Athens Journal of Sports

Quarterly Academic Periodical,
Volume 10, Issue 4, December 2023
URL: https://www.athensjournals.gr/ajspo
Email: journals@atiner.gr
e-ISSN: 2241-7915 DOI: 10.30958/ajspo

Front Pages

Athens Journal of Sports

Published by the Athens Institute for Education and Research (ATINER)

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The ***Athens Journal of Sports (AJSPO)*** is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of sports and related sciences. Many of the papers published in this journal have been presented at the various conferences sponsored by the Sport, Exercise, & Kinesiology Unit of the **Athens Institute for Education and Research (ATINER)** & the Panhellenic Association of Sports Economists and Managers (PASEM). All papers are subject to ATINER's Publication Ethical Policy and Statement.

The Athens Journal of Sports

ISSN NUMBER: 2241-7915 - DOI: 10.30958/ajspo
Volume 10, Issue 4, December 2023
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The current issue is the fourth of the tenth volume of the *Athens Journal of Sports,* published by the Sport, Exercise, & Kinesiology Unit of the ATINER under the aegis of the Panhellenic Association of Sports Economists and Managers (PASEM).

Gregory T. Papanikos, President, ATINER.

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Important Dates

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Dr. Maria Konstantaki, Academic Member, ATINER & Senior Lecturer, Buckinghamshire New University, UK.

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Athens Journal of Sports - Volume 10, Issue 4, December 2023 – Pages 205-214

Evaluation and Discussion of Post-COVID Higher-rated Women's Teams Winning More Often and Men's Teams Less Often in World Championships

By Raymond Stefani[*]

A pre-COVID 2007-2019 data base was gathered to study all team sports that had international recognition, had an official rating system published by the governing federation and had a world championship (WC). The data base included 40 WCs for the 13 men's team sports, 35 WCs for the 12 women's team sports and a total of 3936 games in which the percentage of games won by each higher-rated team was tabulated. The higher-rated women's teams won only 0.25% more than the men's teams. Post-COVID, nine WCs were contested during 2021and 2022, along with one in 2023, using the same rating system as pre-COVID: four for men and five for women. In all four of the men's WCs, the percentage of games won by the higher-rated team was lower post-COVID: curling (-6.1%), rugby 7s (-12.9%) and T20 cricket (-10.9% and -6.9%). However, the women's higher-rated teams had higher percentages of games won in all five WCs post-COVID: curling (+7.3%), rugby 7s (+6.2%), T20 cricket (+7.0%), basketball (+5.0%) and rugby union (+0.4%). During the COVID-era restrictions, women's social cohesiveness drove increased team cohesiveness creating increased cooperative learning and execution of tactical skills, whereas men emerged with less team cohesiveness.

Keywords: *sports predictions, gender differences, team cohesiveness, post-COVID changes*

Introduction

International sports competition suffered severe disruptions in 2020 due to the COVID-19 epidemic. The number of international cancellations, delays in competition and restrictions on training were reminiscent of the devastating effects of World War 2 and of the Cold War. That analogy is highly appropriate since a war was being waged, in that case upon a disease. The goal of this paper is to build upon a sizeable, previously created, data base of sports, rating systems and predictive evaluations to choose appropriate post-COVID results that permit a relative evaluation of how women and men performed post-COVID compared to pre-COVID and to then to discuss the differences.

Stefani (2011) covered significant sports and their rating systems, beginning with an objective selection of significant world sports as recognized internationally. One recognition source was the International Olympic Committee (IOC) which lists sports for inclusion in the summer and winter Olympics in IOC (2023a), with a link to IOC-recognized sports that are thereby eligible for future Olympics in IOC (2023b). Sport Accord, also called the General Association of International

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Sports Federations (GAISF), was a second source of recognized sports. Sport Accord recognized all the IOC sports and several others for which it formerly organized world competition. Sport Accord disbanded in late 2022; but fortunately, its formerly-recognized sports are included in Stefani (2011) and are also included in Wikipedia (2023), along with IOC sports and several others. Wikipedia (2023) also includes handicapped sports which are not included herein. Finally, Stefani (2011) included other sports listed in that Wikipedia link for other widely played international sports.

Stefani (2011) included official rating systems published by the international federations of the recognized sports. In that way, each rating system as published was created to enhance each sport and with full agreement with all stakeholders in each sport.

Stefani (2011) discussed the sports and their rating systems. Since the IOC recognizes the federations that organise chess and bridge, by definition, those federations become sports federations and chess and bridge become sports, requiring a new terminology, mind sports. In combat sports such as wrestling and boxing, one person tries to physically overcome the other and where winning and rating systems are subjective. At the opposite extreme are independent sports such as running and swimming where athletes are not to impede the other. Ratings are usually based on the best yearly performances.

