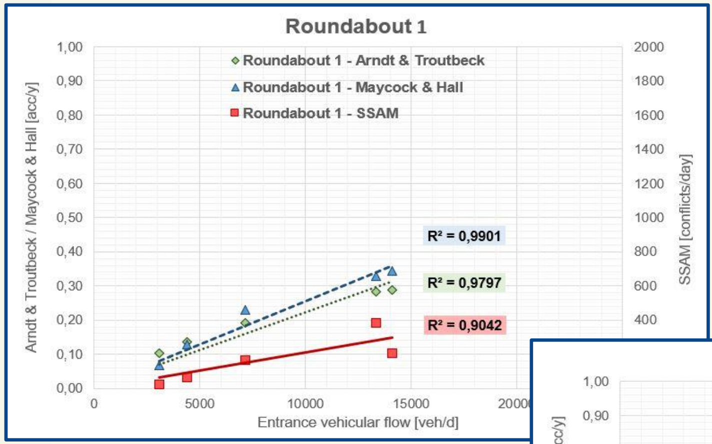
Roundabout	Approach	Qe [veh/d]	Arndt & Troutbeck Rear-end [acc/y]	Maycock & Hall Approach [acc/y]	SSAM (TTC = 1.5 s) [conflicts/d]
1	1	3100	0,10	0,07	24
	2	13340	0,28	0,33	383
	3	4380	0,14	0,13	63
	4	7140	0,19	0,23	165
	5	14080	0,29	0,34	207
2	1	9070	0,16	0,15	120
	2	11340	0,20	0,37	203
	3	10170	0,16	0,27	119
3	1	22290	0,18	0,55	160
	2	4480	0,15	0,13	82
	3	10150	0,16	0,32	104
	4	3260	0,09	0,07	36

- In addition, the image shows an **extract of the QGIS software** of one of the roundabouts chosen as an example, where the points of conflict have been inserted, georeferenced (with **TTC = 1.5 s**) extracted from the SSAM software after processing the ".trj file", which in turn was obtained from the Aimsun™ simulation software.

- The **Time to Collision** (TTC) is one of the SSAM software parameters and expresses the minimum collision time. It can range from an infinite maximum value, when two vehicles never meet, to a minimum value of 0 seconds when an accident occurs.

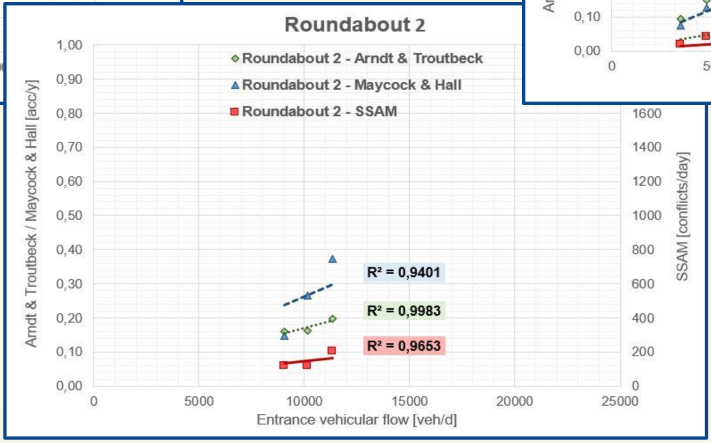
Comparison of the Two Approaches (2)

