Comparison between the TOPSIS method and a "Condorcet winner" based voting method for the evaluation and selection of new services

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Abstract: The current business scenario is characterized by several important factors; among them, the necessity to shrink the time-to-market of new products and services, the need to focus on promising ideas since the early design phases of new solutions, and the involvement of a high number of actors with different perspectives. The latter factor, in particular, underpins the fact that an increasing number of decisions require the participation of multiple stakeholders that frequently have conflicting aims and interests. These factors contribute to increase the complexity of new solutions management. This is even more emphasised in services, especially during the early stages of the engineering process when a new service has to be evaluated and selected with limited support from the available information. Further, the presence of multiple decision makers exacerbates the issues, rendering difficult the attainment of an objective, consensus-based decision. To address this issue, Multi-Criteria Decision-Making (MCDM) methods hold a crucial role in supporting decisions making processes. This paper proposes a comparison of two methods based on an empirical test in order to identify the most suitable and user-friendly to be adopted by heterogeneous engineering teams to make decisions in the field of services. The first, developed in the engineering field, is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) while the second is a "Condorcet winner" based method rooted in voting system theory, which traditionally has been used in social science. The comparison is meant at understanding what method best reflect the preferences of the participants.

Keywords: Multi-criteria decision-making methods; MCDM; multiple stakeholders; TOPSIS; Voting mechanism

1.Introduction

With the increasing needs of sustainable production and consumption, services as a source of core value are becoming more and more important both for private companies and public institutions (Zhang, Xu, Ostrosi, Yu, & Fan, 2017). Contrarily to products, services are mostly intangible and featured by a high interaction between the providers and the customers (Edvardsson et al., 2005). Due to the relationship-based nature of services, their design and engineering shall take into account multiple stakeholders' perspectives and preferences. This is particularly relevant during the early stages of the engineering process which "…can determine the superiority of the final design solution" (Mourtzis et al., 2018). During this phase, the most appropriate service to be implemented shall be selected taking into account the interests of all the involved stakeholders such as the services providers (i.e., limited costs, brand value increase, profit), the customers (i.e., price, utility, economic value), and the society (i.e. the interests of the people not directly involved into the service but upon whom it can impact in terms of sustainability or social relationship). More than this, the possible trade-off generated between the objectives of these actors (Geng, Chu, Xue, & Zhang, 2010) shall be taken into account while selecting such services. For these reasons, service engineering methods and approaches shall propose proper methods in the early concept phase (Rondini et al., 2016) to deal with such complex decision-making problem considering the constraints just identified. To do so, Multi-Criteria Decision-Making (MCDM) methods could be employed. They can be used to take into account the evaluation of many services considering the multiple stakeholders and their different evaluation criteria (Beck, Beimborn, Weitzel, & König, 2008).

In particular, in the area of services, MCDM have been already used to guide stakeholders toward the evaluation of new concepts and services (Triantaphyllou, 2000) and many methods are available to support decisions (e.g., TOPSIS, AHP, ELECTRE, PROMETHEE…) (Toloie-Eshlaghy and Homayonfar, 2011) but the majority of them are very time consuming and cumbersome to use, especially in the multidisciplinary teams characterizing the service engineering. In the service domain, many members do not have the technical competences to cope with MCDM tools.

In the light of such limitations and features of the service engineering domain, the aim of this paper is to test two different MCDM methods for the evaluation and the selection of service concepts by involving all the interested stakeholders in the early concept evaluation phase of the service engineering process. In particular, the goal of this research is to find which is the method that allows the stakeholders to express their own opinion in the easiest and most effective way. The first method developed in the

engineering field is based on the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The second method, a "Condorcet winner" based method rooted in the voting system theory, has been borrowed from social sciences due to its simple and intuitive data entry approach.

