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A Ranking for the Vancouver 2010 Winter Olympic Games Based on a Hyerarchcical Copeland Method

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1. Introduction

Many studies have been carried out to evaluate the results of the Olympic Games. Some of them are based on how these events can bring benefits to the host cities [Glynn (2008); Cheng (2008); Xiaoduo and Jianxin (2008)] and others are interested in social studies [Bernstein (2000), Farrell (1989), Levine (1974) and Ball (1972)].

Besides these studies, we can find researches in the environmental and health areas [Hadjichristodoulou, Mouchtouri and Vaitsi (2006); Allen et al (2006); Weiler, Layton and Hunt (1998); Streets et al (2007)], some about tourism industry and others that evaluate mathematics and economics aspects of the Games [Heazlewood (2006), Bernard and Busse (2004), Lins et al (2003) and Li et al (2008)].

In this work we are interested in studying the results of the Winter Olympic Games, held in Vancouver in 2010, in order to propose a new ranking to the countries that took part in the Games. Traditionally, as discussed in Soares de Mello et al (2009), the International Olympic Committee (IOC) shows the results of both Summer and Winter Olympic Games in a table that rank the nations by the number of gold medals won. This is a Lexicographic method. Although this is not an official ranking, to the media and people in general, this is a summary of the participation of the nations, i.e., their production in the games.

In the literature we can find other studies that suggest alternative rankings for the Olympic Games. As an alternative to rankings based on Lexicographic Methods, some studies as Lozano et al (2002) use Data Envelopment Analysis models with population and GNP as inputs and the number of gold, silver and bronze medals as outputs, to rank the nations. Others authors as Lins et al (2003) improved that model by adding a new constraint that defined as a constant the total number of medals (Zero Sum Gains DEA model (ZSG-DEA).

As an extension of these studies some authors use others social and economics variables to build their models such as Churilov and Flitman (2006). These results found in Lozano et al (2002) were followed by the proposal of using GDP per capita and not only GDP as an input and creating weight restriction to the DMUs as done by Li et al (2008). In almost a sequence many researchers have been published new approaches to the same problem [Wu et al

(2008); Wu, Liang and Chen (2009); Wu, Liang and Yang (2009); Yang et al (2009) and Zhang et al (2009)].

Besides all the works showed before, we can mention studies that took into account only the number of medals won by each country. Soares de Mello et al (2008) used as input the number of athletes brought to the country to the game and Bergiante and Soares de Mello (2010) proposed as output, the number of medals won by each country. There are other works that evaluated the home advantage event [Balmer, Nevill and Williams (2001) and Balmer, Nevill and Williams (2003)] and the difference between the Summer and Winter Olympic Games [Johnson and Ali (2004)]. Beyond that, some rankings are built taking into account the total number of medals, the Lexicographic method (explained by Lins et al (2003)), which under evaluate the gold medal, and others range countries only by the number of gold medals, which don't evaluate the results of silver and bronze medals.

Although the importance of all these studies to the advance of the knowledge of the Olympic Games we noted that a few of them, as can be seen in Soares de Mello et al (2009), concerned about the difference in the value of a medal when comparing different modalities, for example, ice hockey has, at least, five times to get a medal, while, to win a biathlon sport, an athlete has to compete only one time.

Due to this important aspect, in this paper, we propose the use of ordinal multicriteria methods to study the results of the Vancouver 2010 Olympic Games. In our case we intended to use ordinals methods as Condorcet and Copeland [Barba-Romero and Pomerol (1997)] to hierarchy the nations.

To do so, we will divide our study in two steps. In the first part, by gathering information about how many medals each country won in each modality, we will establish two kinds of ranking. One is taking into account the total number of medals per modalities, and the second one is regarding only the number of gold medals distributed by modalities. The idea to use these two rankings, not only one, is based on the criticism of some studies as Soares de Mello et al (2008) that argues that the first type of ranking, based on the total number of medals, underestimate the gold medals and the second ranking, based on the number of gold medals, over evaluate the gold medals.

After built these two rankings, we are going to apply the Copeland method, using them as criteria. As a result, we aim to establish a ranking per each modality.

In the second step, each ranking built in the earlier stage will be seen as criteria to a new application of the Copeland Method to establish our final ranking. As one can note, this final ranking will take into account three different models to assort the countries: the Lexicographic method, the total number of medals and the difference between all the modalities of the Olympic Games. As far as we know, this proposal is an advance in the studies in this field. This can be seen as a hierarchy Copeland method.

It is important to point out the utility of the studies this one in terms of operations management. As discussed by Roy (1992), multicriteria methods can optimize the decision process through the study of the value of each alternative or action taken by the decision maker and the analysis of their robustness. In fact, all these approaches contribute to the efficiency of the operations management processes in many different scenarios, as companies, events as Olympic Games and so on.