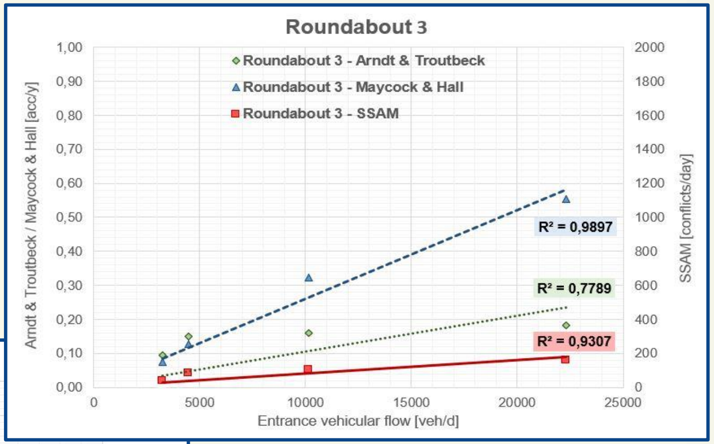
- Each **graph** refers to one of the 3 roundabouts and is structured as follows: the ***Qe*** (entrance vehicular flow) expressed in **vehicles/day** is shown on the abscissa axis; while there are two different y axes. The left y-axis is incident models (**Arndt & Troutbeck / Maycock & Hall**) and is expressed in **accidents/years**, while the right is the **SSAM** results and is expressed in **conflicts/day**.



GRAPH 1

GRAPH 2





GRAPH 3

Comparison of the Two Approaches (3)

- On the graphs, as many points have been reported as there are entrance arms of the roundabout in question and a **linear trend** line passing through the origin ***(0; 0)*** has then been created for them. The coefficient of determination ***R^2*** was calculated for each trend line. (***$R^2 = 0$*** indicates a model whose predictor variables do not explain the variability of y around its mean at all; ***$R^2 = 1$*** indicates a model whose independent variables fully explain the variability of y around its mean). What emerges is that the greater the value of ***R^2***, the more the model has high predictive power (high ***R^2*** values is over ***0.7***).

- For all the graphs, the ***R^2*** values are generally excellent both as regards the accident models and as regards the values of the conflicts obtained with SSAM. Therefore:
  - ✓ The **accident models** used already validated for conventional roundabouts, can also be used **for Unconventional Roundabouts**, using the same formulations and the same coefficients.
  - ✓ Even for Unconventional Roundabouts there is a **correspondence between** the **accident models** and the calculation of the conflicts carried out with **SSAM**.

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Comparison of the Two Approaches (4)

- Finally, the authors also noted a further fact regarding graph 3 referring to roundabout 3. The trend line of the Arndt & Troutbeck model has an ***R^2*** that is always acceptable, but clearly lower than all the others (***0.78***). The explanation is the following: roundabout number 3, in addition to being of an unconventional type, is also atypical from the point of view of the approaches, since, the approach 4 is formed only by the input branch and not the output branch.

Roundabout	Approccio	Qe [veh/d]	Qc [veh/d]	Delta (Qe-Qc/Qc)
3	1	22290	1150	18,38
	2	4480	19540	0,77
	3	10150	4340	1,34
	4	3260	14490	0,78

- This, together with the particular geometry of the roundabout, has led to a high difference between the incoming flow rate ***Qe*** and the circulating flow rate ***Qc*** of the adjacent approach 1. Therefore, another result:
  - ✓ The model of **Arndt & Troutbeck does not adapt perfectly** to Unconventional Roundabouts in which there is, for some branches, a high difference between the incoming flows and circulating flows

