RANKING COUNTRIES MORE RELIABLY IN THE SUMMER OLYMPICS

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ABSTRACT

In this paper we consider the many intangible criteria that influence the outcome of the Summer Olympics by using the Analytic Network Process, and apply the ideas to evaluate the medals won and the country scores in the 2012 London Olympics. Both the categories of games and the events in each game are considered in this weighting process. Different events of the same category game could have different properties. This work shows that the current way of counting the total number of medals is not a bad way of ranking countries. With minor modifications, this systematic approach for ranking countries can be used for any Summer Olympics.

Keywords: OR in sports; country ranking; Olympic Games; Analytic Network Process; rating

1. Introduction

The modern Olympic Games are a major international event featuring summer and winter sports in which thousands of athletes participate in a variety of competitions. They are considered to be the world's foremost sports competitors and represent nearly 200 nations who may participate. The Games are currently held biennially, with Summer and Winter Olympic Games alternating, thus each occurring every four years. Their creation was inspired by the ancient Olympic Games which were held in Olympia, Greece for more than 1000 years from the 8th century BC to the 4th century AD.

There have been a number of studies conductedwhich have focused on the Olympic Games and other Olympic movements. For example, Andrew (2000)'s study researched why countries show different performance in Olympics. This study had three objectives with the key objective being, to examine the influences of factors affecting the Olympic performance.Two specific objectives were (i) to produce a mathematical model facilitating the prediction of the Olympic tally, and (ii) to identify the degree of factors that have influence on the Olympic performance. Bernard (2000) studied different variables in Olympic Games success investigation. On the other hand, Wade (2006)

studied the prediction of medal winners. Our motivation in this paper comes from the need for a scientific methodology to interpret the number of medals the countries have and a way to rank them.

Qualification rules for each of the Olympic sports are set by the International Sports Federations (IFs) that governs that sport's international competition. For individual sports, athletes typically qualify by attaining a certain rank in a major international event and thus gain recognition on the IF's ranking list. National Olympic committees (NOC) may enter a limited number of qualified athletes in each event.

In the ancient Olympics, no medals were awarded. First-place winners were given an olive branch to wear on their head, and second and third place winners did not receive anything. In the first modern Games held in 1896 silver and bronze medals were awarded to first and second place winners. In 1900, most winners received cups or trophies instead of medals. In the 1904 Games in St. Louis, gold replaced silver as the medal awarded for first place, followed by silver and bronze medals awarded to second and third place winners.

Nowadays, the media decides which country has won the Olympics by adding all the medals won by athletes from that country. However, this kind of practice seems self-defeating because it assumes that all gold, silver and bronze medals should be counted as equal in merit and all games and events are assumed equally important. Nevertheless, it is only an approximate way and as it turns out, not an entirely faulty way of deciding which country is the overall winner of medals.

No methodically scientific way to deal with multicriteria ranking involving intangibles has been used to assign appropriate priority weights to each type of sport and medal won in that sport for the Olympic Games. Here we propose using the Analytic Network Process (ANP) for the measurement of intangibles, along with their dependence and feedback, to weight the criteria which we think play an important role in assigning priorities to games and events.

Our methodology consists of the following steps:

1) An ANP model is developed to assign weights to different criteria used to prioritize different games and events in each game.
2) Expert knowledge is used to define the criteria and evaluate the games and events.
3) We prioritize the significance of the three types of medals (gold, silver and bronze), weight them by the overall priorities of the events to obtain the overall priority of a medal won and add these priorities to obtain the priority rank of a country.
4) Our results do not violate intuition about the number and value of the medals and in fact take greater consideration by including the merits of the events in which they are won. Thus, we also show that the ranking of countries produces results that are reasonably close to the current results of adding all medals won but with some important exceptions.

2. Criteria to weight the summer Olympic Games

The priorities of different kinds of games depend on several factors. Table 1 lists the relevant basic criteria groupings or clusters and the elements in each cluster. Figure 1 represents the top level network of the Analytic Network Process model together with the criteria.

Table 1
Criteria and subcriteria

Cluster	Elements in Cluster
Game requirements	Required physical characteristics, Required training time
Game other factors	Risk level involved, Energy spent, Duration of the act
People involved	Number of competitors, Strength of competitors, Audience reaction, popularity
Living environment	Effects of daily life on the game, Effects on daily life, Financial resources needed
Natural environment	Season or climate suitability, Topographic pattern, Absence of pollution
Other factors	Sport commercialization, Technology, Political factors

According to Table 1 and Figure 1 the main cluster of criteria is "Game requirements" which consists of "Required physical characteristics" and "Required training time". For some sports, one may need physical characteristics that deal with strength. For example, in gymnastics one needs to practice for years starting at a young age.

The second cluster of criteria is "Other factors related to the game" which includes "Risk level involved", "Energy spent" and "Duration of the act". The "Risk level" involved is a criterion in our analysis because it affects people's attitudes; some people find it more challenging and encouraging to take risks. We have also included an "Energy spent" criterion because in certain games more energy is needed. For example, wrestling requires a high amount of energy spent, and certain sports also involve higher risk as in some gymnastics events. The duration of an event is another concern because some games last for a relatively long time, and in certain cases as in the marathon, a medal for this game deserves a greater value.

A third cluster of criteria is "People involved" which consists of the "Number of competitors", the "Strength of competitors" and also "Audience reaction, popularity". Here, we think that there are some games that have greater popularity and this makes these sports more attractive to attend (e.g. football, tennis). On the other hand, to be successful in a game that has many competitors is more difficult.

The fourth cluster is "Living environment", with criteria "Effects of daily life on the game", "Effects on daily life" and "Financial resources needed". Some sports can be influenced by the daily life of the competitors; for example football players are usually careful about being involved in too large amounts of social activities and entertainment

that may affect their physical strength during the game due to lack of sleep. This is equally true of organizing daily life in a way to support success in the sport, such as being careful about ones diet. Financial resources are also important in some sports both to facilitate a player's needs and to make it possible to be choosy in meeting basic needs as desired. Tennis, skiing or ice-skating need specific professional environments and specific equipment for training which can be costly.