The remaining sports involve contesting for an object such as in baseball, rugby and basketball. There are two types of objective team rating systems, accumulative and adjustive. In an accumulative system

$$\text{Rating} = \Sigma\, f_i\,(\text{results, importance, ageing}) \qquad (1)$$

Each f_i is ≥ 0 so the result is a non-deceasing accumulated running sum over the time period in years of each accumulative system. The points depend on the final position in a competition, the importance of that competition and how long ago each competition happened. The points generally do not depend game-by-game on each opponent competed against.

In contrast, an adjustive rating system, as the name implies, adjusts after each game as follows:

$$\text{New Rating} = \text{Old Rating} + K\,(\text{Actual} - \text{Expected}) \qquad (2)$$

A rating can adjust depending on factors such as home advantage, opponent rating, rating difference, score difference and match importance. Clearly an adjustive system is sensitive to much more information than is an accumulative system and it adjusts more strongly due to recent results than for an accumulative system.

The remaining sections of this paper cover the pre-COVID work on predictive accuracy as summarized in Stefani (2023), the corresponding selection of sports for which to compare post-COVID values with pre-COVID values and a discussion of those results.

Pre-COVID Sports Predictability

Having created the list of significant world sports and the list of official sports federation rating systems in Stefani (2011), attention turned to understanding the predictive accuracy of the rating systems, defined as the fraction of games won by the higher rated team, excluding draws, so that sports like soccer football that have many draws would not immediately have lower predictability compared to sports without draws. Before 2020, the year when the COVID-19 epidemic had its major effect, the data base included 173 recognized international sports. The IOC recognized 128 sports: 47 in the summer Olympics, 15 in the winter Olympics and another 66 significant world sports that could achieve Olympic status. Sport Accord recognized another 19 sports and 26 more widely played sports were found in the then version of the link in Wikipedia (2023). Of those 173 sports, 113 sports federations published an official rating.

Different types of sports categories would need to be evaluated separately, which was beyond the scope of the study. The four non-physical mind sports were not evaluated. The 10 subjectively scored and subjectively rated combat sports were not considered because the other rating systems were objective. The 60 independent sports like swimming and running were not used, because otherwise, rank-ordered competition would have to be compared to rank-ordered ratings, which could not easily be compared to the percentage of higher-rated teams winning games. There remained 39 sports involving the use of an object, such as tennis, badminton, basketball, and rugby. Of them, sports like tennis and badminton were predominantly individual sports while cooperative team activity was involved in basketball and rugby. The 21 non-cooperative team sports were eliminated leaving 18 cooperative team spots. Of those 18, 5 had no world championship, leaving 13 sports. Cricket was then counted twice, due to having both ODI and T20 world championships, creating Table 1, a 14-sport table of world championships: 11 contested by men and women, 2 by men only and one by women only, resulting is 13 world championships for men and 12 for women.

Table 2 shows that 75 world championships were evaluated pre-COVID, using 3936 games. The championships were mostly contested from 2007 to 2019 with one contested in 2020 before major COVID-19 shutdowns. The percentages of wins by the higher-rated teams were separately calculated for the group phase, the knockout phase and overall. In the group phase, teams play each other in a group with the higher performing teams moving to the knockout phase where each loss usually eliminates the loser until the top four positions were determined. Some world championships allow defeated teams to move on to establish classifications other than just first through fourth.

Table 1. *14 Team Sports, 13 Contested by Men and 12 by Women, with 15 Sport-Rating Combinations Due to Soccer*

Men and Women (11)	Men Only (2)	Women Only (1)
Basketball	Cricket (ODI)	Netball
Cricket (T20)	Rugby League	
Curling		
Field Hockey		
Football (Soccer) (Two Rating Systems)		
Handball		
Ice Hockey		
Rugby 7s		
Rugby Union		
Volleyball		
Water Polo		

Table 2. *Database for the14 Pre-COVID Team Sports in Table 1 (2007 to 2019 plus 1 in 2020)*

Gender	Sports	Competitions	Games
Men	13	40	2245
Women	12	35	1691
Total	25	75	3936

To simplify the presentation of predictabilities, Table 3 shows the overall predictability with men and women's predictabilities combined where possible as per Table 1, creating 15 sport-rating combinations. Six sports used adjustive ratings while the other 9 used accumulative ratings. The highest 6 predictabilities are separated to emphasize the accuracy of adjustive rating systems. Five of the highest 6 are for adjustive ratings and 8 of the lowest 9 are for accumulative ratings. Only one accumulative-rated sport scored in the highest 6, water polo. Only one adjustive-rated sport scored in the lowest 9, men's football.

