Understanding blood donation attitudes in Bulgaria using an intuitionistic fuzzy sets based approach with graded scales

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Introduction and problem statement

Whole blood donation is of vital importance

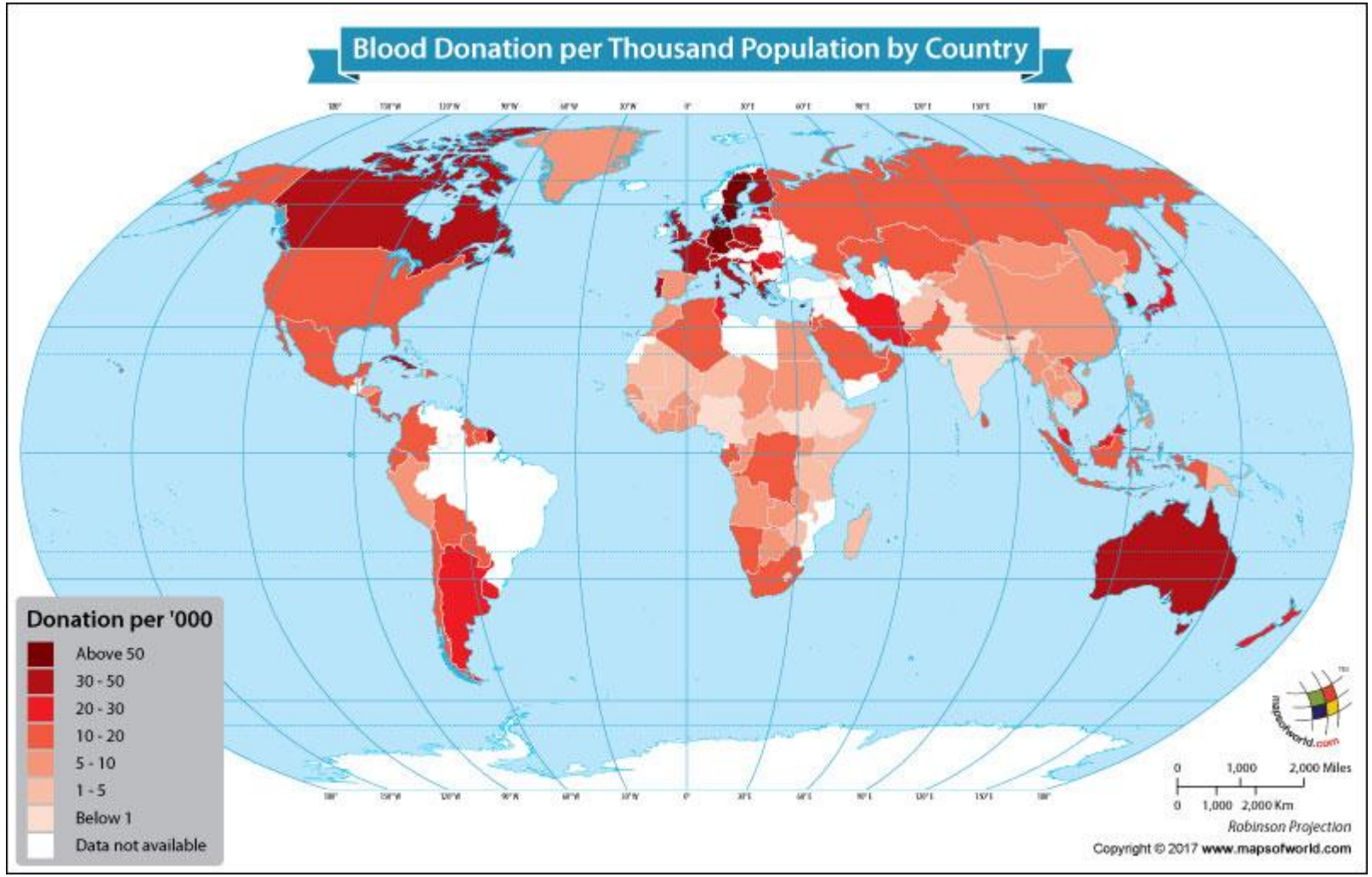
- provides a safe and reliable supply of blood for transfusion and production of blood products,
- used in life-saving surgeries, trauma care, treatment of chronic conditions,
- supports public health systems,
- helps ensure that hospitals are prepared for crisis situations, emergencies, natural disasters, etc.,
- contributes to community solidarity and resilience.

Blood donation can be:

- **remunerated**
- **non-remunerated**
  - **voluntary** (altruistic, internally motivated)
  - **family / replacement** (addressing a need or hospital requirement)

World Health Organization (WHO) advocates for global transition to 100% voluntary blood donation

Introduction and problem statement



https://www.mapsofworld.com/answers/health/countries-record-highest-blood-donors/attachment/map-blood-donation