The fifth cluster is "Natural environment" whose criteria are "Season or climate suitability", "Topographic pattern" and "Absence of pollution". Climate and topographic patterns have important effects on pollution which is an undesirable factor particularly for events like canoeing and marathon.

The sixth cluster is "Other factors" related to political, economic and social issues. Political factors can determine whether the games would be attended by some countries. Technology affects performance and in the long run new technology can change performance in a sport very significantly.

Figure 1 gives a screen view from the SuperDecisions software with the clusters and their criteria from Table 1 along with their interconnections.

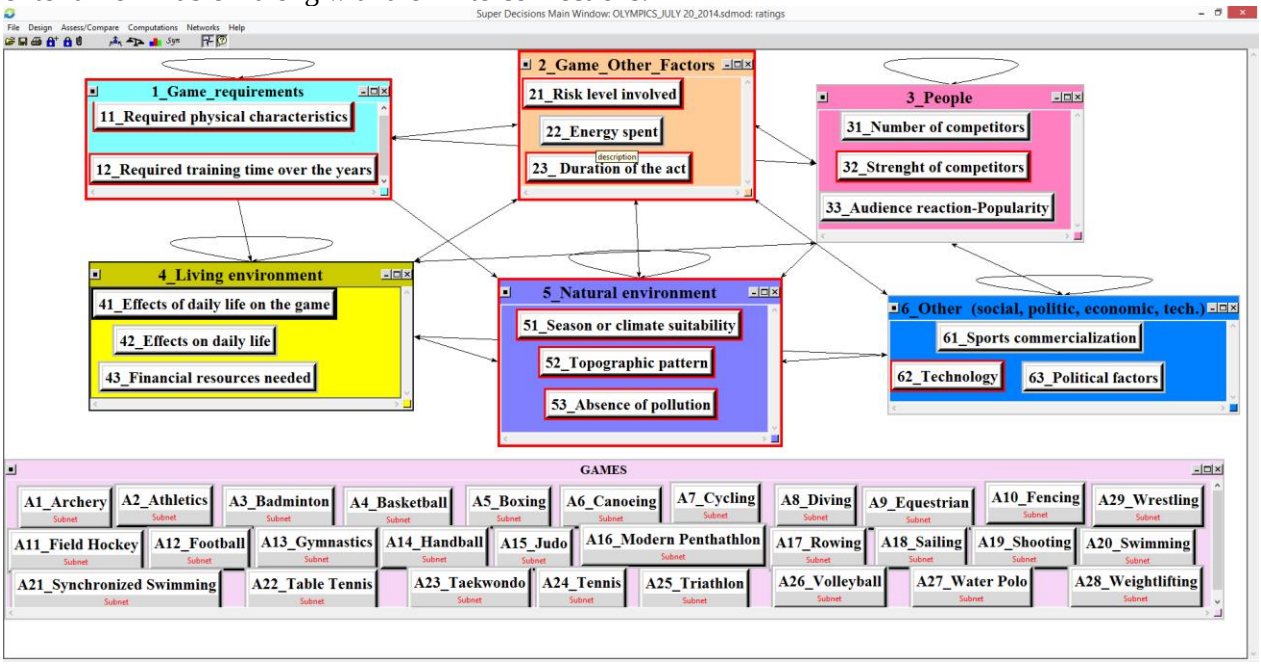


Figure 1. ANP top level model

As an illustration, Table 2 gives a view of paired comparisons related to the effect of "Risk level involved" and "Duration of the act" on the criterion "Energy spent". "Duration of the act" has two times greater influence on the "Energy spent" criterion than "Risk level" does. Table 3 presents the criteria weights. These judgements have been obtained by interviewing different experts who have been a judge or competitor in different Olympic games, and geometric mean is used.

Table 2
Comparisons between "Risk level involved" and "Duration of the act" on "Energy spent"

Energy spent	Risk level involved	Duration of the act	Priorities
Risk level involved	1	1/2	0.3333
Duration of the act	2	1	0.6667

Table 3
Criteria priorities

Criterion	**Priority**	**Criterion**	**Priority**
Required physical characteristics	0,0606	Effects of the daily life on the game	0,0935
Required training time	0,0735	Effects on the daily life	0,0170
Risk level involved	0,0107	Financial resources needed	0,0136
Energy spent	0,0692	Season or climate suitability	0,0805
Duration of the act	0,0740	Topographic pattern	0,0921
Number of competitors	0,0539	Absence of pollution	0,0673
Strength of competitors	0,0735	Sports commercialization	0,0463
Audience reaction, popularity	0,0760	Political factors	0,0296
Technology	0,0679		

3. How to evaluate different games and different events involved in each game

Based on the previous discussion, it appears that declaring a winning country by adding all medals may not reflect the quality of the games that are won by the athletes from that country. The difference in the quality of the sports themselves is an important factor. By using the Fundamental Scale of absolute numbers of the AHP given in Table 4, one can compare the importance of different games and the importance of the events involved in each game (Saaty, 2004).

Table 4
Fundamental scale of absolute numbers

Intensity of Importance	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor the dominance of one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor the dominance of one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly in dominating over another activity; its dominance may even be demonstrated in practice
8	Very, very strong	
9	Extreme	An activity extremely domiantes another activity

The experts who provided the judgments were a group of four people who have taken part in sports games as a referee, a coach and/or an athlete for over 12 years. We interviewed them for several days with regard to the criteria to be considered in the evaluation of the games and their events. We prepared a questionnaire to obtain the weights for each game and event, and then used the geometric mean to aggregate their judgments into a representative judgment for the group. When an inconcistency was discovered, we discussed the possibility of changing a judgment with the relevant person in order to reduce the inconsistency to an acceptable level and be closer to consensus on that set of judgments. We also did a literature review to obtain detailed data and information related to the criteria and the games themselves. Finally, we applied our approach to rank the winning countries for the 2012 London Summer Olympics. Table 5 lists all the games for this particular Olympics.