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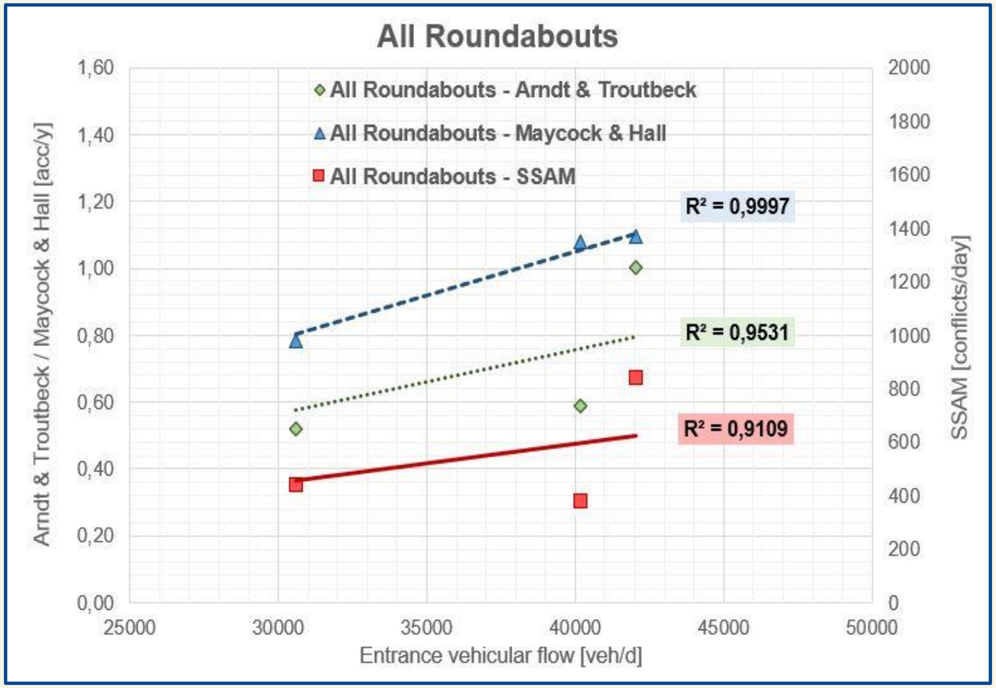
Comparison of the Two Approaches (5)

- A final comparison was also made for the **3 Unconventional Roundabouts** as a whole. In fact, a last graph of the same typology as the previous ones, was constructed however by taking into consideration the roundabouts as a whole and no longer approach by approach. In this way, it was possible **to compare the 3 roundabouts** on a single graph and this led to the following consideration.



- The values of ***R^2*** are excellent and also the roundabout 3 which had a deficit on the Arndt & Troutbeck model due to the difference between the incoming flows and the circulating flows at one of the approaches, if it is considered as a whole, it is possible to homogenize with the other results.

Conclusions & Future Research Work (1)

- This article describes the **comparison between** the Federal Highway Administration (FHWA) Surrogate Safety Assessment Model (**SSAM**) and the predicted number of accidents calculated using the **Arndt & Troutbeck and Maycock & Hall analytical models**, as concern the Unconventional Roundabouts.

- **3 Unconventional Roundabouts** located in **Italy** that have different shapes and sizes from the regulatory standards were analysed. Other works have been published regarding the comparison between the models mentioned, however, the novelty of this research lies precisely in the different base data (the Unconventional Roundabouts).

- The type of accident and conflict chosen for the comparison made is that of **rear-end collisions**, as it is the most common present on roundabout intersections. In the sections of the article, various initial considerations follow one another which deepen the concepts of Unconventional Roundabouts, surrogate safety analysis models (SSAM) and accident models; up to the last section where the **results of the entire research** were clearly explained.

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Conclusions & Future Research Work (2)

- Summarizing these results, the authors found that:

1. the **accident models** used already valid and validated for conventional roundabouts, **can also be used for Unconventional Roundabouts**, using the same formulations and the same coefficients also because a certain correspondence was also found between them in terms of the number of accidents per year;
2. also for Unconventional Roundabouts there is a **correspondence between the accident models and** the calculation of the conflicts carried out with **SSAM**;
3. **Arndt & Troutbeck model is not perfectly suited** to Unconventional Roundabouts in which there is, for one or more branches, too **high a difference between incoming flows and circulating flows**.

- Finally, this work can certainly be expanded by **analysing further case studies** and thus obtaining more points to use on the graphs. Furthermore, another steps could be to go and search for **the actual accident data** and thus verify whether the **parameters used can be further improved and recalibrated** for Unconventional Roundabouts.

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THANK YOU FOR YOUR ATTENTION

QUESTIONS OR SUGGESTIONS

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