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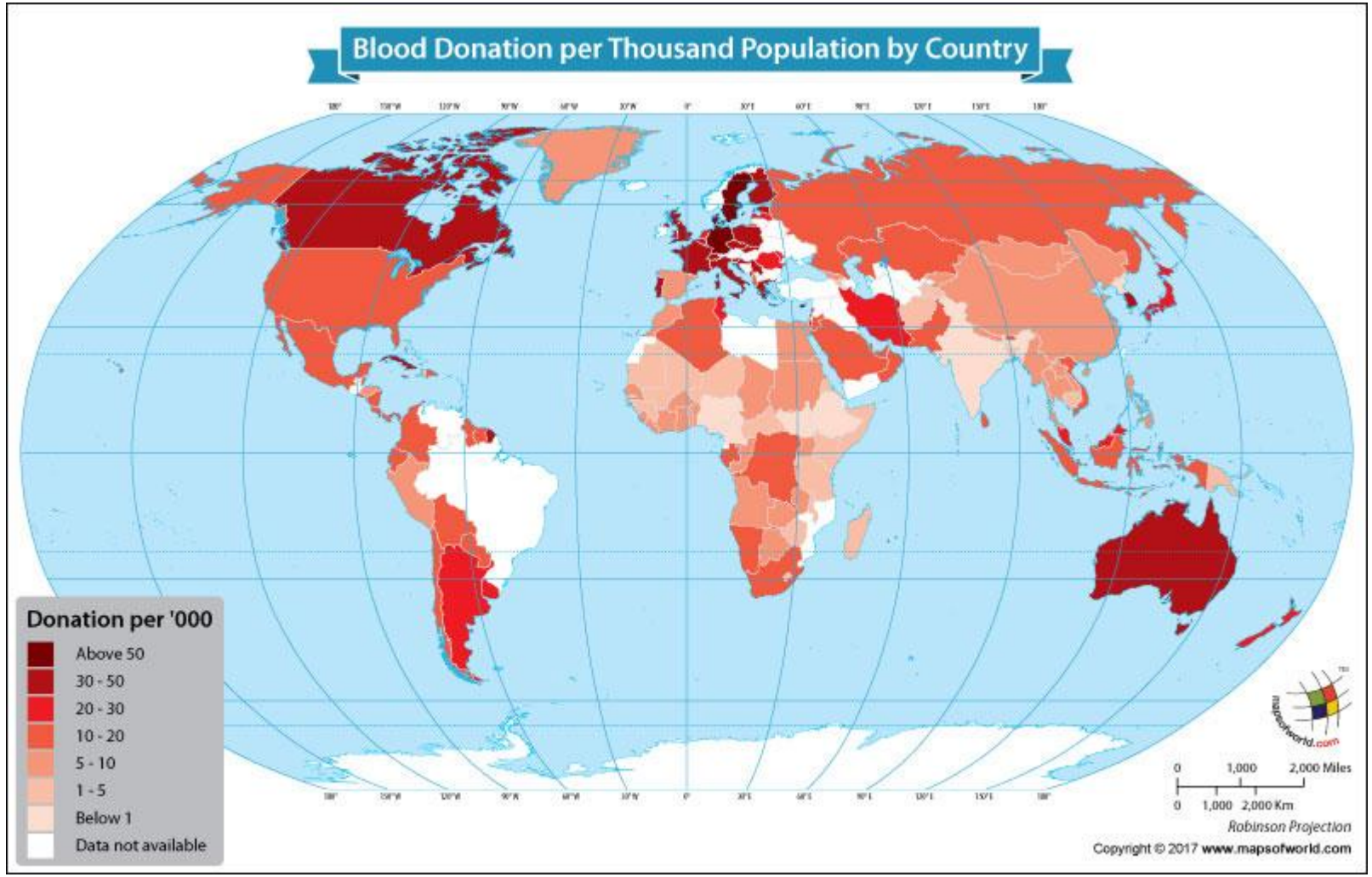

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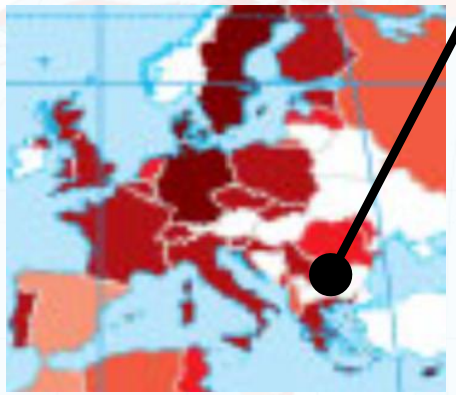
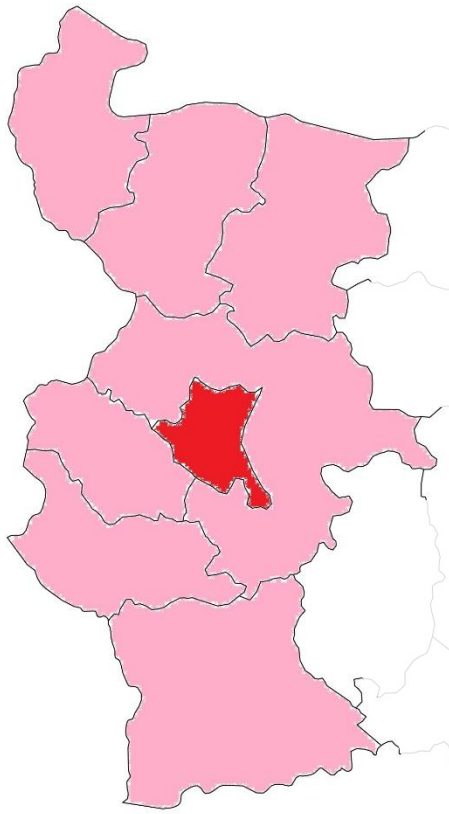


Bulgaria represents a context with low culture of voluntary blood donation:

- Low overall rate of blood donations per capita
  (25.90 donations per 1000 people for 2023,
  for Sofia and the region: 33.02 donations per 1000 people)
- Predominance of family/replacement donations
  (approximately 85–95% of all blood donations are family/replacement)
- Need to predict the most promising blood donors.

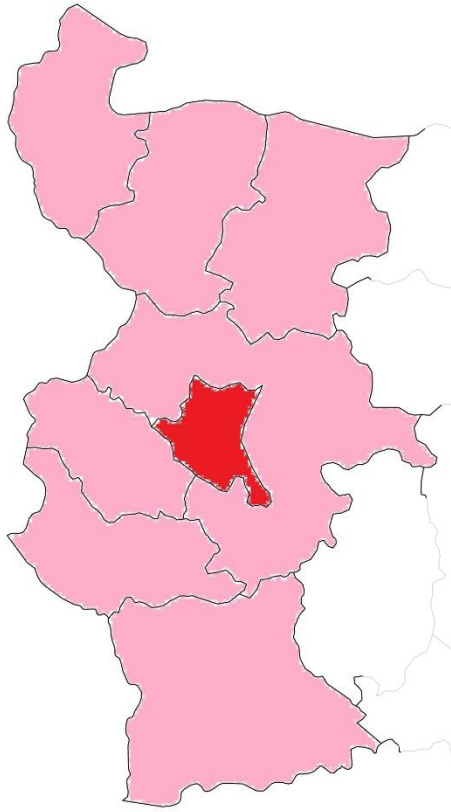
Materials and methods



Materials: Anonymized dataset for the blood donors in the National Centre of Transfusion Haematology of Bulgaria for 2024, comprising data for **Sofia City** and its subordinate transfusion haematology departments collecting blood for **Sofia District, and the towns of Blagoevgrad, Kyustendil, Lom, Montana, Pernik, Vidin, and Vratsa**.