Table 5
2012 London Summer Olympic Games

Archery	Cycling	Gymnastics	Shooting	Triathlon
Athletics	Diving	Handball	Swimming	Volleyball
Badminton	Equestrian	Judo	Synchronized swimming	Water polo
Basketball	Fencing	Modern pentathlon	Table tennis	Weightlifting
Boxing	Field hockey	Rowing	Taekwondo	Wrestling
Canoe	Football	Sailing	Tennis	

We categorized Olympic games in terms of the "Risk levels involved", "Energy spent" and "Duration of the act". Tables 6, 7 and 8 present these categories, noticing that games could fall into different categories for different criteria.

Table 6
Summer Olympic Games according to the "Risk level involved"

HIGH	**MEDIUM**		**LOW**	
Modern pentathlon	Football	Boxing	Fencing	Equestrian
Diving	Basketball	Canoeing	Taekwondo	Volleyball
Weightlifting	Water polo	Cycling	Badminton	Field Hockey
Gymnastics	Sailing	Tennis	Table tennis	Judo
Athletics		Rowing	Archery	Wrestling
Triatlon			Shooting	Badminton
Swimming			Synchronized Swimming	Handball

Table 6 implies that sports like diving and weightlifting have higher risks. They are usually considered dangerous sports that may cause harmful injuries and even death. On the other hand, according to the classification of "Energy spent" in Table 7, we obtain a different grouping of sports, i.e. fencing is a game that needs less energy when compared with other games like football.

Table 7
Summer Olympic Games according to the "Energy spent"

HIGH		**MEDIUM**		**LOW**
Weightlifting	Modern pentathlon	Sailing	Badminton	Archery
Athletics	Basketball	Volleyball	Table tennis	Fencing
Swimming	Football	Equestrian	Diving	Shooting
Wrestling	Water polo	Canoeing	Synchronized Swimming	Field Hockey
Tennis	Rowing	Handball	Cycling	Badminton
Gymnastics	Triatlon	Boxing	Judo	
		Taekwondo		

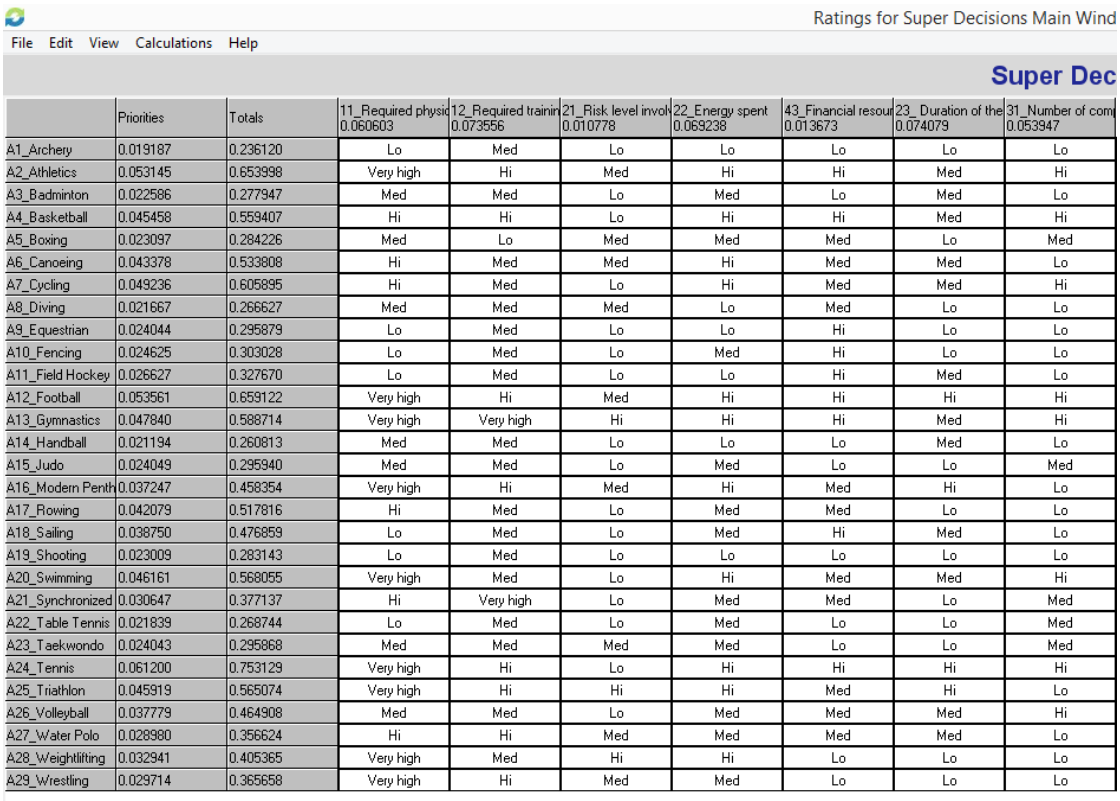
Similarly, Table 8 groups the games according to "Duration of the act". Football and volleyball have long durations while others, like Taekwondo and wrestling, generally take shorter times.

Table 8
Summer Olympic Games according to the "Duration of the act"

HIGH		MEDIUM		LOW	
Athletics	Triatlon	Canoeing	Field Hockey	Archery	Fencing
Basketball	Voleyball	Gymnastic	Rowing	Boxing	Shooting
Cycling		Swimming	Sailing	Badminton	Taekwondo
Football		Handball		Diving	Water polo
Modern pentathlon		Table tennis		Equestrian	Weightlifting
Tennis		Synchronized Swimming		Judo	Wrestling

There were 29 games in the 2012 London Olympics. In order to prioritize them we used the ANP ratings module by evaluating them one at a time. The categories "low, medium, high" or "low, medium, high, very high" were chosen for the 17 criteria with an appropriate adjustment for the number of categories in each group (3 or 4). Tables 9(a) and 9(b) show a screen view of the rating module from the Super Decisions software. Five different experts from different professions were consulted.

