Table 5. Example of a pairwise comparison (excerpt from 1 customer for 3 CRs)

	CR 1			CR 2			CR 3		
	L	M	U	L	M	U	L	M	U
CR 1	1	1	1	1/8	1/7	1/6	1	1	1
CR 2	6	7	8	1	1	1	6	7	8
CR 3	1/4	1/3	1/2	1/8	1/7	1/6	1	1	1

Table 6. Results of the HoQ augmented by the FAHP

	Importance	Relative Importance	*CR ranking*	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6	SC 7	SC 8	SC 9	SC 10	SC 11	SC 12	SC 13	SC 14	SC 15
CR 1	0.813	9.9%	*4*	9		3	3					3	3	9	9			
CR 2	2.896	35.3%	*1*							9	3	9				1	9	3
CR 3	0.307	3.7%	*8*	3									3	9	9			1
CR 4	2.058	25.1%	*2*							9	9	3	9			9	9	9
CR 5	0.932	11.4%	*3*							1	1	9	9			9		
CR 6	0.361	4.4%	*7*				9	9	9									
CR 7	0.442	5.4%	*5*	1		9								3				
CR 8	0.393	4.8%	*6*	1	9	1		1					1					
SC importance				9.08	3.54	6.82	5.69	3.65	3.25	45.52	28.15	43.07	30.67	11.41	10.08	29.81	44.59	27.52
SC relative importance				3.0%	1.2%	2.3%	1.9%	1.2%	1.1%	15.0%	9.3%	14.2%	10.1%	3.8%	3.3%	9.8%	14.7%	9.1%
SC ranking				*10*	*14*	*11*	*12*	*13*	*15*	*1*	*6*	*3*	*4*	*8*	*9*	*5*	*2*	*7*

4. Discussion of results

The case study targeted the early stages of the service development in a PSS context by identifying the CRs and assessing them. The information can assist manufacturers in augmenting the product-related service offerings (i.e. the hemodialysis device in this context). The three approaches implemented led to a different understanding of the needs of the customers which was explicated through the different importance levels of CRs and subsequently their different priorities (i.e. ranking). In detail the FAHP augmentation (i.e. fuzzy logic and pairwise comparisons) provided the most distinct and sensible assessment of the CRs resulting in a 31.6% variation range whereas the traditional approaches resulted in a smaller variation range 5.7% (Figure 3). Accordingly, we can note that the FAHP enables a clearer distinction of the CRs highlighting the most important requirements in a more distinct manner than the traditional QFD.

Regarding the SCs, their importance levels differ less than the CRs: the FAHP led to a variation range of 14.0% compared to 8.0% for the and traditional approach (Figure 4).

Hence, the customer requirements are discerned more evidently, and the service characteristics are clearer which allows a better direction of the design and development process.

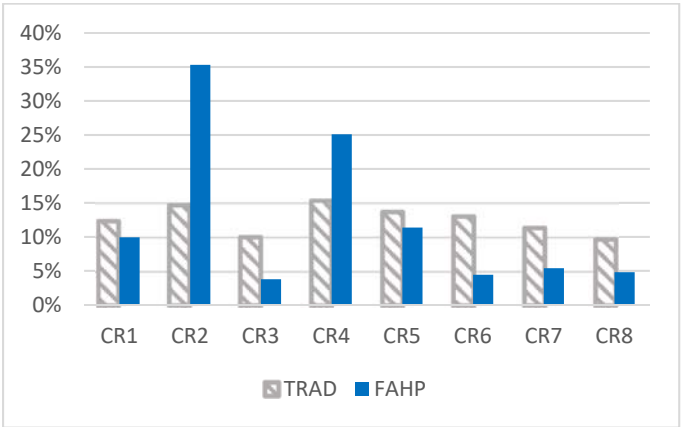

Figure 3. Comparison of the relative importance of the CRs (normalized values (%))

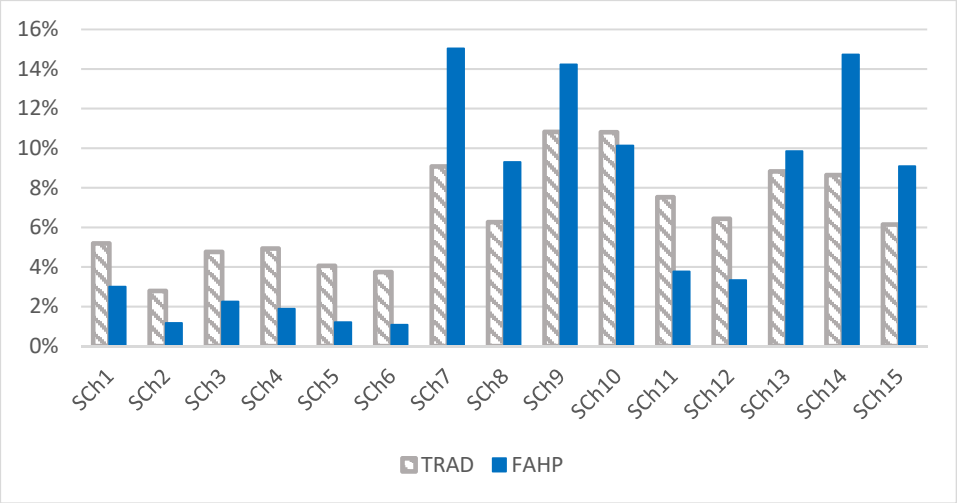

Figure 4. Comparison of the relative importance of the SCs (%)

Furthermore, the ranking of the CRs and SCs differed as each approach led to a different prioritization of the CRs and the measures (i.e. SCs) to satisfy them (Table 7).