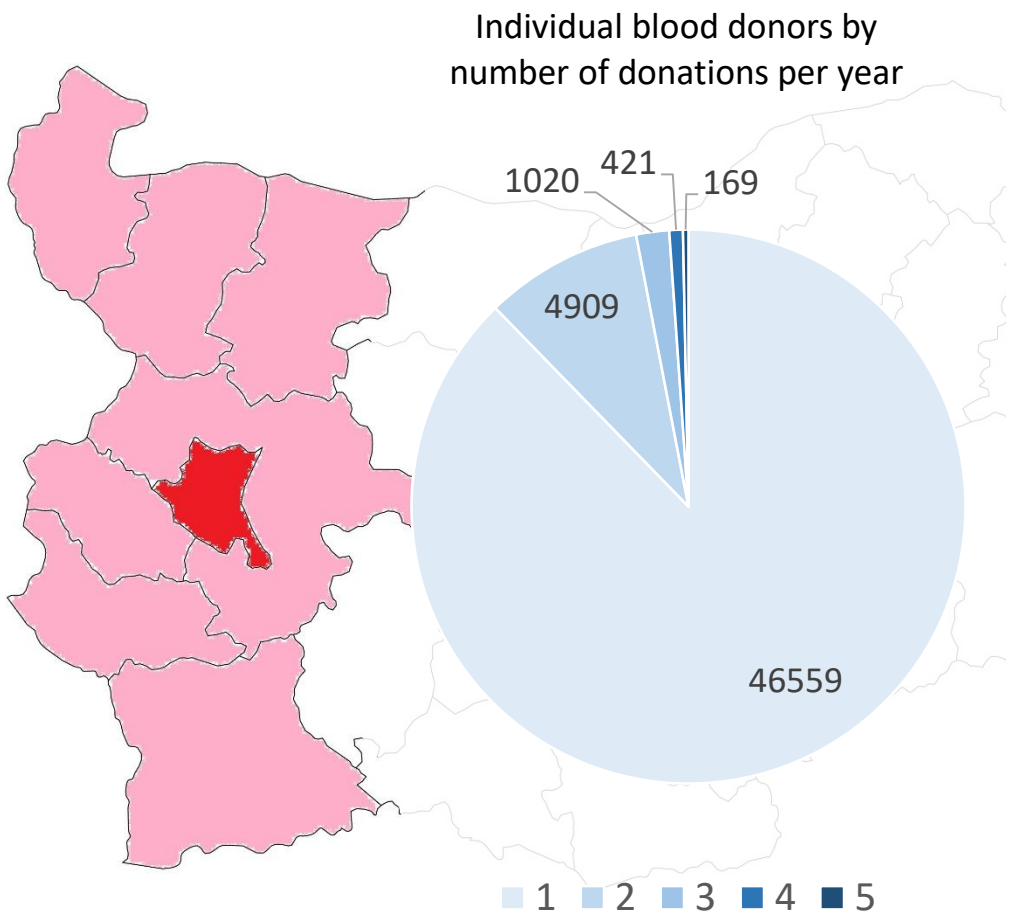
- 61973 donation acts – **75.3%** or 46661 by male blood donors, and **24.7%** or 15312 by female blood donors.
- **86.9%** or 53831 family/replacement (40661 male and 13170 female donors), and **13.1%** or 8135 voluntary donations (5989 male and 2146 female donors).

Materials and methods



# donations	Donation acts	Donation acts – M	Donation acts – F	Donors	Donors – M	Donors – F
1	46559	34618	11941	46559	34618	11941
2	9818	7508	2310	4909	3754	1155
3	3060	2394	666	1020	798	222
4	1684	1284	400	421	321	100
5	845	845	0	169	169	0

Materials and methods



#	Sex	Total	Donation modes ← voluntary / replacement →				
1			1 voluntary			1 replacement	
	M	34618	3666			30952	
	F	11941	1513			10428	
	M+F	46559	5179			41380	
2			2 voluntary		1 voluntary, 1 replacement		2 replacement
	M	3754	460		589		2705
	F	1155	155		188		812
	M+F	4909	615		777		3517
3			3 voluntary	2 voluntary, 1 replacement		2 replacement 1 voluntary	3 replacement
	M	798	83	82		84	549
	F	222	18	21		18	165
	M+F	1020	101	103		102	714
4			4 voluntary	3 voluntary, 1 replacement	2 voluntary, 2 replacement	1 voluntary, 3 replacement	4 replacement
	M	321	25	20	18	8	250
	F	100	2	1	3	4	90
	M+F	421	27	21	21	12	340
5			5 voluntary	4 voluntary, 1 replacem.	3 voluntary, 2 replacem.	2 voluntary, 3 replacem.	1 voluntary, 4 replacem.	5 replacem.
	M	169	10	6	9	3	6	135
	F	0	0	0	0	0	0	0
	M+F	169	10	6	9	3	6	135