By improving the operational efficiency these methods help organizations to accomplish their objectives, strategies and action plans. They also allow a better control of the resources involved in the business. For all kind of organizations, managing operations remains a priority and because of that, multicriteria method should be seen as an useful tool to operations managers and operations executives since they enhance the process of decision making.

The next section will point out some aspects of the Winter Olympic Game. The section 3 summarizes the Methodology used, i.e., the multicriteria decision support tools and in the Section subsequent we described the model used in this study. After that, we will present the results and a briefly analysis of them. Following we summarize our conclusions and some future research directions.

2. The winter olympic games

In 776 AC, in Olympia, Greece, was born the Ancient Games. As an evolution of this proposal, in 1896, it started the Modern Games, as discussed by Wallechinsky (2004). But, until 1920, the only competition existing was the Summer Olympic Games. The Winter version was held in Chamonix, France in 1924, and since then, these two competitions have been happened every four year, in the same year. However, from 1994 and on, these games have been staggered two years apart.

Some authors, as Johnson and Ali (2004), have been study the difference between these two Olympic Games. These researchers found that the ability to participate in both Games is not the same to all countries and even if all the countries took part in the two Games, they will not have an equal ability to win medals [Bergiante and Soares de Mello (2010)]. This study argues, as expected, that countries with heavy winter will have better results in the Winter Games than in the Summer Games. Another research of Balmer, Nevill and Williams (2001) found home advantages in some modalities in the Winter Games related to familiarity with local conditions which could prejudice away athletes.

In the very first Winter Olympic Games, in 1924, there were a total of 258 athletes representing 16 countries and six modalities to compete. The majority of the nation that took part in the Games was from Europe and North America.

Nowadays, the participation in these Games has been enlarged. The last competition, held in Vancouver, Canada in 2010, is an example of this. A total of 82 countries, including nations from South America, as Brazil, and others as India and Hong Kong, attended to the Games. There were a total of 2600 athletes participated in the events, which is much more than the 258 of Chamonix, France, 1924.

In relation to the number of disciplines programmed, there was a huge improvement. In the past, as mentioned before, there were only six sports: bobsleigh, curling, ice hockey, figure and speed skating, skiing and the military patrol race. In the 2010 version of the Winter Olympic Games, a total of fifteen sports were programmed. They were: alpine skiing, biathlon, bobsleigh, cross-country, curling, figure skating, freestyle skiing, ice hockey, luge, nordic combined, short track, skeleton, ski jumping, snowboard and speed skating.

Obviously, the increment also happens in the number of medals distributed in these Games. Comparing to the first Game, in which 49 medal were disputed, Vancouver, 2010 Games, had more than five times medals to distributed, adding up a total of 258 medals (including gold, silver and bronze). Since many competitions were composed by teams, an amount of 615 medals was awarded.

In terms of medals, Johnson and Ali (2004), in the same work presented before, will argue that it has become easier to win any medal as the number of available medals in the Olympic Games has increased. From this only study we could infer that win a medal in the Winter Game is harder than in the Summer Game. However, Bergiante and Soares de Mello (2010) discussed, based on the work of Hilvoorde, Elling and Stokvis (2010), that due to the obtainment of the medals and all their positive impact as economy growth and a superior international prestige, many countries have been invested more and more to achieve a better position in the medals ranking in the Olympic Games.

So, although the number of medal has increased, the number of countries that took part in the games has also growth. This become clear the difficulty to win a medal in the Olympic Games and, as might as be expected, it was not different in the Winter Olympic Games.

3. Borda, Condorcet and Copeland methods

In situations where there are a lot of criteria and objectives, some conflicting to analyze a problem, it is convenient to use a Multicriteria Decision Support. This system consists in methods and techniques to help the decision making process [Roy and Bouyssou (1993)].

There are many multicriteria decision methods. In this work we are interested in the ordinals methods. Some authors as Gomes et al (2009) affirm that there are three most referenced ordinal methods namely Borda, Condorcet and Copeland methods. The authors said that these methods are seen as intuitive and even less complex in terms of computational efforts and information needed to solve the problems.

In these methods the data requested to the decision makers is, based on their preferences, the ranking of alternatives with a preorder for each criterion [Barba-Romero and Pomerol (1997)]. The Borda method was proposed by Jean-Charles de Borda in the 18^{th} century and it is used to aggregate binary relations among the alternatives. An ordinal scale is given to the decision makers. They must order the alternatives based on their preferences, attributing a certain number of points for each first, second and other places of the ranking.

If there are n alternatives to be ranked, the alternative preferred is worth 1 point, the second place vote is worth 2 points, and so on all the way to an nth place vote, which will worth the lesser pointing.

In the end, these points are counted and the alternatives are sorting by the crescent order of pointing (respecting the totality axiom). The first alternative considered will be that one with the lesser sum of points.

Despite the simplicity of the Borda Method, some authors as Gomes et al (2009) argued that this method fails to satisfy the Arrow axiom [Arrow (1951)], i.e., the independence of irrelevant alternatives. Wherefore, the final ranking would be relative to the group of alternatives evaluated which is not a desirable situation.