Table 7. Ranking of the CRs and SCs using the traditional and FAHP approaches

Customer Requirements (CRs)			Service Characteristics (SCs)		
CR Code	CR Ranking		SC Code	SC Ranking	
	Traditional	FAHP		Traditional	FAHP
CR 1	5	4	SC 1	10	10
CR 2	2	1	SC 2	15	14
CR 3	7	8	SC 3	12	11
CR 4	1	2	SC 4	11	12
CR 5	3	3	SC 5	13	13
CR 6	4	7	SC 6	14	15
CR 7	6	5	SC 7	3	1
CR 8	8	6	SC 8	8	6
			SC 9	1	3
			SC 10	2	4
			SC 11	6	8
			SC 12	7	9
			SC 13	4	5
			SC 14	5	2
			SC 15	9	7

Concerning the CRs, it can be noted that despite the ranking differences, the same three CRs are the most important despite a different ordering (CR2, CR4 and CR5). While regarding the SCs, two remain within the three most important characteristics while SC14, which resulted significant in the FAHP), had a considerably lower ranking through the traditional approach (rank 5).

The obtained results underline the limitations of the traditional QFD when intangibilities and subjectivities are involved (i.e. in a PSS). The latter is portrayed through the smaller variation ranges regarding CRs and SCs. The FAHP augmentation however, was more effective in quantifying the subjectivities of services for a better assessment enabled by the pairwise comparisons and fuzzy logic which reduced ambiguities and imprecisions. The latter allowed a better determination of the SCs to implement.

The benefits achieved through the FAHP augmentation correspond to the findings of Kurtulmuşoğlu and Pakdil (2016) who emphasized the necessity of an accurate and precise evaluations of the customer's needs when it comes to developing services. In line with Shad et al. (2014), the FAHP-augmented QFD enabled a more sensible and precise evaluation of the CRs underlining its effectiveness in managing customers' requirements. In fact, the pairwise comparisons permitted a holistic understanding of the CRs by considering the relations that tie them.

From a more general standpoint, the case study illustrated a promisingly effective approach to address and manage customer requirements in a PSS setting. The approach is based on the practical needs of a manufacturer who seeks to improve its services as to augment customer value to better satisfy his customers and attract potential ones. The results obtained showed that, although the company operates in a regulated market where availability and customer care are the core-requests of the calls for tender, the implementation of additional supporting services can increase the customers' satisfaction. In particular, services related to the environmental aspects of the PSS, such as the SC2 (environmental conformity (Fargnoli et al., 2013)) and SC3 (dematerialization of data storage) can offer the company the possibility to expand its business providing customized solutions (Sakao and Shimomura, 2007; Sakao and Fargnoli, 2010; Turki et al., 2017). Hence, they are worth further investigations.

Nevertheless, despite the positive aspects of the approach, it should be noted that the manufacturer operates in a business-to-customer context where associated costs cannot be overlooked and should hence be considered when developing a solution (Rexfelt and Ornas, 2009). Further work to incorporate the economic aspects is planned and underway.

5. Conclusion

Given the growing importance of services in today's market on one hand and the increasing competition between manufacturers on the other, an effective implementation of services for increase value has become essential. Nevertheless, traditional product design and development tools (i.e. QFD) are limited when service attributes are involved.

This paper contributes to the present research literature by proposing the FAHP augmentation to a service-oriented QFD as a means of addressing the intangibility and subjectivity of services. In fact, the FAHP augmentation resulted in a higher variation range concerning the CR priorities which facilitates the decision-making process and enables manufacturers a clearer choice when addressing the SCs. From a managerial perspective, the proposed approach can contribute to the practical needs of manufacturers that deal with the necessity to find a good balance between the improvement of product and service components to provide more convenient offerings. Despite this aspect being more relevant to practice in industry, the achieved results can be considered useful to augment scientific knowledge regarding ontologies in the PSS domain (Ki Moon et al., 2009).

The case study demonstrated how the approach can be applied in a practical context, yet future research work is needed to refine it. For instance, the use of the Analytic Network Process (ANP) should be investigated as it enables a more comprehensive evaluation of the CRs by incorporating the SCs and their interrelationships for the prioritization of the customers' requirements. In addition, the adoption of other fuzzy numbers (i.e. trapezoidal) may be explored.

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