To compare the usability and the efficacy of the two methods, a case based on the evaluation of service concept to be implemented at the University of Bergamo was settled. People that are involved with the services provided by the university were involved in the case (i.e., students, professors, and non-teaching staff). They were required to prioritize five new services (not yet implemented) using the two methods. After setting their preferences about the proposed services, the participants in the study were asked to evaluate the critical points and the strengths of each of the selected methods with a specific focus concerning the complexity in the adoption of the methods and in the data entry process to find which of the two methods better gave them the possibility to express their opinions.

2. Decision methods examined

There exist many methods that could be used to address the above-mentioned problem and to prioritize different alternatives (Rondini et al., 2018). In this work, only two out of the available ones are discussed and compared in detail. In particular, two methods coming from two different area of research (engineering vs social science) have been investigated in order to compare methods with completely different characteristics both in the data collection and in the evaluation process.

The two compared methods are the Technique for Order Preference by Similarity to Ideal Solution TOPSIS algorithm, coming from the engineering field and mainly selected for its ease of use and the "Condorcet winner" voting method originally adopted in the social science domain that due to its origins, is also straightforward to use and apply. Both the two methods involve the identification of a *"score"* associated with an alternative presented to the decision maker.

The general problem that is examined in this work can be summarized as follows.

A set of alternative configurations $A = \{a_1, \dots, a_N\}$ should be evaluated by a set of stakeholders $S = \{s_1, \dots, s_M\}$. Each stakeholder $s_j \in S$ has his/her own preference with regard to the alternatives in A, and this results in different priorities of implementation. The alternatives are evaluated considering multiple criteria, represented as a set $C = \{c_1, \dots, c_K\}$. Each stakeholder has to express his/her preference on the set C for each alternative in A according to the rules of the selected method.

Thus, considering the evaluation that the stakeholders provide an alternative that is preferred along one dimension might not be preferred along another dimension.

Both the two methods tested in this study, as a result, provide a final ranking of the identified alternatives, but the logic behind the two approaches is different. The TOPSIS method requires an evaluation of the alternatives for each criterion, while the voting mechanism needs the settlement of a ranking of all the alternatives considering each criterion. A detailed description of the two methods is reported hereafter.

2.1 The TOPSIS algorithm

The first method analyzed is the TOPSIS algorithm. It requires as input a score, for each alternative with respect to all the criteria identified. Hence, once all the scores are assigned, for each stakeholder analyzed a matrix composed of *k* criteria (rows), and *n* alternatives (columns) is obtained:

$$X = \left(x_{ij}\right)_{k \times n} \quad [1]$$

Starting from this matrix, all the steps foreseen by the TOPSIS method and reported in (Behzadian et al., 2012) shall be computed to obtain a final ranking of the proposed solutions.

2.2 "Condorcet winner" based method

The second method adopted in this analysis is a "Condorcet winner" based method rooted in the voting systems theory, where the goal is to make the largest number of people (voters) happy with the final outcome. Voting methods are defined by rules indicating how voters' preferences are elicited and ordered to identify winners (De Sinopoli, 2000). The ideal voting method would elicit a clear winner that maximizes the voters' preferences (Menezes, da Silveira, & Drezner, 2016). In the specific context, the candidates are represented by the alternatives that should be compared, and the voters are represented by the stakeholders expressing their preferences on the alternatives. For what concerns the computation perspective, the voting method based on "Condorcet winner" criteria considers that each stakeholder can provide his/her own ranking, that is, he/she can order the items in A from the most preferred to the least preferred according to his/her own preferences with respect to each criterion. The position of the alternative a_i in the ranking provided by stakeholder s_j is defined as:

$$\sigma_{s_j}(a_i) = p \quad [2]$$

where

$$p \in [1, \dots, N] \quad [3]$$

Similarly, considering any stakeholder s_j, given any two elements a_i, a_h in A we define the operator of preference $\succcurlyeq$ with the following meaning: $a_i \succcurlyeq a_h$ if stakeholder s_j prefers alternative a_i over the alternative a_h, that is if $\sigma_{s_j}(a_i) \leq \sigma_{s_j}(a_h)$.