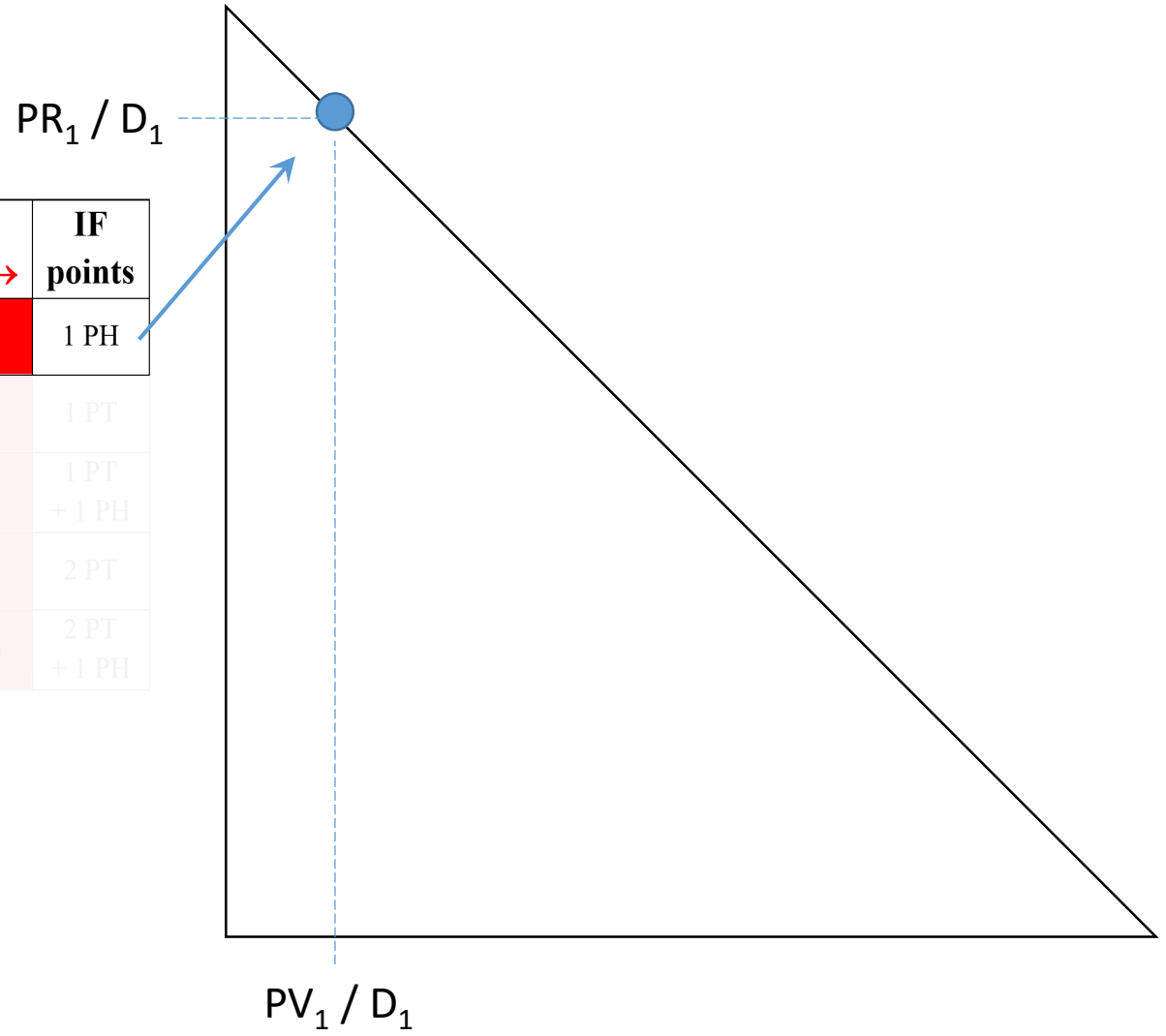
Materials and **methods**

#	# donors	Donation modes ← voluntary				replacement →	IF points
1 (m,f)	**D_1**	PV_1 (1V)				PR_1 (1R)	1 PH
2 (m,f)	**D_2**	PV_2 (2V)		MX_2 (1V + 1R)		PR_2 (2R)	1 PT
3 (m,f)	**D_3**	PV_3 (3V)	SV_3 (2V + 1R)		SR_3 (1V + 2R)	PR_3 (3R)	1 PT + 1 PH
4 (m,f)	**D_4**	PV_4 (4V)	MV_4 (3V + 1R)	MX_4 (2V + 2R)	MR_4 (1V + 3R)	PR_4 (4R)	2 PT
5 (m)	**D_5**	PV_5 (5V)	MV_5 (4V + 1R)	SV_5 (3V + 2R)	SR_5 (2V + 3R)	MR_5 (1V + 4R)	PR_5 (5R)	2 PT + 1 PH