Table 9 (a)
Screen view of the rating module to weight the games (for the criteria 1-7)



	Priorities	Totals	11_Required physic 0.060603	12_Required trainin 0.073556	21_Risk level invol 0.010778	22_Energy spent 0.069238	43_Financial resou 0.013673	23_Duration of the 0.074079	31_Number of com 0.053947
A1_Archery	0.019187	0.236120	Lo	Med	Lo	Lo	Lo	Lo	Lo
A2_Athletics	0.053145	0.653998	Very high	Hi	Med	Hi	Hi	Med	Hi
A3_Badminton	0.022586	0.277947	Med	Med	Lo	Med	Lo	Med	Lo
A4_Basketball	0.045458	0.559407	Hi	Hi	Lo	Hi	Hi	Med	Hi
A5_Boxing	0.023097	0.284226	Med	Lo	Med	Med	Med	Lo	Med
A6_Canoeing	0.043378	0.533808	Hi	Med	Med	Hi	Med	Med	Lo
A7_Cycling	0.049236	0.605895	Hi	Med	Lo	Hi	Med	Med	Hi
A8_Diving	0.021667	0.266627	Med	Med	Med	Lo	Med	Lo	Lo
A9_Equestrian	0.024044	0.295879	Lo	Med	Lo	Lo	Hi	Lo	Lo
A10_Fencing	0.024625	0.303028	Lo	Med	Lo	Med	Hi	Lo	Lo
A11_Field Hockey	0.026627	0.327670	Lo	Med	Lo	Lo	Hi	Med	Lo
A12_Football	0.053561	0.659122	Very high	Hi	Med	Hi	Hi	Hi	Hi
A13_Gymnastics	0.047840	0.588714	Very high	Very high	Hi	Hi	Hi	Med	Hi
A14_Handball	0.021194	0.260813	Med	Med	Lo	Lo	Lo	Med	Lo
A15_Judo	0.024049	0.295940	Med	Med	Lo	Med	Lo	Lo	Med
A16_Modern Penth	0.037247	0.458354	Very high	Hi	Med	Hi	Med	Hi	Lo
A17_Rowing	0.042079	0.517816	Hi	Med	Lo	Med	Med	Lo	Lo
A18_Sailing	0.038750	0.476859	Lo	Med	Lo	Med	Hi	Med	Lo
A19_Shooting	0.023009	0.283143	Lo	Med	Lo	Lo	Lo	Lo	Lo
A20_Swimming	0.046161	0.568055	Very high	Med	Lo	Hi	Med	Med	Hi
A21_Synchronized	0.030647	0.377137	Hi	Very high	Lo	Med	Med	Lo	Med
A22_Table Tennis	0.021839	0.268744	Lo	Med	Lo	Med	Lo	Lo	Med
A23_Taekwondo	0.024043	0.295868	Med	Med	Med	Med	Lo	Lo	Med
A24_Tennis	0.061200	0.753129	Very high	Hi	Lo	Hi	Hi	Hi	Hi
A25_Triathlon	0.045919	0.565074	Very high	Hi	Hi	Hi	Med	Hi	Lo
A26_Volleyball	0.037779	0.464908	Med	Med	Lo	Med	Med	Med	Hi
A27_Water Polo	0.028980	0.356624	Hi	Hi	Med	Med	Med	Med	Lo
A28_Weightlifting	0.032941	0.405365	Very high	Med	Hi	Hi	Lo	Lo	Lo
A29_Wrestling	0.029714	0.365658	Very high	Hi	Med	Med	Lo	Lo	Lo

Table 9(b)

Screen view of **r**ating module to weight the games (for the criteria 8-17)

cisions Ratings

	Priorities	Totals	32_Strenght of com 0.073581	33_Audiences' read 0.076012	41_Effects of daily 0.093591	42_Effects to the d 0.017005	52_Topographic pa 0.092124	51_Season or clima 0.080547	61_The sport comn 0.046377	53_Absence of poli 0.067333	62_Technology 0.067916	63_Political factors 0.029642
A1_Archery	0.019187	0.236120	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo
A2_Athletics	0.053145	0.653998	Hi	Med	Med	Hi	Med	Hi	Hi	Lo	Lo	Med
A3_Badminton	0.022586	0.277947	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo
A4_Basketball	0.045458	0.559407	Hi	Hi	Lo	Med	Lo	Lo	Hi	Lo	Lo	Lo
A5_Boxing	0.023097	0.284226	Med	Med	Lo	Med	Lo	Lo	Lo	Lo	Lo	Lo
A6_Canoeing	0.043378	0.533808	Med	Lo	Lo	Lo	Hi	Hi	Med	Lo	Hi	Lo
A7_Cycling	0.049236	0.605895	Med	Hi	Lo	Lo	Med	Hi	Hi	Med	Med	Lo
A8_Diving	0.021667	0.266627	Lo	Med	Lo	Med	Lo	Lo	Lo	Lo	Lo	Lo
A9_Equestrian	0.024044	0.295879	Med	Med	Lo	Lo	Lo	Med	Lo	Med	Lo	Lo
A10_Fencing	0.024625	0.303028	Lo	Lo	Lo	Lo	Lo	Lo	Hi	Lo	Lo	Lo
A11_Field Hockey	0.026627	0.327670	Lo	Lo	Lo	Lo	Med	Med	Lo	Med	Med	Lo
A12_Football	0.053561	0.659122	Hi	Hi	Med	Med	Lo	Med	Hi	Lo	Lo	Med
A13_Gymnastics	0.047840	0.588714	Hi	Med	Lo	Hi	Lo	Lo	Med	Lo	Hi	Lo
A14_Handball	0.021194	0.260813	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo
A15_Judo	0.024049	0.295940	Lo	Lo	Med	Med	Lo	Lo	Lo	Lo	Lo	Lo
A16_Modern Penth	0.037247	0.458354	Med	Lo	Med	Med	Lo	Lo	Lo	Lo	Lo	Lo
A17_Rowing	0.042079	0.517816	Lo	Lo	Lo	Med	Hi	Hi	Lo	Hi	Hi	Lo
A18_Sailing	0.038750	0.476859	Lo	Lo	Lo	Lo	Med	Hi	Hi	Med	Hi	Lo
A19_Shooting	0.023009	0.283143	Lo	Lo	Lo	Lo	Med	Med	Lo	Lo	Med	Lo
A20_Swimming	0.046161	0.568055	Hi	Hi	Med	Hi	Lo	Lo	Med	Lo	Lo	Hi
A21_Synchronized	0.030647	0.377137	Med	Med	Lo	Med	Lo	Lo	Lo	Lo	Lo	Med
A22_Table Tennis	0.021839	0.268744	Med	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo	Lo
A23_Taekwondo	0.024043	0.295868	Med	Med	Lo	Med	Lo	Lo	Lo	Lo	Lo	Lo
A24_Tennis	0.061200	0.753129	Hi	Hi	Hi	Hi	Lo	Med	Hi	Hi	Lo	Med
A25_Triathlon	0.045919	0.565074	Med	Lo	Med	Hi	Med	Hi	Med	Lo	Lo	Lo
A26_Volleyball	0.037779	0.464908	Very high	Hi	Lo	Med	Lo	Lo	Lo	Lo	Lo	Med
A27_Water Polo	0.028980	0.356624	Med	Lo	Lo	Med	Lo	Lo	Med	Lo	Lo	Lo
A28_Weightlifting	0.032941	0.405365	Med	Med	Med	Med	Lo	Lo	Med	Lo	Lo	Med
A29_Wrestling	0.029714	0.365658	Lo	Lo	Med	Med	Lo	Lo	Lo	Lo	Lo	Lo