Our goal in using this method is to define a single, common ranking of the alternatives in A considering the preferences of all the stakeholders in S. According to these features, the method could be considered as part of the the class of Condorcet methods, in which candidates are compared pairwise, and the candidate that wins in all of the head-to-head elections against each of the other candidates is the Condorcet winner. A voting system is said to satisfy the

Condorcet criterion if it always chooses the pairwise champion, if one exists.

3. Research methodology

For the initial part of this experiment, we involved 15 people that live daily the University of Bergamo: five students (both graduates and doctorates), five people from the teaching staff (i.e., professors and researchers) and five people in the non-teaching staff (i.e., people doing secretary and consulting activities). The restricted number of people involved is due to the fact that this research only reports the initial phase of research. In the first phase, the goal of the study is to understand how the interviewed people can deal with the proposed methods and how they are able to evaluate the proposed methods. Importantly, the people interviewed covers different roles in the university in order to reduce the overall subjectivity of the study.

Table 1 - List of possible services: assessed based on secondary data sources (i.e., foreign university websites) and on the basis of services currently missing in the Bergamo University

Services	Sources
1.Career, Teaching, Study skills consulting	https://www.topuniveristies.com/student-info/choosing-univeristy/7-amazing-student-services-you-definitely-need-use
2.Medical services (including free psychological counselling service)	https://www.gooduniversitiesguide.com.au/study-information/student-life/student-services-and-facilities
3. Recreation offices	https://uwaterloo.ca/future-students/student-life/student-services
4.Parcel lockers	https://www.theatlantic.com/education/archive/2016/10/the-most-popular-office-on-campus/504701/
5.Additional eating facilities (i.e. public Kitchen, fresh fruits in the vendor machines)	https://www.unomaha.edu/student-life/wellness/services.php

During this preliminary study, the people involved were asked to evaluate the concept of different university services using the two methods discussed before. All the people were volunteers. The possible services to be implemented have been chosen by evaluating the services offered by other universities in the world and not provided at the University of Bergamo. In particular, to analyse the services offered by most universities, secondary data sources (i.e. universities websites, students and professors' university guides) were mainly used (Table 1). After choosing the possible services to offer, we have also chosen the evaluation criteria through which the solutions are assessed by the participants. These criteria were chosen analyzing existing literature regarding university services evaluation parameters (Table 2).

3.1. Comparison Procedure

As stated in the previous section, the 15 participants were asked to assess the five services (Table 1) using the two methods. In order to introduce the topic and the criteria identified for the evaluation, a general introduction was provided by the researchers leading the study. Then, the first method was explained, and the participants were asked to prioritize the solutions according to its mechanism. In order to carry out the comparison between the usability of the two methods, an ad-hoc table was prepared to include the participants' evaluations and preferences considering the rules of the specific method. At the end of the exercise, the participants were asked to fill in a short survey regarding the method. The survey requires to fill in two closed questions and to provide short comments regarding the method. The two questions are: 1) "Could you indicate how complex is understanding the data entry mechanism of the adopted method?"; 2) "Could you indicate how complex is the data entry mechanism of the adopted method?". The possible answers to the two questions are: i) very easy, ii) easy, iii) average complexity, iv) difficult, v) very difficult. Moreover, the participants were required to state at least one positive and one negative element of the method. The same procedure was adopted for the second method. At the end of the overall experiment, the participants were also asked to indicate their preferred method and the related motivations.

Importantly, the 15 people that were involved in the experiment were just required to input data in the two methods, based on the provided tables. In particular, for what concerns the voting, participants were required to set a ranking of the five solutions for each of the six different criteria. For what concern the TOPSIS method, they were required to put a score based on a Likert Scale from 0 to 5 for each solution with respect to each criterion. They were not required to do all the calculations required to obtain the results since this won't be required during the actual application of the method. Being different, the two methods required a different kind of data to be included.