IF membership, μ **IF non-membership, ν**

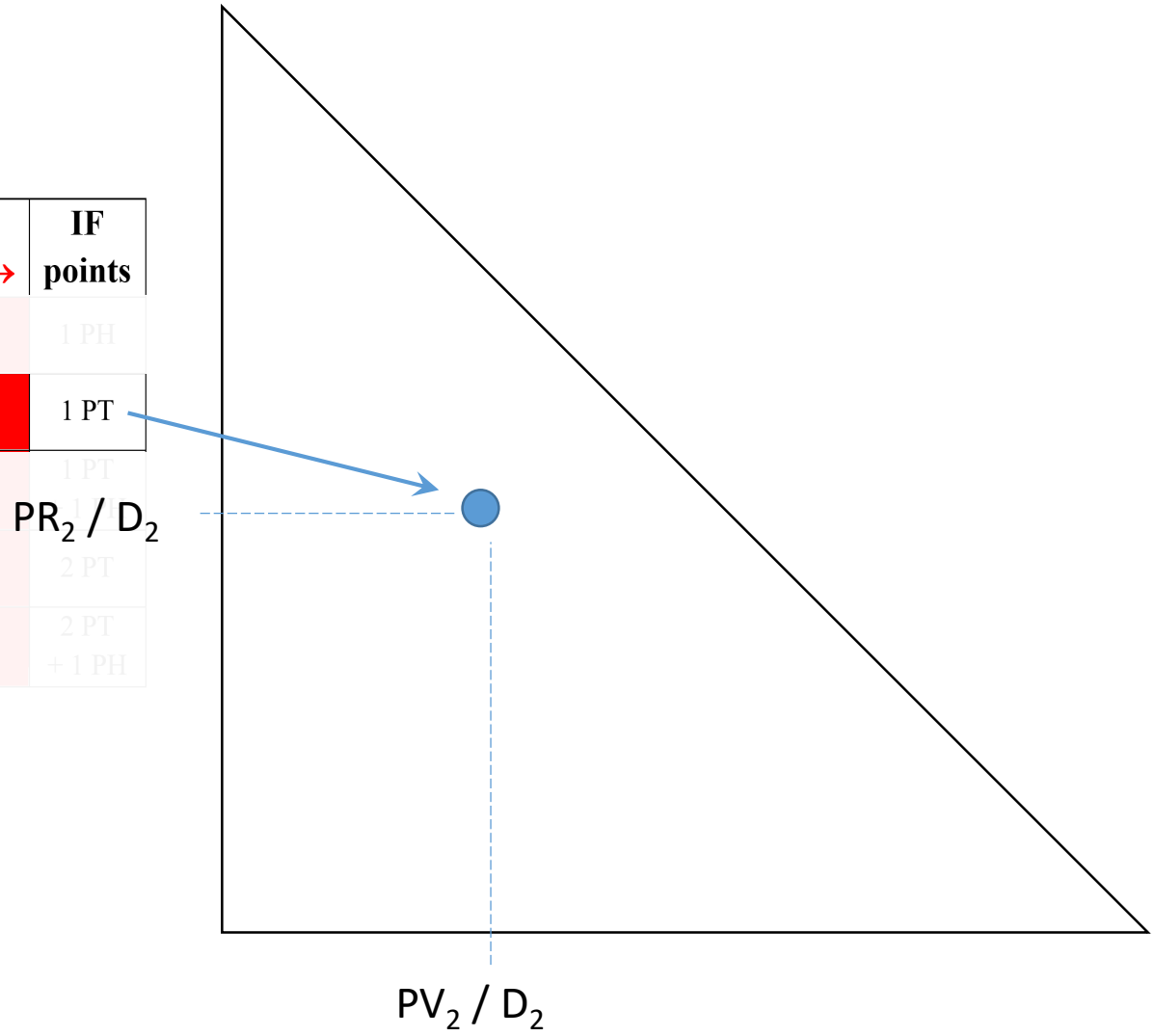
Materials and **methods**

#	# donors	Donation modes ← voluntary				replacement →	IF points
1 (m,f)	**D_1**	PV_1 (1V)				PR_1 (1R)	1 PH
2 (m,f)	**D_2**	PV_2 (2V)		MX_2 (1V + 1R)		PR_2 (2R)	1 PT
3 (m,f)	**D_3**	PV_3 (3V)		SV_3 (2V + 1R)	SR_3 (1V + 2R)	PR_3 (3R)	1 PT + 1 PH
4 (m,f)	**D_4**	PV_4 (4V)	MV_4 (3V + 1R)	MX_4 (2V + 2R)	MR_4 (1V + 3R)	PR_4 (4R)	2 PT
5 (m)	**D_5**	PV_5 (5V)	MV_5 (4V + 1R)	SV_5 (3V + 2R)	SR_5 (2V + 3R)	MR_5 (1V + 4R)	PR_5 (5R)	2 PT + 1 PH