In the Condorcet Method, the decision makers are required to express their preferences in a series of pairwise comparisons. From that information, it is possible to build a graph to express their relations [Boaventura Neto (2003)].

Using the graph built we establish preferences relations of the alternatives. We will select a dominant alternative, i.e., an alternative that beats every other feasible alternative in the pairwise comparison. The decision procedure of comparing pairs of alternatives might lead to an intransitive situation, in which Condorcet winners may not exist.

In the Condorcet paradox, as this situation is called, any alternative can be reached from any other by a sequence of alternatives. An example, called Condorcet triplet, can be illustrated as follows: an alternative A beats the alternative B, and B beats C. However, the alternative C beats A leading to a cycle where a Condorcet winner cannot exist. When the intransitive situation does not happen, the Condorcet Method should be used instead of Borda Method [Soares de Mello, Quintella and Soares de Mello (2004)].

A preference aggregation method called Copeland method was design to overcome the voting cycles that impedes to determine a Condorcet winner. The Copeland method uses the adjacency matrix of the Condorcet method graph. After the pairwise comparison, we calculate the number of simply majority wins minus losses, for each alternative. Hence, the Copeland ranking is given by ordering the alternatives according to the results of this sum.

The Copeland method always gives an order of alternatives and in its set will contain the Condorcet winner if there is not an intransitive cycle. Its computational effort is higher than the Condorcet method but it is able to reduce the influence of the irrelevant alternatives [Gomes Junior, Soares de Mello and Soares de Mello (2008)].

Due to all the arguments presented before, in this work we choose to use the Copeland method since its taking into account important issues of the Borda and Condorcet approaches.

The method proposed here has two important goals. The first one is to propose a ranking that will not overvalue the gold medal as generally happens in the Lexicographic method. The second one is to use an approach that take into account that are differences in terms of value among all the disciplines and their medals in the Olympic Games. As an example in the Alpine Skiing there are five possibilities to earn a gold medal but in Ice Hockey there are only two opportunities (men's and women's tournaments).

There are others studies that try to take into consideration these aspects and some of them use DEA methods, as Soares de Mello et al (2009) and Lins et al (2003). However we believe that our approach truly valued the differences among all the medals disputed and fundamentally with less effort than in the DEA methods.

In the second step, each ranking built in the earlier stage will be seen as criteria to a new application of the Copeland Method to establish our final ranking. As one can note, this final ranking will take into account three different models to assort the countries: the Lexicographic method, the total number of medals and the difference between all the modalities of the Olympic Games. As far as we know, this proposal is an advance in the studies in this field. This can be seen as a hierarchy Copeland method.

4. Modelling

As we want to propose a new ranking to the 2010 Winter Olympic Games, in this section we are going to fix up the elements of the problem. Some authors as Gomes et al (2009) argue that to organize a multicriteria problem, we should define the alternatives, the criteria and choose an appropriate method to solve the problem.

Based on the explanation in the third section, we are going to use the Copeland Method, applied in two phases. To the first step, the alternatives will be all the countries that took part in the Vancouver Winter Games, gathered by the modalities disputed. A complete example of data used in the first stage is given in Table 1. The next five tables are excerpts of others modalities.

ALPINE SKIING					
COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
United States	2	3	3	1	2
Germany	1	2	1	2	4
Canada	1	1	2	2	5
Norway	3	0	0	4	1
Austria	2	0	1	4	3
Russia	0	2	0	6	7
South Korea	0	2	0	6	7
China	0	0	2	6	9
Sweden	1	0	0	9	6
France	0	0	1	9	10
Switzerland	0	0	0	11	11
Netherlands	0	0	0	11	11
Czech Republic	0	0	0	11	11
Poland	0	0	0	11	11
Italy	0	0	0	11	11
Japan	0	0	0	11	11
Finland	0	0	0	11	11
Australia	0	0	0	11	11
Belarus	0	0	0	11	11
Slovakia	0	0	0	11	11
Croatia	0	0	0	11	11
Slovenia	0	0	0	11	11
Latvia	0	0	0	11	11
Great Britain	0	0	0	11	11
Kazakhstan	0	0	0	11	11
Estonia	0	0	0	11	11
Albania	0	0	0	11	11
Algeria	0	0	0	11	11
Andorra	0	0	0	11	11
Argentina	0	0	0	11	11
Armenia	0	0	0	11	11
Azerbaijan	0	0	0	11	11
Belgium	0	0	0	11	11
Bermuda	0	0	0	11	11
Bosnia & Herzegovina	0	0	0	11	11
Brazil	0	0	0	11	11
Bulgaria	0	0	0	11	11