Table 2 - Evaluation criteria for solutions (taken from literature)

Criteria	References
1. Campus life, social life, interactions: this criterion regard all the "social aspects" of the campus life (e.g., the interactions among people, the networking opportunities and the possibility to meet new people).	Tasirin et al. 2013; Fine et al., 2016, Elsharnoby, 2016; Simadi et al., 2017, De Besa_Gutierrez et al., 2017
2. Individual motivation: this criterion includes all the aspects related to the own personal motivations (e.g., dreams, ambitions, own necessities).	Chong and Ahmed, 2015; Fine et al., 2016
3. Personal development opportunity: this criterion regards all the opportunities to develop own capabilities, skills and competencies.	Tasirin et al. 2013, Noaman et al., 2017; De Besa_Gutierrez et al., 2017
4. Healthiness: this criterion take into consideration all the aspects related to a healthier lifestyle (e.g., healthy food, sports activities, mental health, greener lifestyle).	Elsharnoby, 2016; Simadi et al., 2017
5. Financial and Economic value: this criterion is an indicator of how much the people living in the university environment save in economic terms with the introduction of some services compared to what they would spend to take advantage of these services outside the university.	Elsharnoby, 2016; Sanchez-Fernandez et al., 2017
6. University physical environment/image: this criterion is related to the improvement that the image of the university could have on the city and, in general, on people outside the university environment.	Sanchez-Fernandez et al., 2017; Simadi et al., 2017

4. Analysis of the results

Once the participants expressed their preferences into the two tables prepared for the experiment, the researchers guiding the test, performed the necessary computations to obtain the final scoring.

For what concerns the "Condorcet winner" based voting method, first the overall decision maker preference was computed and a single ranking of the alternatives was set considering the six different rankings he/she provided. Then, a single ranking for each decision maker category was computed. Three different rankings were obtained, one that stands for the students' preferences, one for the teaching staff, and one for the non-teaching staff.

The prioritization based on the TOPSIS method was computed as follows. A table including the average scores of evaluation for each category (student, teaching staff, non-teaching staff) was computed considering the preferences of the five people involved in each category. As a result, three different tables including the average scores for each category were obtained. Each table includes as in the original tables a score for each alternative with respect to each category. The three different tables were used as a starting point for the adoption of the TOPSIS algorithm described in (Behzadian et al., 2012) not described here due to space constraints. Also in this case, three different rankings were obtained.

4.1 Results of the methods adoption

The results obtained from the two methods are different with respect to each other (Table 3). It can also be noted that the result obtained with the TOPSIS method is the same for all the categories, while with the "Condorcet winner" based method the result obtained for the "Teaching staff" category is different from that obtained for the "student and non-teaching staff ", and in any case still different from that obtained with the TOPSIS method. In particular, we noticed that there is a convergence on the least preferred solutions (solutions 4 and 5), while preferences on preferred positions are more difficult to determine (solutions 1, 2 and 3).

Table 3 – Results obtained using the two different method

Voters categories	"Condorcet winner" based method	TOPSIS method
Students	1	3
	3	2
	2	1
	5	5
	4	4
Non-teaching staff	1	3
	3	2
	2	1
	5	5
	4	4
Teaching staff	1	3
	2	2
	3	1
	5	5
	4	4

The results pointed out some differences between the results obtained from the two methods. These inconsistencies are mainly due to the intrinsic characteristics of the two methods and to the differences in the data input process which requires a different reasoning approach of the interviewed people. The small differences between the results of the two methods can be attributed to the differences between the two methods algorithms and the adopted scores and evaluation approaches. The evaluation provided in each method with respect to each solution does not have the same impact on all the final scoring obtained. Another issue is which method provides the "correct" result or rather a transparent and comprehensible result (due to the fact that a "correct" result does not exist), which is even more important. A comprehensible result is given by both the two used methods, since the evaluations and the differences were always clear and comprehensible. Hence, the main comparison between the two methods is focused on their ease of use and ease of understanding according to the participants' opinions. In the light of this, more detailed considerations will be provided in paragraphs 4.2 and 5.

4.2 Preferences of the participants on the methods

According to the goal of the paper, analyses regarding the two methods were carried out to identify what is the preferred method, and to register the ease of use of the two methods. To this end, all the time required by the participants to apply the method to the selected case was measured. The "Condorcet winner" based method required around 3,3 minutes while TOPSIS required 2,6 minutes.