Table 10 summarizes all the game priorities.

Table 10

2012 London Summer Olympic Games weights

Olympic game	**Weight**	**Olympic game**	**Weight**	**Olympic game**	**Weight**	**Olympic game**	**Weight**
Archery	0.019	Equestrian	0.024	Rowing	0.042	Triathlon	0.045
Athletics	0.053	Fencing	0.024	Sailing	0.038	Volleyball	0.038
Badminton	0.022	Field Hockey	0.027	Shooting	0.023	Water polo	0.029
Basketball	0.045	Football	0.054	Swimming	0.046	Weightlifting	0.032
Boxing	0.023	Gymnastics	0.048	Synchronized swimming	0.030	Wrestling	0.029
Canoe	0.043	Handball	0.021	Table tennis	0.021		
Cycling	0.049	Judo	0.024	Taekwondo	0.024		
Diving	0.021	Modern pentathlon	0.037	Tennis	0.061		

Tables 11 and 12 below present examples of category comparisons from the rating scale for the criteria "Energy spent" and "Physical characteristics", respectively.

Table 11
Category comparisons on the criteria "Energy spent"

Energy spent	High	Medium	Low	Priorities
High	1	2	3	0.5396
Medium	1/2	1	2	0.2970
Low	1/3	1/2	1	0.1634

Table 12
Category comparisons on the criteria "Physical characteristics"

Energy spent	Very high	High	Medium	Low	Priorities
Very high	1	2	4	6	0.4990
High	1/2	1	3	5	0.3129
Medium	1/4	1/3	1	2	0.1202
Low	1/6	1/5	1/2	1	0.0679

Table 13 presents the priorities of the events.

Table 13
2012 London Summer Olympic Events Priorities

Games	**Events**	**Event priorities**	**Games**	**Events**	**Event priorities**
Archery	Archery		Modern Pentathlon	Modern Pentathlon	0,011862
Athletics	Decathlon	0.014525	Rowing	Double Sculls	0,012572
	Heptathlon	0.013967		Eight	0.012273
	Jump	0.012536		Four	0.01159
	Marathon	0.016925		Lightweight Four	011405
	Pole Vault	0.012636		Pair	0,012273 0.012273
	Relay	0.009546		Quadruple Sculls	0,012273
	Shot Put	0.012382		Single Sculls	0,013401
	Throw	0.0091			
	Track	0.011834			
	Walk	0.010107			0,012572
Badminton		0.007193	Sailing	470	0.008177

				49 Er	0.009312
				Elliot	0.009312
				Finn	0.011755
				Laser	0.012341
				Rs-X	0.009312
				Star	0.009312
Basketball	Basketball	0.014477	Shooting	Pistol	0.007328
				Rifle	0.004107
				Rifle 25m	0.004107
				Rifle 50m	0.007328
				Skeet	0.007328
				Trap	0.007328
Boxing	Bantam	0.003306	Swimming	Backstroke	0.008692
	Fly	0.003919		Breaststroke	0.009397
	Heavy	0.004534		Butterfly	0.010527
	Light	0.003428		Freestyle	0.009397
	Light Fly	0.003638		Marathon	0.014701
	Light Heavy	0.00362		Medley	0.009397
	Light Welter	0.00362			
	Middle	0.004044			
	Super Heavy	0.007356			
	Welter	0.006076			
Canoeing	Slalom	0.013815	Synchronized Swimming	Synchronized Swimming	0,00976
	Sprint	0.011023			
Cycling	Bmx	0.013819	Table tennis	Table tennis	0.006955
	Mountain	0.01568			
	Road	0.010855			
	Track	0.01568			
Diving	Platform	0.0069	Taekwondo	49	0.004095
	Springboard	0.00481		57	0.004095
				58	0.004095
				67	0.006577
				68	0.007224
				80	0.007657
Equestrian	Dressage	0.004108	Tennis	Tennis	0,01949
	Eventing	0.007657			
	Jumping	0.005944			
Fencing	Epee	0.007842			
	Foil	0.006532			
	Sabre	0.004283	Triathlon	Triathlon	0,014624 0.014624