ALPINE SKIING					
COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
Cayman Islands	0	0	0	11	11
Chile	0	0	0	11	11
Chinese Taipei	0	0	0	11	11
Colombia	0	0	0	11	11
Costa Rica	0	0	0	11	11
Cyprus	0	0	0	11	11
Denmark	0	0	0	11	11
North Korea	0	0	0	11	11
Ethiopia	0	0	0	11	11
Macedonia	0	0	0	11	11
Georgia	0	0	0	11	11
Ghana	0	0	0	11	11
Greece	0	0	0	11	11
Hong Kong	0	0	0	11	11
Hungary	0	0	0	11	11
Iceland	0	0	0	11	11
India	0	0	0	11	11
Iran	0	0	0	11	11
Ireland	0	0	0	11	11
Israel	0	0	0	11	11
Jamaica	0	0	0	11	11
Kenya	0	0	0	11	11
Kyrgyzstan	0	0	0	11	11
Lebanon	0	0	0	11	11
Liechtenstein	0	0	0	11	11
Lithuania	0	0	0	11	11
Mexico	0	0	0	11	11
Moldova	0	0	0	11	11
Monaco	0	0	0	11	11
Mongolia	0	0	0	11	11
Montenegro	0	0	0	11	11
Morocco	0	0	0	11	11
Nepal	0	0	0	11	11
New Zealand	0	0	0	11	11
Pakistan	0	0	0	11	11
Peru	0	0	0	11	11
Portugal	0	0	0	11	11
Serbia	0	0	0	11	11
Romania	0	0	0	11	11
San Marino	0	0	0	11	11
Senegal	0	0	0	11	11
South Africa	0	0	0	11	11
Spain	0	0	0	11	11
Tajikistan	0	0	0	11	11
Turkey	0	0	0	11	11
Ukraine	0	0	0	11	11
Uzbekistan	0	0	0	11	11

Table 1. Example of the ranking per modality (including all countries) - Alpine Skiing.

BIATHLON					
COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
France	1	2	3	6	1
Norway	3	2	0	5	2
Germany	2	1	2	5	2
Russia	2	1	1	4	4
Slovakia	1	1	1	3	5
Austria	0	2	0	2	6
Belarus	0	1	1	2	6
Sweden	1	0	0	1	8
Kazakhstan	0	1	0	1	8
Croatia	0	0	1	1	8

Table 2. Example of ranking per modality – Biathlon.

CROSS-COUNTRY SKIING					
COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
Norway	5	2	2	9	1
Sweden	3	2	2	7	2
Germany	1	4	0	5	3
Russia	1	1	2	4	4
Poland	1	1	1	3	5
Czech Republic	0	0	2	2	6
Finland	0	0	2	2	6
Switzerland	1	0	0	1	8
Estonia	0	1	0	1	8
Italy	0	1	0	1	8

Table 3. Example of ranking per modality – Cross-Country Skiing.

FREE STYLE SKIING

COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
United States	1	1	2	4	1
Canada	2	1	0	3	2
China	0	1	2	3	2
Australia	1	1	0	2	4
Norway	0	1	1	2	4
Belarus	1	0	0	1	6
Switzerland	1	0	0	1	6
Austria	0	1	0	1	6
France	0	0	1	1	6

Table 4. Example of ranking per modality – Free Style Skiing.

SNOWBOARD

COUNTRY	GOLD MEDALS	SILVER MEDALS	BRONZE MEDALS	RANKING TOTAL NUMBER OF MEDALS	RANKING NUMBER OF GOLD MEDALS
United States	2	1	2	5	1
Canada	2	1	0	3	2
France	0	1	2	3	2
Austria	0	1	1	2	4
Australia	1	0	0	1	5
Netherlands	1	0	0	1	5
Finland	0	1	0	1	5
Russia	0	1	0	1	5
Switzerland	0	0	1	1	5

Table 5. Example of ranking per modality – Snowboard.

Using the data of the Table 1 and all the others tables, we built the adjacency matrix by the Condorcet method. To the examples given before, as the Alpine Skiing modality, the matrices are shown hereafter. The last columns is calculated as showed here: ($\sum$ wins - $\sum$ losses)

ALPINE SKIING	United States	Norway	Austria	Germany	Switzerland	Croatia	Slovenia	Sweden	Italy	Czech Republic	Sum of Wins	Wins minus Losses
United States		1	1	1	1	1	1	1	1	1	9	8
Norway	0		1	1	1	1	1	1	1	1	8	5
Austria	0	0		1	1	1	1	1	1	1	7	3
Germany	1	1	1		1	1	1	1	1	1	9	6
Switzerland	0	1	1	0		1	1	1	1	1	7	3
Croatia	0	0	0	0	0		1	1	1	1	4	-3
Slovenia	0	0	0	0	0	1		1	1	1	4	-4
Sweden	0	0	0	0	0	0	1		1	1	3	-5
Italy	0	0	0	0	0	1	1	1		1	4	-4
Czech Republic	0	0	0	0	0	0	0	0	0		0	-1
Sum of losses	1	3	4	3	4	7	8	8	8	9		

1

Table 6. Adjacency matrix built by the Condorcet Method – Alpine Skiing.