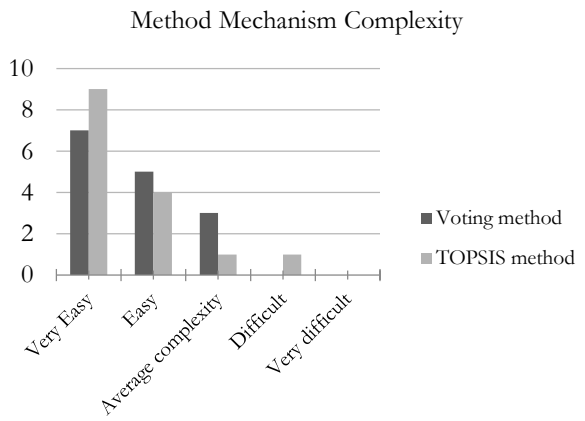

Figure 1 – Respondents' answers to the first question of the survey: "Could you indicate how complex is understanding the data entry mechanism of the adopted method?".

It emerged that, on average, the "Condorcet winner" based method required one minute more than the TOPSIS method in order to complete the judgement. The advantages of the TOPSIS method are also sustained by the results of the short survey which highlight that 14 out of 15 of the people involved prefer the TOPSIS. This is due to the ease of including judgment and values into the TOPSIS predefined matrix as explained by Figures 1 and 2 which reflect the results of the questions proposed at the end of the method application. The two figures show that both the logic of two methods are generally "very easy" or "easy" to be understood, but the inclusion of the judgment information into the "Condorcet winner" based voting approach is more intricate. Notably, the majority of the participants find easier to understand the mechanism and the logic behind the TOPSIS approach. Only one participant considered the TOPSIS approach as challenging to be understood.

Different preferences can be observed in Figure 2 considering the complexity of input data into the two selected approaches. Only one out of the fifteen participants (6%) considered the definition of preference through voting "very easy" while nine (60%) consider it of "average complexity". The motivations of such complexity, as reported in the free comments of the survey, lay on the difficulty to provide a ranking of all the identified solutions as requires by the method. Regarding a specific criterion could be difficult to understand which solution is better than another, even if the participants perceive a difference between them. This explains the main complexity of including data in the voting method, as emerged in the study.

On the other hand, the TOPSIS method enabled the participants to provide equal scores to different solutions and this made less complex the input data process.

In the light of this, it could be possible to highlight that, according to the majority of the 15 people interviewed, the TOPSIS method is the easiest to use and to input data in.

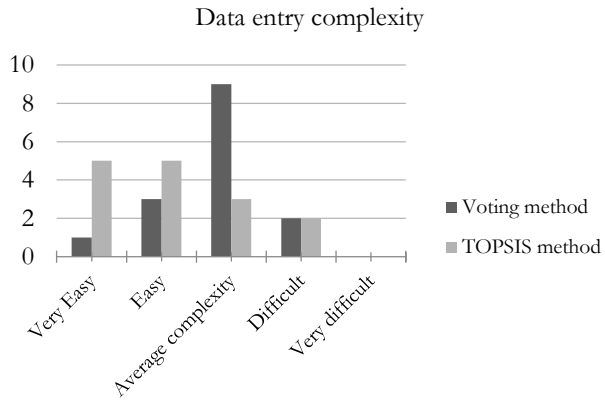

Figure 2 – Respondents' answers to the second question of the survey: "Could you indicate how complex is the data entry mechanism of the adopted method?".

5. Discussion

From what emerged from the short survey, both methods are easy to be understood and rather simple to apply; however, some differences emerge not only in the final results, as discussed in paragraph 4.1, but above all from the comments that the respondents have reported in the final evaluation survey of the two voting methods.

As for the "Condorcet winner" based voting method, the participants indicated that they felt "forced" to place the

different solutions in a ranking and for some criteria, they considered certain concepts not classifiable (i.e., parcel lockers for the "healthiness" criterion). On the other hand, for few voters, the TOPSIS method did not seem to actually express the order of preference of the different solutions, unlike the "Condorcet winner" based method which gave more "satisfaction" to the voters as regards the expression of their real preferences.