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Field Hockey	Field Hockey	0,00848	Volleyball	Beach	0.012032
				Indoor	0.010881
Football	Football	0,017058	Water Polo	Water Polo	0,009229
Gymnastic	Artistic	0.015236	Weightliftin g	48	0.00652
	Rhythmic	0.013007		53	0.00652
	Trampoline	0.01403		56	0.00652
				58	0.00652
				62	0.00652
				63	0.00652
				69	0.00652
				75	0.00652
				+75	0.006704
				77	0.006704
				85	0.006704
				94	0.009347
				105	0.010491
				105+	0,010491
Handball	Handball	0,00675	Wrestling	Freestyle	0.009463
				Greco-Roman	0.005714
				Greco-Roman 120	0.005714
				Greco-Roman 60	0.005994
				Greco-Roman84	0.008799
Judo	J1 48	0.005035			
	J2 52	0.005035			
	J3 57	0.005035			
	J4 60	0.005546			
	J5 63	0.005546			
	J6 66	0.006			
	J7 70	0.006287			
	J8 73	0.006287			
	J9 78	0.006287			
	J10 81	0.005777			
	J11 90	0.007659			
	J12 100	0.007659			
	J13 100+	0.007659			

4. How to obtain medal weights and their priorities for each event under different games

The relative values of gold, silver and bronze medals were studied in an earlier work as follows (Saaty, 2008). Thirteen sets of comparisons and their actual outcomes are shown in Tables 14-19. From the pairwise comparison judgments between different types of medals, one derives the priorities of different types of medals under 13 possible situations and then averages them to obtain the priorities of gold, silver and bronze medals.

In Table 14, a gold medal is very slightly favored over a silver medal and is not dependent on whether it is moderately or extremely favored over a bronze medal.

Table 14
Gold slightly over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	2	3	0.55
Silver	1/2	1	3/2	0.27
Bronze	1/3	2/3	1	0.18

	Gold	Silver	Bronze	Relative Values
Gold	1	2	9	0.61
Silver	1/2	1	5	0.32
Bronze	1/9	1/5	1	0.07

Table 15 shows that the gold medal is moderately favored over the silver medal and from very strongly to extremely over the bronze medal, and is noy dependent on whether a silver medal is moderately or strongly favored over a bronze medal.

Table 15
Gold moderately over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	3	7	0.64
Silver	1/3	1	3	0.26
Bronze	1/5	1/3	1	0.10

	Gold	Silver	Bronze	Relative Values
Gold	1	3	7	0.65
Silver	1/3	1	5	0.28
Bronze	1/7	1/5	1	0.07

	Gold	Silver	Bronze	Relative Values
Gold	1	3	9	0.67
Silver	1/3	1	3	0.27
Bronze	1/9	1/3	1	0.06

In Table 16, the strength of a gold medal over a silver medal increases even more to between moderately and strongly and a gold medal is favored nearly very strongly to extremely over a bronze medal, while a silver medal is only moderately favored over a bronze medal in both cases.

Table 16
Gold between moderately and strongly over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	4	6	0.69
Silver	1/4	1	3	0.22
Bronze	1/6	1/3	1	0.09

	Gold	Silver	Bronze	Relative Values
Gold	1	4	9	0.73
Silver	1/4	1	3	0.20
Bronze	1/9	1/3	1	0.07

In Table 17, a gold medal is strongly favored over a silver medal and very strongly to extremely favored over a bronze medal.

Table 17
Gold strongly over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	5	7	0.72
Silver	1/5	1	4	0.21
Bronze	1/7	1/4	1	0.07

	Gold	Silver	Bronze	Relative Values
Gold	1	5	9	0.74
Silver	1/5	1	4	0.19
Bronze	1/9	1/4	1	0.07

In Table 18, a gold medal is considered strongly more important than a silver medal and extremely more than a bronze medal while a silver medal is first moderately and then between moderately and strongly more important over a bronze medal.

Table 18
Gold very strongly over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	7	9	0.79
Silver	1/7	1	3	0.15
Bronze	1/9	1/3	1	0.06

	Gold	Silver	Bronze	Relative Values
Gold	1	7	9	0.78
Silver	1/7	1	4	0.16
Bronze	1/9	1/4	1	0.06

In Table 19, a gold medal is extremely important over a silver medal and a bronze medal while a silver medal is first strongly important and then extremely important than a bronze medal.

Table 19
Gold extremely over Silver

	Gold	Silver	Bronze	Relative Values
Gold	1	9	9	0.80
Silver	1/9	1	5	0.15
Bronze	1/9	1/5	1	0.05

	Gold	Silver	Bronze	Relative Values
Gold	1	9	9	0.78
Silver	1/9	1	9	0.18
Bronze	1/9	1/9	1	0.04

The tables given above give the priorities of different types of medals under 13 different situations shown in Tables 14-19, and then the priorities of different types of medals are

obtained by taking the geometric mean of the priorities derived from the judgment matrices above as seen in Table 20.

Table 20
The 13 vectors of priorities from Tables 10-15 and their average

														Total	GEO. MEAN
G*	0.55	0.61	0.64	0.65	0.67	0.69	0.73	0.72	0.74	0.79	0.78	0.80	0.78	9.15	0.6900
S	0.27	0.32	0.26	0.28	0.27	0.22	0.20	0.21	0.19	0.15	0.16	0.15	0.18	2.86	0.2000
B	0.18	0.07	0.10	0.07	0.06	0.09	0.07	0.07	0.07	0.06	0.06	0.05	0.04	0.99	0.0060