BIATHLON	France	Norway	Germany	Russia	Slovakia	Austria	Belarus	Sweden	Kazakhstan	Croatia	Sum of Wins	Wins minus Losses
France		1	1	1	1	1	1	1	1	1	9	6
Norway	1		1	1	1	1	1	1	1	1	9	8
Germany	1	0		1	1	1	1	1	1	1	8	6
Russia	1	0	0		1	1	1	1	1	1	7	4
Slovakia	0	0	0	0		1	1	1	1	1	5	1
Austria	0	0	0	0	0		1	1	1	1	4	-2
Belarus	0	0	0	0	0	0		1	1	1	3	-4
Sweden	0	0	0	0	0	1	1		1	1	4	-3
Kazakhstan	0	0	0	0	0	0	0	0		1	1	-7
Croatia	0	0	0	0	0	0	0	0	0		0	-9
Sum of losses	3	1	2	3	4	6	7	7	8	9		

1

Table 7. Adjacency matrix built by the Condorcet Method – Biathlon.

CROSS-COUNTRY SKIING	Norway	Sweden	Germany	Russia	Poland	Czech Republic	Finland	Switzerland	Estonia	Italy	Slovenia	Sum of Wins	Wins minus Losses
Norway		1	1	1	1	1	1	1	1	1	1	10	10
Sweden	0		1	1	1	1	1	1	1	1	1	9	8
Germany	0	0		1	1	1	1	1	1	1	1	8	6
Russia	0	0	0		1	1	1	1	1	1	1	7	4
Poland	0	0	0	0		1	1	1	1	1	1	6	2
Czech Republic	0	0	0	0	0		1	1	1	1	1	5	-4
Finland	0	0	0	0	0	1		1	1	1	1	5	-4
Switzerland	0	0	0	0	0	1	1		1	1	1	5	-2
Estonia	0	0	0	0	0	1	1	0		1	1	4	-5
Italy	0	0	0	0	0	1	1	0	1		1	4	-5
Slovenia	0	0	0	0	0	0	0	0	0	0		0	-10
Sum of losses	0	1	2	3	4	9	9	7	9	9	10		

1

Table 8. Adjacency matrix built by the Condorcet Method - Cross-Country Skiing.

FREE STYLE SKIING	United States	Canada	China	Australia	Norway	Belarus	Switzerland	Austria	France	Sum of Wins	Wins minus Losses
United States		1	1	1	1	1	1	1	1	8	7
Canada	1		1	1	1	1	1	1	1	8	7
China	0	0		1	1	1	1	1	1	6	1
Australia	0	0	1		1	1	1	1	1	6	3
Norway	0	0	0	0		1	1	1	1	4	-2
Belarus	0	0	1	0	1		1	1	1	5	-1
Switzerland	0	0	1	0	1	1		1	1	5	-1
Austria	0	0	0	0	0	0	0		1	1	-6
France	0	0	0	0	0	0	0	0		0	-8
Sum of losses	1	1	5	3	6	6	6	7	8		

1

Table 9. Adjacency matrix built by the Condorcet Method – Free Style Skiing.

SNOWBOARD	United States	Canada	France	Austria	Australia	Netherlands	Finland	Russia	Switzerland	Sum of Wins	Wins minus Losses
United States		1	1	1	1	1	1	1	1	8	8
Canada	0		1	1	1	1	1	1	1	7	6
France	0	0		1	1	1	1	1	1	6	2
Austria	0	0	0		1	1	1	1	1	5	0
Australia	0	0	1	1		1	1	1	1	6	1
Netherlands	0	0	1	1	1		1	1	1	6	1
Finland	0	0	0	0	0	0		1	1	2	-5
Russia	0	0	0	0	0	0	1		1	2	-5
Switzerland	0	0	0	0	0	0	0	0		0	-8
Sum of losses	0	1	4	5	5	5	7	7	8		

Table 10. Adjacency matrix built by the Condorcet Method – Snowboard.

Now we are able to rank the countries and the results are seen in the following tables.

ALPINE SKIING	TOTAL (∑ wins - ∑losses)	RANKING
United States	8	1
Germany	6	2
Norway	5	3
Austria	3	4
Switzerland	3	4
Czech Republic	-1	6
Croatia	-3	7
Slovenia	-4	8
Italy	-4	8
Sweden	-5	10

Table 11. Ranking in the first stage – Alpine Skiing.

BIATHLON	TOTAL (∑ wins - ∑losses)	RANKING
Norway	8	1
France	6	2
Germany	6	2
Russia	4	4
Slovakia	1	5
Austria	-2	6
Sweden	-3	7
Belarus	-4	8
Kazakhstan	-7	9
Croatia	-9	10

Table 12. Ranking in the first stage – Biathlon.