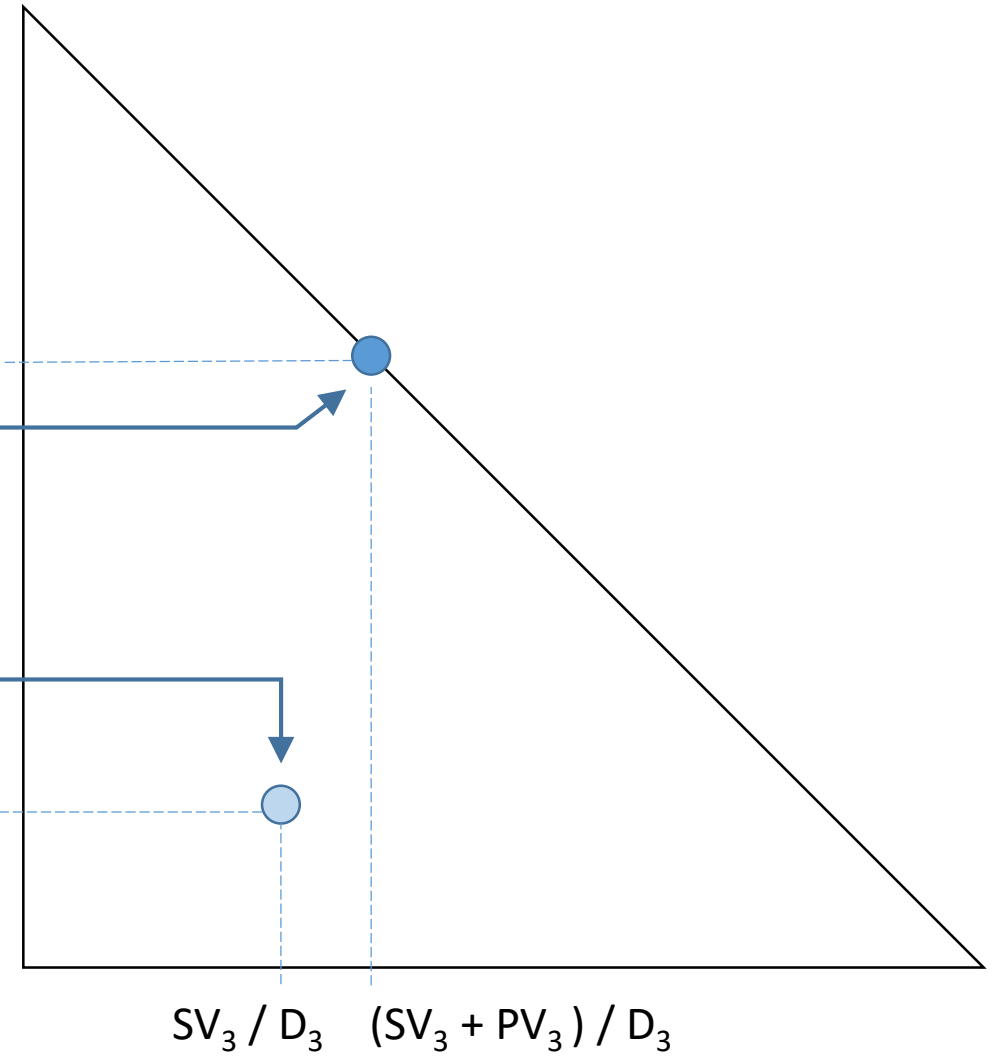
Materials and **methods**

#	# donors	Donation modes ← voluntary		replacement →	IF points
2 (m,f)	**D_2**	PV_2 (2V)	MX_2 (1V + 1R)	PR_2 (2R)	1 PT



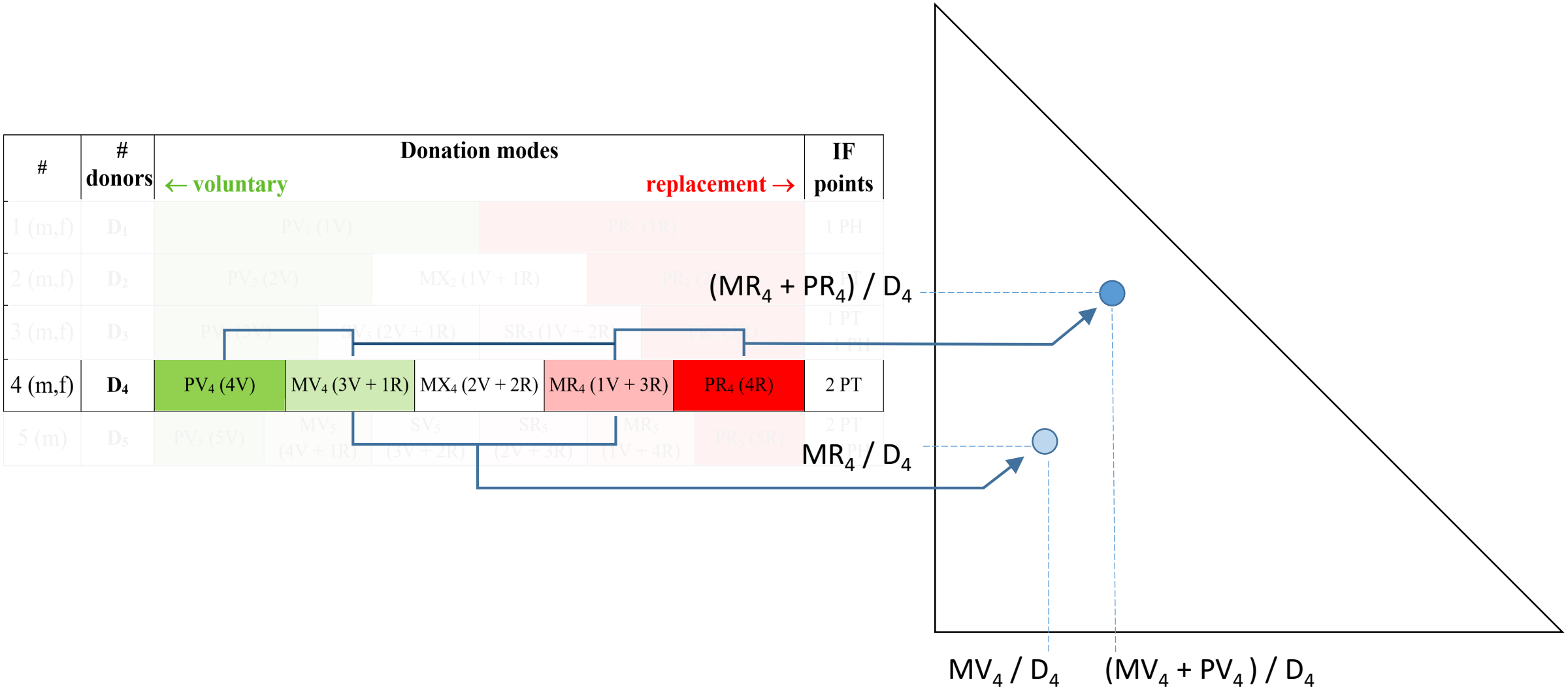
Materials and **methods**

#	# donors	Donation modes ← voluntary			replacement →	IF points
3 (m,f)	D_3	PV_3 (3V)	SV_3 (2V + 1R)	SR_3 (1V + 2R)	PR_3 (3R)	1 PT + 1 PH



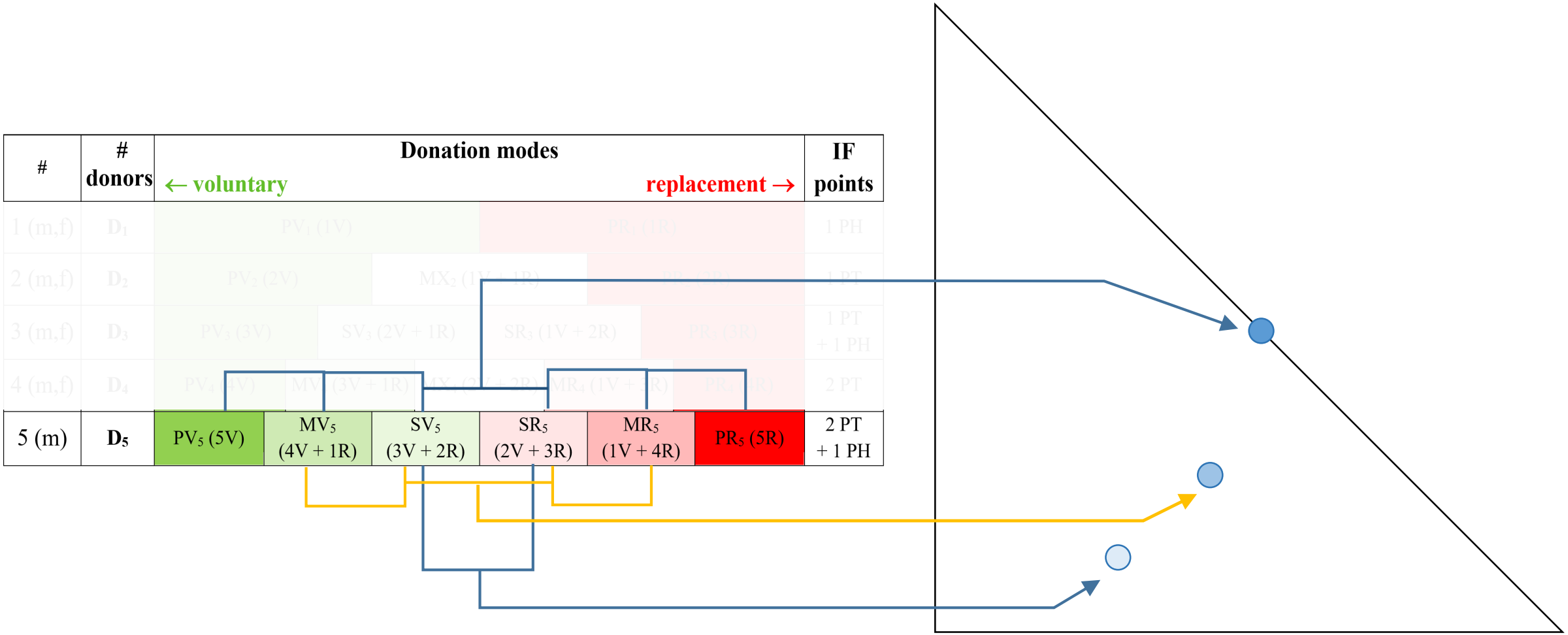
Materials and **methods**

#	# donors	Donation modes ← voluntary				replacement →	IF points
4 (m,f)	**D_4**	PV_4 (4V)	MV_4 (3V + 1R)	MX_4 (2V + 2R)	MR_4 (1V + 3R)	PR_4 (4R)	2 PT