Most part of voters seems to prefer the TOPSIS method because it gives a general visualization of all available options and because it allows both to give score "zero", as a mean to highlight that certain solutions are not relevant to certain criteria. Nevertheless, voters also stated that applying TOPSIS method they felt slightly influenced by scores that they have assigned to other alternatives.

Another important analysis that has been done is the verification of the consistency of the participants' answers with respect to the two methods. From this analysis, it emerged that the judgments of the participants are not always consistent with the two methods. This inconsistency may be associated with three different reasons. *First*, the participants could have misunderstood the method features and hence could have provided wrong judgments. *Second*, it could be possible that the kind of reasoning of each method influences the preference assignments in the two methods leading to a different evaluation. *Third*, the discrepancy of the judgments could be motivated by the lack of attention during the application of the two procedures. In other words, they haven't paid proper attention in providing evaluations making the results biased. It is also worth noticing that the chosen criteria could be not the most suitable to evaluate the university services according to the participants. Indeed in this first step of the research, the criteria were not discussed with the participants before the voting procedures, as always happen among stakeholders in real situations: this could constitute a limitation of this research.

6. Conclusions

This paper reports the results of a comparison between two multi-criteria decision-making methods: the TOPSIS method and the "Condorcet winner" based voting method.

From the performed voting procedures, different results emerged between the two methods and among the three different categories analysed (i.e., students, non-teaching staff, and teaching staff). The participants found both the method easy to apply, however, the majority of them seem to prefer the TOPSIS method because is faster and allows to give the same evaluation to different solutions (and also to assign the "zero" score).

Some limitations of the proposed study can be described especially with respect to the validation of the methods results with respect to reality. As previously hinted, the methods provide slightly different results and this could be due to their differences in computation. Moreover, inconsistency in the preferences expressed in terms of evaluation of the solutions, still remains a subjective aspect being a personal assessment.

On the other hand, this does not influence the preference of the voters in terms of a preferred method to apply. Thus, the preference of the voters for the TOPSIS method and their motivation remains a validate output of this research considering that the goal of the paper is to carry on a preliminary analysis aiming to understand which method is easier and faster to apply and the better in reporting the voters' opinions.

In order to make this initial results more robust, more people with different roles, expertise and background will be further interviewed to understand if their preferences are in line with the results obtained in this former study or they are different.

Further evaluations of the method and evaluation consistency would be also done showing the results of the two methods to all the participants. In turn, this could help in understanding how their preferences changed during the realization of the voting process and compare them with the results obtained. Currently, due to time constraints, this analysis has not been performed. Discussing the criteria with participants before the voting procedures could be also a good way to avoid inconsistencies between the given scores and preferences. Finally, it could be convenient to extend the method comparison to additional MCDM methods that allow both to prioritize the solutions and give a score, for example, AHP.

References

Beck, R., Beimborn, D., Weitzel, T., König, W. (2008), Network effects as drivers of individual technology adoption: Analyzing adoption and diffusion of mobile communication services. *Information Systems Frontiers*, 10(4), 415-429.

Behzadian, M., Khanmohammadi Otaghsara, S., Yazdani, M. and Ignatius, J. (2012), "A state-of-the-art survey of TOPSIS applications", *Expert Systems with Applications*, 39(17), 13051–13069.

Chong, Y. S., & Ahmed, P. K. (2015). Student motivation and the "feel good" factor: an empirical examination of motivational predictors of university service quality evaluation. *Studies in Higher Education*, 40(1), 158–177.

De-Besa-Gutiérrez, M. R., Lugo-Muñoz, M., & Limón-Domínguez, D. (2017). University services for students' transition to higher education. In *ACM International Conference Proceeding Series* (Vol. Part F1322, pp. 1–5). New York, New York, USA: ACM Press.