CROSS-COUNTRY SKIING	TOTAL (∑ wins - ∑losses)	RANKING
Norway	10	1
Sweden	8	2
Germany	6	3
Russia	4	4
Poland	2	5
Switzerland	-2	6
Czech Republic	-4	7
Finland	-4	7
Estonia	-5	9
Italy	-5	9
Slovenia	-10	11

Table 13. Ranking in the first stage – Cross-Country Skiing.

FREESTYLE SKIING	TOTAL (∑ wins - ∑losses)	RANKING
United States	7	1
Canada	7	1
Australia	3	3
China	1	4
Belarus	-1	5
Switzerland	-1	5
Norway	-2	7
Austria	-6	8
France	-8	9
United States	7	1
Canada	7	1

Table 14. Ranking in the first stage – Freestyle Skiing.

SNOWBOARD	TOTAL (∑ wins - ∑losses)	RANKING
United States	8	1
Canada	6	2
France	2	3
Australia	1	4
Netherlands	1	4
Austria	0	6
Finland	-5	7
Russia	-5	7
Switzerland	-8	9
United States	8	1
Canada	6	2

Tabela 15. Ranking in the first stage – Snowboard.

We have obtained a ranking as in Table 11, Table 12, Table 13, Table 14 and Tabela 15 for all the 15 modalities in the Vancouver 2010 Olympic Games. These rankings were used as criteria to the second step of the method used here. An example of the aggregated results is showed in Table 16.

	Position in the ranking by modality														
	ALPINE SKIING	BIATHLON	BOBSLEIGH	CROSS-COUNTRY SKIING	CURLING	FIGURE SKATING	FREESTYLE SKIING	ICE HOCKEY	LUGE	NORDIC COMBINED	SHORT TRACK	SKELETON	SKI JUMPING	SNOWBOARD	SPEEDSKATING
United States	1	11	3	12	6	1	1	2	5	1	3	6	5	1	6
Germany	2	2	1	3	6	7	10	4	1	4	6	1	3	10	4
Canada	11	11	1	12	1	3	1	1	5	6	3	1	5	2	3
Norway	3	1	5	1	3	8	7	4	5	6	6	6	4	10	9
Austria	4	6	5	12	6	8	8	4	2	2	6	6	1	6	12
Switzerland	4	11	5	6	4	8	5	4	5	6	6	6	1	9	12
Russia	11	4	4	4	6	4	10	4	5	6	6	5	5	7	12
China	11	11	5	12	4	1	4	4	5	6	2	6	5	10	9
South Korea	11	11	5	12	6	4	10	4	5	6	1	6	5	10	1
France	11	2	5	12	6	8	9	4	5	3	6	6	5	3	12
Sweden	10	7	5	2	2	8	10	4	5	6	6	6	5	10	12
Netherlands	11	11	5	12	6	8	10	4	5	6	6	6	5	4	1
Czech Republic	6	11	5	7	6	8	10	4	5	6	6	6	5	10	5
Australia	11	11	5	12	6	8	3	4	5	6	6	6	5	4	12
Poland	11	11	5	5	6	8	10	4	5	6	6	6	2	10	9
Italy	8	11	5	9	6	8	10	4	4	4	5	6	5	10	12
Japan	11	11	5	12	6	4	10	4	5	6	6	6	5	10	7
Finland	11	11	5	7	6	8	10	3	5	6	6	6	5	7	12
Belarus	11	8	5	12	6	8	5	4	5	6	6	6	5	10	12
Slovakia	11	5	5	12	6	8	10	4	5	6	6	6	5	10	12
Great Britain	11	11	5	12	6	8	10	4	5	6	6	1	5	10	12
Croatia	7	10	5	12	6	8	10	4	5	6	6	6	5	10	12
Latvia	11	11	5	12	6	8	10	4	3	6	6	4	5	10	12
Slovenia	8	11	5	11	6	8	10	4	5	6	6	6	5	10	12
Estonia	11	11	5	9	6	8	10	4	5	6	6	6	5	10	12
Kazakhstan	11	9	5	12	6	8	10	4	5	6	6	6	5	10	12

Table 16. Examples of the results used in the second stage

Using the results found in the Table 16 we built a new adjacency matrix of the Condorcet Method and then we apply again the Copeland Method in order to establish a final ranking. In the next section the results will be shown and analyzed.

5. Results

After we used the method presented before, we have built a table by doing a paired comparison of the countries, taking into account the criteria established (in our case, each ranking of every modality). The result is a square matrix in which each country is compared with each other. The principal diagonal of the adjacency matrix is blank. In each other cell are computed the comparison between the country in the row and the candidate in the column. A score of 1 is signaling a pairwise victory for the country in the row over the country in the column. If happens a draw, both, row and columns of the pairwise in the matrix will get a score of 1.

Here we showed an excerpt of the adjacency matrix of the Condocert Method.