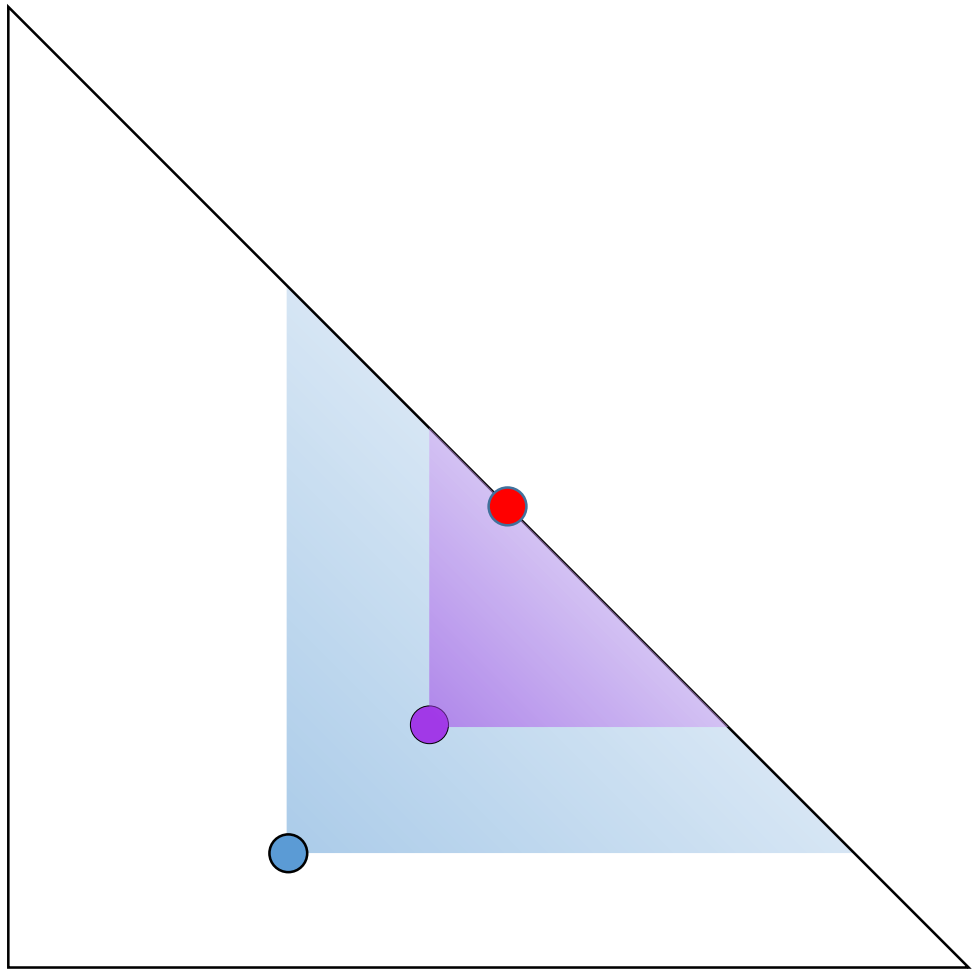
Materials and **methods**

#	# donors	Donation modes ← voluntary				replacement →		IF points
1 (m,f)	D_1	PV_1 (1V)				PR_1 (1R)		1 PH
2 (m,f)	D_2	PV_2 (2V)	MX_2 (1V + 1R)			PR_2 (2R)		1 PT
3 (m,f)	D_3	PV_3 (3V)	SV_3 (2V + 1R)	SR_3 (1V + 2R)		PR_3 (3R)		1 PT + 1 PH
4 (m,f)	D_4	PV_4 (4V)	MV_4 (3V + 1R)	MX_4 (2V + 2R)		MR_4 (1V + 3R)	PR_4 (4R)	2 PT
5 (m)	D_5	PV_5 (5V)	MV_5 (4V + 1R)	SV_5 (3V + 2R)	SR_5 (2V + 3R)	MR_5 (1V + 4R)	PR_5 (5R)	2 PT + 1 PH



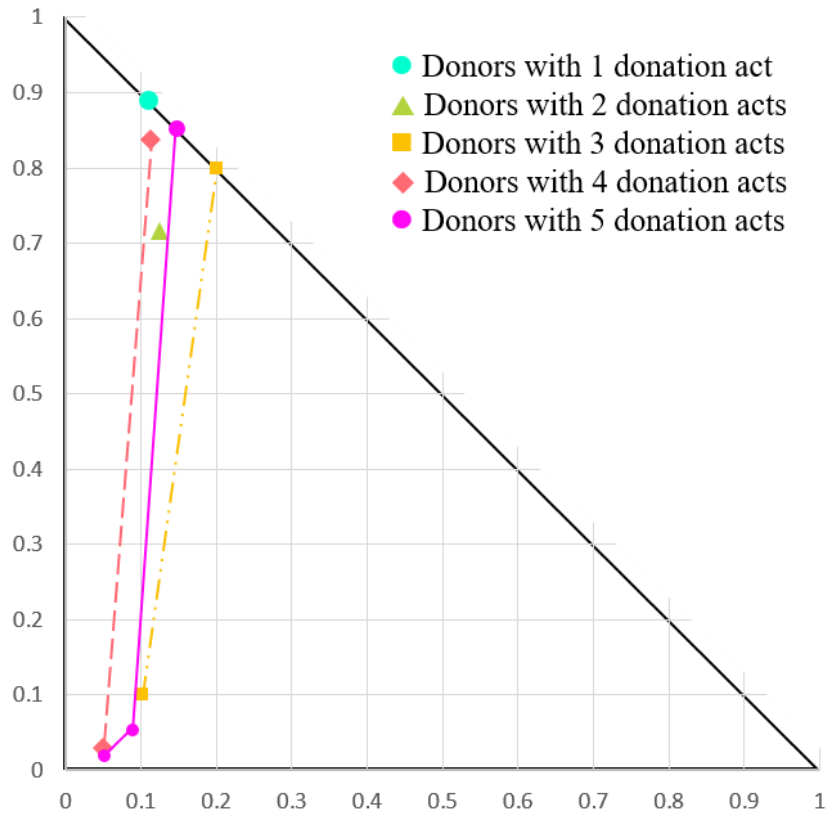
Materials and **methods**

Domain of action coincides with the intuitionistic fuzzy operator $F_{\alpha,\beta}$