De Sinopoli, F. (2000), Sophisticated voting and equilibrium refinements under plurality rule. *Social Choice and Welfare*, 17, 655–672.

Edvardsson, Bo, Anders Gustafsson, and Inger Roos. (2005). Service Portraits in Service Research: A Critical Review. *International Journal of Service Industry Management* 16 (1), 107–21.

Elsharnouby, T. H. (2016). Participation behaviour among international students. *International Journal of Educational Management*, 30(5), 679–697.

Fine, M. B., Clark, M. N., & Scheuer, C.-L. (2016). Value-Added University Services: The Importance of On-Campus Recreational Facilities. *Services Marketing Quarterly*, 37(1), 24–35.

Geng, X., Chu, X., Xue, D., Zhang, Z. (2010). An integrated approach for rating engineering characteristics' final importance in product-service system development. *Computers and Industrial Engineering* 59, 585–594.

Menezes, M.B.C., Huang, R. (2015). Comparison of Condorcet and Weber solutions on a plane: Social choice versus centralization. *Computers and Operations Research*, 62, 350-355.

Mourtzis, D., Doukas, R., Fotia, S. (2016). Classification and Mapping of PSS Evaluation Approaches. *IFAC-PapersOnLine,* 49(12), 1555-1560.

Noaman, A. Y., Ragab, A. H. M., Madbouly, A. I., Khedra, A. M., & Fayoumi, A. G. (2017). Higher education quality assessment model: towards achieving educational quality standard. *Studies in Higher Education*, 42(1), 23–46.

Rondini, A., Bertoni, M., Pezzotta, G. (2017) An IPA based method for PSS design concept assessment. *9th CIRP IPSS Conference, Circular Perspectives on Product/Service-Systems*, Copenhagen 19th-21st June 2017

Rondini, A., Lagorio, A. Pezzotta, G e Pinto R. (2017). Adopting a Multi-Criteria Decision method for the introduction of PSSs in the smart city context. *XXII Summer school Francesco Turco*. Palermo, September.

Rondini, A., Lagorio, A. Pezzotta, G e Pinto R. (2018). A Multi-Criteria Decision Making approach for prioritising Product-Service systems implementation in smart cities. *International Journal of Management and Decision Making, forthcoming, In press.*

Rondini, A., Pezzotta, G., Pirola, F., Rossi, M., & Pina, P. (2016). How to design and evaluate early PSS concepts: the Product Service Concept Tree. Procedia CIRP, 50, 366-371.

Sánchez-Fernández, R., Jiménez-Castillo, D., & Iniesta-Bonillo, A. (2017). Economic Value for University Services: Modelling and Heterogeneity Analysis. *International Journal of Market Research*, 59(5), 671–690.

Simadi, F. A., & Alqaryouti, I. A. (2017). Students with disabilities' satisfaction with their universities' services. *International Journal of Human Rights in Healthcare*, 10(4), 239–247.

Tasirin, S. M., Omar, M. Z., Esa, F., Zulkifli, N. M., & Amil, Z. (2013). Measuring student satisfaction towards engineering postgraduate programme in ukm. *Journal of Engineering Science and Technology* Special Issue on UKM Teaching and Learning Congress, 100–109.

Toloie-Eshlaghy, A. and Homayonfar, M. (2011), "MCDM Methodologies and Applications: A Literature Review from 1999 to 2009", *Research Journal of International Studies*, No. 21, p. 53.

Triantaphyllou, E., (2000). Multi-criteria decision making methods. In *Multi-criteria decision making methods: A comparative study* (pp. 5-21). Springer, Boston, MA.

Tscheikner-Gratl, Franz, Patrick Egger, Wolfgang Rauch, and Manfred Kleidorfer. (2017), Comparison of Multi-Criteria Decision Support Methods for Integrated Rehabilitation Prioritization. *Water* 9 (2): 68.

Zhang, Z., Xu, D., Ostrosi, E., Yu, L., Fan, B. (2017). A systematic decision-making method for evaluating design alternatives of product service system based on variable precision rough set. *Journal of Intelligent Manufacturing* 1–15.