COUNTRY	United States	Germany	Canada	Norway	Austria	Russia	South Korea	China	Sweden	France	Switzerland	Netherlands	Czech Republic	Poland	Italy	Japan	Finland	Australia	Belarus	Slovakia	Croatia	Slovenia	Latvia	Great Britain	Kazakhstan	Estonia
United States		1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Germany	1		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Canada	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Norway	0	0	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Austria	0	0	0	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Russia	0	0	0	0	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
South Korea	0	0	0	0	0	0		0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
China	0	0	0	0	0	0	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sweden	0	0	0	0	0	0	1	1		0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
France	0	0	0	0	0	0	1	0	1		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Switzerland	0	0	0	0	0	0	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Netherlands	0	0	0	0	0	0	0	0	0	0	0		1	1	0	1	1	1	1	1	1	1	1	1	1	1
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Poland	0	0	0	0	0	0	0	0	0	0	0	1	1		0	1	1	1	1	1	1	1	1	1	1	1
Italy	0	0	0	0	0	0	1	0	1	1	0	1	1	1		1	1	1	1	1	1	1	1	1	1	1
Japan	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	1	1	1	1	1	1	1	1	1
Finland	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	1		1	1	1	1	1	1	1	1	1
Australia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1		1	1	1	1	1	1	1	1
Belarus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0		1	1	1	1	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		1	0	0	1	1	1
Croatia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1		1	1	1	1	1
Slovenia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0		0	1	1	1
Latvia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1		0	1	1
Great Britain	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1		1	1
Kazakhstan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1		1
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	

Table 17. Adjacency Matrix - Condocert Method.

To calculate the Copeland Ranking it is necessary to compare each cell with its diagonal opposite. For each country in the row we do a subtraction between the sum of its pairwise victories (number of “1" in the row) and the sum of its losses (number of \1" in the column). These results are computed and a Copeland Ranking is established.

In Table 18 we show the results of the method proposed in this work and others types of rankings.

COUNTRY	RANKING 1 – LEXICOGRAPHIC	RANKING 2 – TOTAL NUMBER OF MEDALS	RANKING 3 – PROPOSED COPELAND METHOD
Canada	1	3	1
United States	3	1	2
Germany	2	2	2
Norway	3	4	4
Austria	9	5	5
Russia	11	6	5
China	7	8	7
Switzerland	5	11	7
France	12	8	9
Italy	15	15	9
Sweden	7	8	11
South Korea	5	7	12
Czech Republic	12	13	12
Netherlands	9	12	14
Poland	15	13	14
Finland	24	15	14
Australia	12	18	17
Japan	20	15	18
Croatia	21	18	19
Latvia	23	23	19
Slovenia	21	18	21
Belarus	15	18	22
Slovakia	15	18	23
Great Britain	15	24	23
Kazakhstan	25	25	25
Estonia	25	26	25
Albania	26	27	27
Albania	26	27	27
Algeria	26	27	27
Andorra	26	27	27
Argentina	26	27	27
Armenia	26	27	27
Azerbaijan	26	27	27
Belgium	26	27	27
Bermuda	26	27	27
Bosnia & Herzegovina	26	27	27
Brazil	26	27	27
Bulgaria	26	27	27
Cayman Islands	26	27	27
Chile	26	27	27
Chinese Taipei	26	27	27

Colombia	26	27	27
Costa Rica	26	27	27
Cyprus	26	27	27
Denmark	26	27	27
North Korea	26	27	27
Ethiopia	26	27	27
Macedonia	26	27	27
Georgia	26	27	27
Ghana	26	27	27
Greece	26	27	27
Hong Kong	26	27	27
Hungary	26	27	27
Iceland	26	27	27
India	26	27	27
Iran	26	27	27
Ireland	26	27	27
Israel	26	27	27
Jamaica	26	27	27
Kenya	26	27	27
Kyrgyzstan	26	27	27
Lebanon	26	27	27
Liechtenstein	26	27	27
Lithuania	26	27	27
Mexico	26	27	27
Moldova	26	27	27
Monaco	26	27	27
Mongolia	26	27	27
Montenegro	26	27	27
Morocco	26	27	27
Nepal	26	27	27
New Zealand	26	27	27
Pakistan	26	27	27
Peru	26	27	27
Portugal	26	27	27
Serbia	26	27	27
Romania	26	27	27
San Marino	26	27	27
Senegal	26	27	27
South Africa	26	27	27
Spain	26	27	27
Tajikistan	26	27	27
Turkey	26	27	27
Ukraine	26	27	27
Uzbekistan	26	27	27

Table 18. Comparison between the ranking proposed and the others rankings.

Other analysis, in terms of the variation among the types of rankings, is showed. In the follow table we calculated the variation between the ranking proposed and the Lexigraphic Ranking.