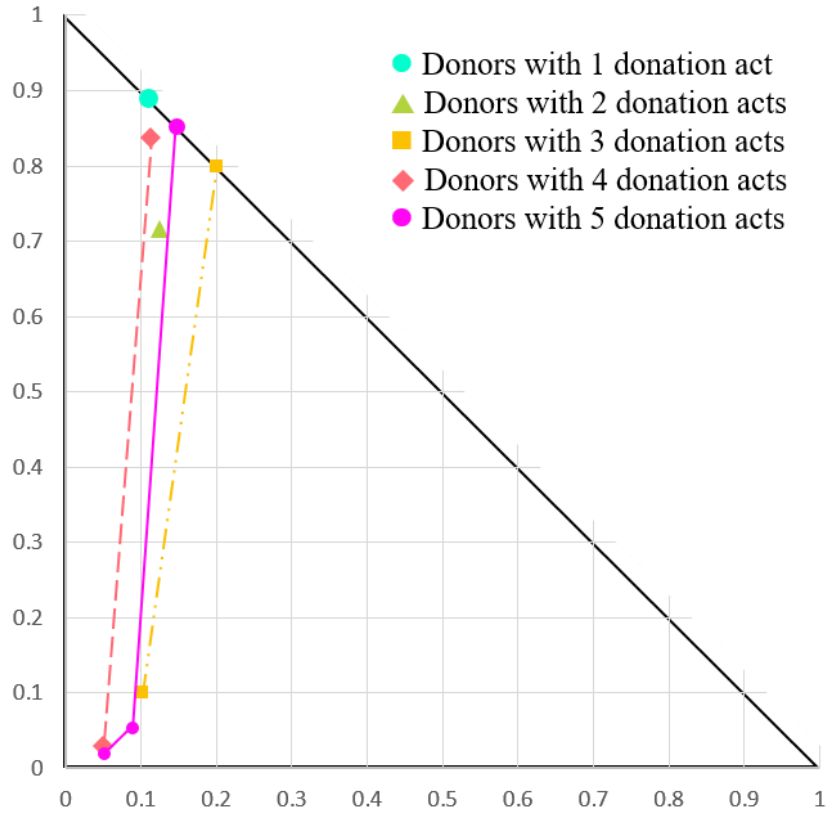
Results and discussions

#	Sex	Donation modes ← voluntary, μ					replacement, ν →	IF points (M+F)
1		PV_1 (1V)					PR_1 (1R)	1 PH (0.111; 0.889)
	M	0.106					0.894	
	F	0.127					0.873	
	M+F	**0.111**					**0.889**	
2		PV_2 (2V)		MX_2 (1V + 1R)			PR_2 (2R)	1 PI (0.125; 0.716)
	M	0.123		0.157			0.721	
	F	0.134		0.163			0.703	
	M+F	**0.125**		**0.158**			**0.716**	
3		PV_3 (3V)	SV_3 (2V + 1R)		SR_3 (1V +2R)		PR_3 (3R)	1 PI (0.101; 0.100) 1 PH (0.200; 0.800)
	M	0.104	0.103		0.105		0.688	
	F	0.081	0.095		0.081		0.743	
	M+F	**0.099**	**0.101**		**0.100**		**0.700**	
4		PV_4 (4V)	MV_4 (3V+1R)	MX_4 (2V + 2R)	MR_4 (1V+3R)		PR_4 (4R)	2 PIs (0.050; 0.029) (0.114; 0.836)
	M	0.078	0.062	0.056	0.025		0.779	
	F	0.020	0.010	0.030	0.040		0.900	
	M+F	**0.064**	**0.050**	**0.050**	**0.029**		**0.808**	
5		PV_5 (5V)	MV_5 (4V+1R)	SV_5 (3V+2R)	SR_5 (2V+3R)	MR_5 (1V+4R)	PR_5 (5R)	2 PIs (0.053; 0.018) (0.089; 0.053) 1 PH (0.148; 0.852)
	M	0.059	0.036	0.053	0.018	0.036	0.799	
	F	0	0	0	0	0	0	
	M+F	**0.059**	**0.036**	**0.053**	**0.018**	**0.036**	**0.799**	



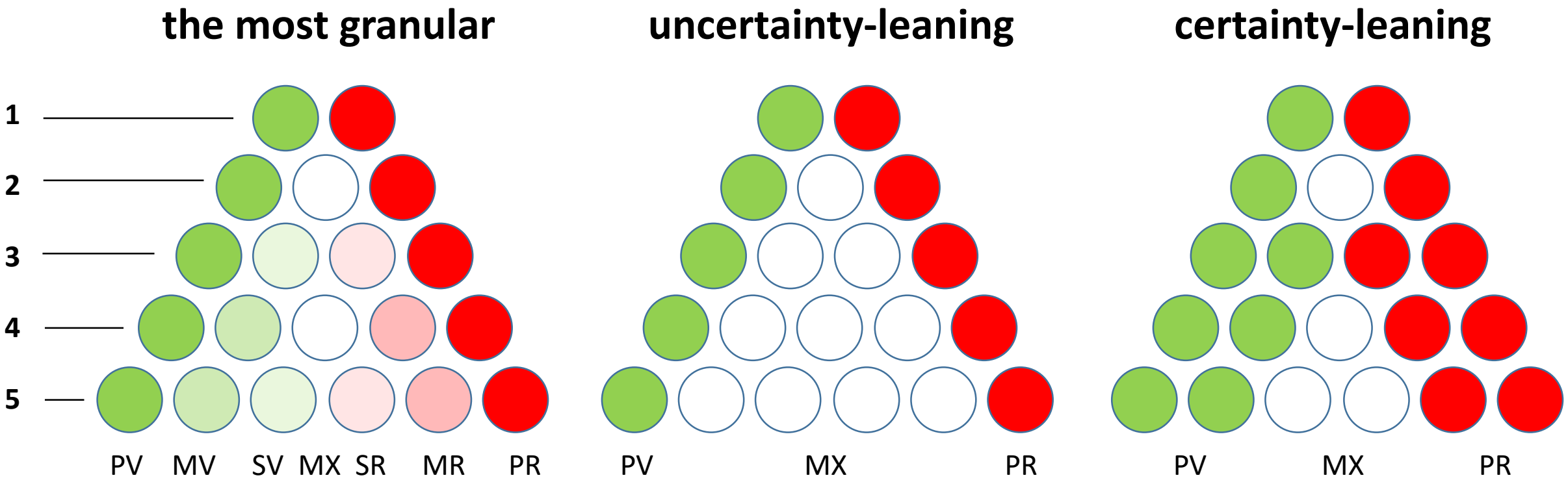
Results and **discussions**

- One-time / incidental blood donors are mostly family / replacement (89%), forced by need or hospital requirement.
- Four- and five-timers who reach the maximal permissible number of donations per year are 80% replacement donors. This potentially comprises a share of unofficially remunerated / pair donors.
- Largest shares of voluntary blood donation is recorded in two- and three-timers: non-routinized yet non-incidental donors; highest uncertainty in two-timers.



Results and **discussions**

- Future discussions: How about changing the granularity of the method?



Conclusion

- The problem of predicting the volume of voluntary blood donation encompasses both uncertainty and multimodal donation behaviours.
- Intuitionistic fuzzy sets are considered to provide a good theoretical framework to describe both the problem and seek solutions.
- IFS allow visualization in the IF interpretational triangle and an immediate application of the existing operator $F_{\alpha,\beta}$.
- An interesting direction for future research will be investigating distinct granularities, e.g. the uncertainty- and certainty-leaning.

Thank you for your attention!

And thank you for your blood donation!

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