*G: Gold, S: Silver, B: Bronz

Now we re-rank the countries that won medals in the 2012 London Summer Olympics according to a our method which considers not only the total medals won but also the weighted priority of each game and event under each game. The rank of the countries when simply counting medals won is shown in the sixth column of Table 21. Following the traditional way of counting the total number of medals won, the USA is the top ranked country followed by China and Russia. However, the ranking of the countries that won medals in the 2012 London Summer Olympics (shown in the last column of Table 21) is different when based on our finer approach. For example, the Ukraine won 20 medals in boxing, canoeing, fencing, gymnastic, rowing, shooting, weighlifting and wrestling. This includes 6 gold medals 5 silver medals, and 9 bronze medals. When counting the total number of medals won, the Ukraine is ranked 10^{th} place (if we use the total number of gold medals as a second criterion for the countries when the total number of medals are the same, then Ukraine ranked as 12th place in the current methodology, South Korea is 9^{th}, Italy is 10^{th}, Netherland is 11^{th} and Ukraine is 12^{th}), but when considering the priorities of the events and the games by proposed methodology the Ukraine's rank moves to 15^{th} place. This is because gymnastics is one of the important games considered in this research, and the Ukraine won a bronze medal in gymnastics. On the other hand, they won 5 medals in boxing and 2 medals in fencing events which have relatively lower priorities. Another example is Latvia which won only two medals, one in cycling (gold) and the other in beach volleyball (bronze). When considering the number of medals won, Latvia is one of the lowest ranked countries by current ranking system. As we explained above in the Ukraine example, the countries that have an equal number of medals are ranked as the same. Latvia, Bulgaria, Indonesia, Dominican Republic and so on are ranked 25^{th} by the current ranking. However, although Latvia is ranked 25^{th}, it is actually 57^{th} if we use the number of gold medals as the second criterion (when we just count the countries above Latvia in the current order, Latvia is 57^{th} not 25^{th}). When we look at it like this, we can more easily interpret the difference from the proposed rank and say that Latvia deserves a better rank even though it has just two medals because the priorities of those games are high. Our methodology ranked Latvia 42^{th} because the priorities of the events in which Latvia won medals are relatively high. A similar example is Tunisia which won only three medals. These medals were won in the marathon, track and swimming, all events with higher priorities as compared to other games.

Table 21
2012 London Olympics medals current and proposed ranking comparisons

Current Methodology						Proposed Methodology	
Country	Gold	Silver	Bronze	Total Medal Count	Current Ranking	Total Priority Score	Proposed Ranking
USA	**46**	**29**	**29**	**104**	**1**	**0.4348**	**1**
China	38	27	23	88	2	0.2515	3
Russian	24	25	32	81	3	0.2237	4
Great Britain	29	17	19	65	4	0.2868	2
Germany	**11**	**19**	**14**	**44**	**5**	**0.1288**	**5**
Japan	7	14	17	38	6	0.0756	8
Australia	**7**	**16**	**12**	**35**	**7**	0.0899	**7**
France	11	11	12	34	8	0.1248	6
South Korea	**13**	**8**	**7**	**28**	**9**	**0.0710**	**9**
Italy	8	9	11	28	9	0.0686	11
Netherlands	6	6	8	20	10	0.0502	13
Ukraine	6	5	9	20	10	0.0404	15
Hungary	8	4	6	18	11	0.0687	10
Canada	1	5	12	18	11	0.0356	20
Spain	3	10	4	17	12	0.0402	16
Brazil	3	5	9	17	12	0.0256	27
Cuba	5	3	7	15	13	0.0258	26
Kazakhstan	7	1	5	13	14	0.0396	17
New Zeland	6	2	5	13	14	0.0536	12
Belarus	2	5	5	12	15	0.0384	18
Iran	4	5	3	12	15	0.0300	23
Jamaica	4	4	4	12	15	0.0450	14
Kenya	2	4	5	11	16	0.0345	21
Czech Republic	4	3	3	10	17	0.0278	24
Azerbaijan	2	2	6	10	17	0.0202	32
Poland	2	2	6	10	17	0.0209	31
Romania	2	5	2	9	18	0.0238	29
Denmark	2	4	3	9	18	0.0358	19

Colombia	1	3	4	8	19	0.0190	34
Sweden	1	4	3	8	19	0.0190	34
Ethiopia	3	1	3	7	20	0.0343	22
Mexico	1	3	3	7	20	0.0177	37
Georgia	1	3	3	7	20	0.0074	50
North Korea	4	0	2	6	21	0.0195	33
Croatia	3	1	2	6	21	0.0215	30
South Africa	3	2	1	6	21	0.0275	25
India	0	2	4	6	21	0.0146	40
Mongolia	0	2	3	5	22	0.0043	56
Turkey	2	2	1	5	22	0.0163	38
Lithuania	2	1	2	5	22	0.0094	45
Ireland	1	1	3	5	22	0.0040	57
Trinidad And Tobago	1	0	3	4	23	0.0095	44
Switzerland	2	2	0	4	23	0.0189	35
Norway	2	1	1	4	23	0.0186	36
Slovenia	1	1	2	4	23	0.0048	59
Argentina	1	1	2	4	23	0.0098	43
Serbia	1	1	2	4	23	0.0063	53
Malaysia	0	1	3	4	23	0.0021	64
Finland	0	1	2	3	24	0.0037	58
Tunisia	**1**	**1**	**1**	**3**	**24**	**0.0254**	**28**
Uzbekistan	1	0	2	3	24	0.0085	47
Armenia	0	1	2	3	24	0.0160	39
Belgium	0	1	2	3	24	0.0087	47
Thailand	0	2	1	3	24	0.0024	63
Indonesia	0	1	1	2	25	0.0020	65
Dominic Republic	1	1	0	2	25	0.0083	48
Latvia	1	0	1	2	25	0.0109	42
Chinese Tapei	0	1	1	2	25	0.0004	73
Estonia	0	1	1	2	25	0.0027	61
Puerto Rico	0	1	1	2	25	0.0031	60
Bulgaria	0	1	1	2	25	0.0068	51

Egypt	0	2	0	2	25	0.0025	62
Moldova	0	0	2	2	25	0.0016	67
Qatar	0	0	2	2	25	0.0020	64
Greece	0	0	2	2	25	0.0019	66
Singapore	0	0	2	2	25	0.0014	69
Algeria	1	0	0	1	26	0.0083	47
Bahamas	1	0	0	1	26	0.00668	52
Botswana	0	1	0	1	26	0.0024	63
Guatemala	0	1	0	1	26	0.0020	65
Grenada	1	0	0	1	26	0.0083	49
Uganda	1	0	0	1	26	0.0118	41
Slovakia	0	1	0	1	26	0.0050	55
Montenegro	0	1	0	1	26	0.0014	69
Venezuela	1	0	0	1	26	0.0055	54
Bahrain	0	0	1	1	26	0.0090	46
Gabon	0	1	0	1	26	0.0015	68
Morocco	0	0	1	1	26	0.0012	70
Portugal	0	1	0	1	26	0.0022	64
Tajikistan	0	0	1	1	26	0.0003	74
Cyprus	0	1	0	1	26	0.0025	62
Afghanistan	0	0	1	1	26	0.0007	71
Hong Kong	0	0	1	1	26	0.0016	67
Saudi Arabia	0	0	1	1	26	0.0006	72
Kuwait	0	0	1	1	26	0.0007	71