COUNTRY	VARIATION $(X_{tk} - X_{tk-1})$	QUADRATIC VARIATION $(X_{tk} - X_{tk-1})^2$
Canada	0	0
United States	-1	1
Germany	0	0
Norway	1	1
Austria	-4	16
Russia	-6	36
China	0	0
Switzerland	2	4
France	-3	9
Italy	-6	36
Sweden	4	16
South Korea	7	49
Czech Republic	0	0
Netherlands	5	25
Poland	-1	1
Finland	-10	100
Australia	5	25
Japan	-2	4
Croatia	-2	4
Latvia	-4	16
Slovenia	0	0
Belarus	7	49
Slovakia	8	64
Great Britain	8	64
Kazakhstan	0	0
Estonia	0	0
Albania	1	1
Albania	1	1
Algeria	1	1
Andorra	1	1
Argentina	1	1
Armenia	1	1
Azerbaijan	1	1
Belgium	1	1
Bermuda	1	1
Bosnia & Herzegovina	1	1
Brazil	1	1
Bulgaria	1	1
Cayman Islands	1	1
Chile	1	1
Chinese Taipei	1	1
Colombia	1	1
Costa Rica	1	1
Cyprus	1	1
Denmark	1	1

North Korea	1	1
Ethiopia	1	1
Macedonia	1	1
Georgia	1	1
Ghana	1	1
Greece	1	1
Hong Kong	1	1
Hungary	1	1
Iceland	1	1
India	1	1
Iran	1	1
Ireland	1	1
Israel	1	1
Jamaica	1	1
Kenya	1	1
Kyrgyzstan	1	1
Lebanon	1	1
Liechtenstein	1	1
Lithuania	1	1
Mexico	1	1
Moldova	1	1
Monaco	1	1
Mongolia	1	1
Montenegro	1	1
Morocco	1	1
Nepal	1	1
New Zealand	1	1
Pakistan	1	1
Peru	1	1
Portugal	1	1
Serbia	1	1
Romania	1	1
San Marino	1	1
Senegal	1	1
South Africa	1	1
Spain	1	1
Tajikistan	1	1
Turkey	1	1
Ukraine	1	1
Uzbekistan	1	1

Tabela 19. Variation between the Proposed Ranking and the Lexicografic Ranking.

To organize the results we can separate them into four categories. The first one includes countries that have almost the same results in the ranking 1 and 2 but in ranking 3 they lost some positions. As examples are Sweden and South Korea. These results show that the medals won by these countries are balanced and they have invested in sports that distribute a large number of medals.

The second cluster is composed by countries that have the same (or almost the same) results in the ranking 1 and 2 and they win some positions in ranking 3. In this class we have countries as Italy and Latvia. In this situation are countries that have won a balanced number of gold, silver and bronze medals and also have invested in modalities that offer a small number of medals.

The third set of countries includes those with the same position in ranking 2 and 3 but in lower position in the ranking 1 as Austria and France. Some of them have the higher quadratic variation as Finland. These results indicate that probably the investments politics in sports of these countries are based in team-based sports which are not a good option to win medals. Another analysis is that they have won more silver and bronze medals than gold medals.

The fourth category is given by countries that have the same position (or a difference of one or two positions) in all the three rankings and the lowest quadratic variation, as Canada, United States, Germany, Norway, China, Czech Republic and Poland. These countries invested equally in a search for all types of medals in the modalities that distribute a good number of medals.

We can also take into account a case of countries as Switzerland. They have won a number of gold medals large than the others types of medals, but they invested in sports that allocate a small number of medals.

6. Conclusion

In this work we have proposed a study of the results of Vancouver 2010 Olympic Games. We have obtained some interesting results such as countries that have an unbalanced number of medals and take part in modalities that distribute a small number of medals.

Another interesting aspect found in this study is the Finland results. In the evaluation, we found that it probably invest in sports based in teams in which the number of medals are smaller than in other modalities and also it had won more silver and bronze medals than gold medals. This result corroborates the findings in Bergiante and Soares de Mello (2010) and helps us to understand some peculiar political sports decisions took by a couple of countries.

As a future work suggestion, an interesting proposal is to cluster countries by modalities in order to build others Olympic Rankings [Soares de Mello et al (2009)]. Another option is to explore the economic aspect of these conclusions and develop a model of investment politics in sports for each country.

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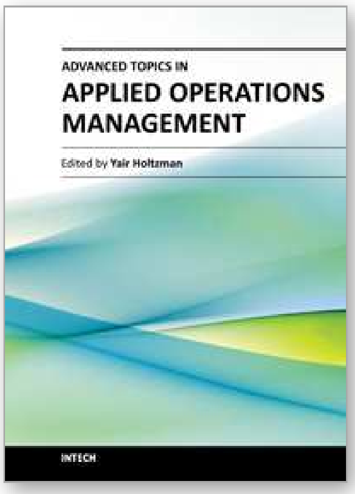

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The chapters in Advanced Topics in Applied Operations Management creatively demonstrate a valuable connection among operations strategy, operations management, operations research, and various departments, systems, and practices throughout an organization. The authors show how mathematical tools and process improvements can be applied effectively in unique measures to other functions. The book provides examples that illustrate the challenges confronting firms competing in today's demanding environment bridging the gap between theory and practice by analyzing real situations.