* The rows in bold show that the rank of a country obtained by the proposed method is the same as its current rank

5. Conclusion

Training for competition in the Olympics requires time and resources with different types of events having different characteristics. Individual games require more concentration while team games require more cooperation. To become successful in gymnastics, one usually has to start training at a very young age (five or six). The duration of a volleyball game is usually about one to two hours, and the marathon takes about two hours and requires more energy when compared to other events. On the other hand, archery takes only a few seconds. Thus, a medal should be given a different value depending on which game it is won for. We propose that ranking countries in the Olympics should not only be decided by counting the total medals won, but also by the type of game in which the medal was won. In this study we prioritized different games and the events under each

game. Our elaborate approach to the Olympics shows that counting the total numbers of medals won is not a bad way of ranking countries. Finally, while it is known that multi-criteria decision making is very important in optimal allocation of limited resources, it may not always produce radically better results than much simpler existing ways of ranking. For the last winter Olympics (2014) in Sochi, Russia, there were more noticeable differences in the two rankings methods so that Norway which ranked third according to the number of medals won, actually ranked first according to prioritization of the different kinds of games. This is a significant finding because ranking first would have been a very distinguished and celebrated outcome for Norway. We also performed Compatibility Index calculations to compare actual ranking and the estimated one as shown in Appendix. Since the ranks are slightly different, the index is obtained was 1,22 which could be acceptable and reasonable.

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APPENDIX

COMPATIBILITY INDEX ANALYSIS

Pairwise Comparison Matrix from Actual Data

	A1	A2	A3	A4	A5	A6	A7	A8
A1	1	1,14433	1,32934	1,59712	2,00000	2,67470	3,96429	7,92857
A2	0,8738739	1,00000	1,16168	1,39568	1,74775	2,33735	3,46429	6,92857
A3	0,7522523	0,86082	1,00000	1,20144	1,504504505	2,01205	2,98214	5,96429
A4	0,6261261	0,71649	0,83234	1	1,25225	1,67470	2,48214	4,96429
A5	0,5	0,57216	0,66467	0,79856	1	1,33735	1,98214	3,96429
A6	0,3738739	0,42784	0,49701	0,59712	0,747747748	1	1,48214	2,96429
A7	0,2522523	0,28866	0,33533	0,40288	0,504504505	0,674699	1	2,00000
A8	0,1261261	0,14433	0,16766	0,20144	0,252252252	0,337349	0,5	1

Pairwise Comparison Matrix from Estimated Data

	A1	A2	A3	A4	A5	A6	A7	A8
A1	1	1,743141	1,959768	1,528591	3,403727	5,798942	4,876529	3,512821
A2	0,573677	1,00000	1,12427	0,87692	1,95264	3,32672	2,79755	2,01522
A3	0,510265	0,88946	1,00000	0,77999	1,736801	2,95899	2,48832	1,79247
A4	0,654197	1,14036	1,28207	1	2,22671	3,79365	3,19021	2,29808
A5	0,293796	0,51213	0,57577	0,44909	1	1,70370	1,43270	1,03205
A6	0,172445	0,30060	0,33795	0,26360	0,265569	1	0,84093	0,60577
A7	0,205064	0,35746	0,40188	0,31346	0,697981	1,189153	1	0,72035
A8	0,284672	0,49622	0,55789	0,43515	0,968944	1,650794	1,388209	1

Transpose of Comparison Matrix from Estimated Data

	A1	A2	A3	A4	A5	A6	A7	A8
A1	1	0,573677	0,510264599	0,654197	0,29379562	0,172445	0,20506387	0,284672
A2	1,7431412	1,00000	0,88946	1,14036	0,51213	0,30060	0,35746	0,49622
A3	1,9597675	1,12427	1,00000	1,28207	0,57577	0,33795	0,40188	0,55789
A4	1,5285914	0,87692	0,77999	1	0,44909	0,26360	0,31346	0,43515
A5	3,4037267	1,95264	1,736801242	2,22671	1	0,265569	0,69798137	0,968944
A6	5,7989418	3,32672	2,95899	3,79365	1,70370	1	1,18915344	1,650794
A7	4,8765295	2,79755	2,48832	3,19021	1,43270	0,84093	1	1,388209
A8	3,5128205	2,01522	1,79247	2,29808	1,03205	0,60577	0,72035	1

Result of Hadamard (Cell-wise) Multiplication of Previous Two Matrices

	A1	A2	A3	A4	A5	A6	A7	A8
A1	1	0,6564758	0,678315814	1,044833	0,587591241	0,461239	0,81293176	2,257039
A2	1,52329	1	1,03327	1,59158	0,89507	0,70260	1,23833	3,43811
A3	1,47424	0,96780	1	1,540334	0,86625	0,67998	1,19846	3,32742
A4	0,95709	0,62831	0,649209948	1	0,56238	0,44145	0,77805	2,16019
A5	1,70186	1,11723	1,154400826	1,778163	1	0,35516	1,38350	3,84117
A6	2,16807	1,42329	1,47064	2,26527	1,27394	1	1,76250	4,89342
A7	1,23012	0,80754	0,83441	1,28527	0,72281	0,56738	1	2,77642
A8	0,44306	0,29086	0,30053	0,46292	0,26034	0,20436	0,36018	1

TOTAL	10,49773	6,89150	7,12077	10,96837	6,16837	4,41215	8,53394	23,69377

Cell sum of previous matrix =			78,286		Number of Alternatives (n) =	8
					Saaty Compatibility Index = Sum/n^2	**1,22**