Table 3. *Predictability of the 15 Sport-Rating Combinations from Table 1*

Position	Sport (M/W)	WCs	Rating System	Predictability (%)
1	Netball (W)	6	Adj	87.4
2	Rugby Union (M,W)	4,2	Adj	85.8
3	Football (W)	4	Adj	81.5
4	Water Polo (M,W)	2,2	Acc	80.6
5	Cricket (ODI) (M)	4	Adj	79.6
6	Cricket T20 (M,W)	2,1	Adj	78.2
7	Rugby 7s (M,W)	2,2	Acc	75.8
8	Volleyball (M,W)	3,3	Acc	75.0
9	Basketball (M,W)	3,2	Acc	74.7
10	Field Hockey (M,W)	3,3	Acc	73.2
11	Ice Hockey (M,W)	5,5	Acc	73,2
12	Handball (M,W)	3,2	Acc	72.5
13	Rugby League (M)	3	Acc	72.2
14	Football (M)	3	Adj	72.0
15	Curling (M,W)	3,3	Acc	66.9

A regression analysis was performed using the 75 world championship predictabilities as the dependent variable while using 8 independent variables, each identified by 1 indicating presence and 0 indicating absence, causing each regression coefficient to be expressed as a percentage increase (plus) or decrease (negative) to the intercept value. The intercept value was 79.3%. Positive coefficients were observed for women (only 0.25%, so little gender difference was observed pre-COVID), for sports with 7 or less athletes (2.6%), for invasion sports (3.5%) and for substitutes returning (5.4%). Negative coefficients were observed for using an accumulative rating system (-10.9%), for space-restricted indoor and pool sports (-3.4%), and for sports with goalkeepers (-3.9%). When the knockout phase included classification matches for teams who would normally have been eliminated, the group phase coefficient was +4.7% while the knockout phase value was -3.0%. Organizers thus get more consistent play out of all teams trying to move toward higher classification possibilities while in the group phase and closer pairings in the knockout phase leading to less predictable outcomes than with the usual deletion of losing teams.

The information above provides guidance for selecting post-COVID competitions for meaningful comparisons to pre-COVID predictabilities. We know that the adjustive rating systems are much more accurate than the accumulative systems and that small differences in predictability exist for various sports due to competitive conditions. To make meaningful post-COVID comparisons for each gender, the comparisons must be made for the same sport with the same rating system as used pre-COVID. During the COVID period of 2020, some sports changed rating systems and thus cannot be used post-COVID. The two sports in Table 1 that were for men only introduced women's competition, but no pre-COVID values exist. The resulting nine comparisons are now discussed.

Post-COVID versus Pre-COVID Comparisons

Table 4 contains the 9 post-COVID versus pre-COVID comparisons, selected as per the pre-COVID analyses. World championships are included for 2021, 2022 and one that was early enough in 2023 to still have been affected by COVID era disruptions. Five comparisons are for women and four are for men. Three competitions were delayed for one year. For example, the notation 2021/22 means that competition was delayed from 2021 until 2022.

Table 4. *Post-COVID versus Pre-COVID Percentage of Wins by Higher-Rated Teams (Years are Shown for Accumulative Systems)*

Sport	**Rating System**	**Pre-COVD**			**Post-COVID**			**Change (%)**	
		Years	G	%	Year	G	%	M	W
Curling (M)	Acc(6)	3	214	71.0	2021	97	64.9	-6.1	
Curling (W)	Acc(6)	3	215	62.8	2021	97	70.1		+7.3
Rugby 7s (M)	Acc(1)	2	108	76.4	2022	52	63.5	-12.9	
Rugby 7s (W)	Acc(1)	2	74	75.0	2022	32	81.2		+6.2
Cricket T20 (M)	Adj	2	69	77.6	2020/21	45	66.7	-10.9	
Cricket T20 (M)	Adj	2	69	77.6	2021/22	45	70.7	-6.9	
Cricket T20 (W)	Adj	1	23	80.0	2023	23	87.0		+7.0
Basketball (W)	Acc(8)	2	80	75.0	2022	40	80.0		+5.0
Rugby Union (W)	Adj	2	60	88.1	2021/22	26	88.5		+0.4

Two of the five sports, curling and cricket, require careful tactical decision making followed by skillful action. The other three sports, rugby 7s, basketball and rugby union, are invasion sports requiring instant reactions and strong physical interactions among the players. That is a meaningful breadth of coverage.

For pre-COVID curling, higher-seeded men were 8.2% more predictable than women, but post-COVID men become 6.1% less predictable while women became 7.3% more predictable. For rugby 7s, higher-seeded men were only slightly ahead of women by 1.4% pre-COVID, but lost 12.9% of their predictability post-COVID while women gained 6.2%.

T20 cricket provides three comparisons, two for men and one for women. Pre-COVID women were the more predictable by 2.4%. Men were 10.9% less predictable in their first post-COVID competition, followed by being 6.9% less predictive in their second post-COVID WC, a movement of 4% towards their pre-COVID value. It will be interesting to see if later world championships will show similar movement towards pre-COVID values for the other competitions. Women gained 7.0% post-COVID.

The last two comparisons are for basketball where women gained 5.0% and for rugby union where women gained 0.4%. While 0.4% is much less than their other gains, the pre-COVID predictability was 88.1%, the highest among the 13 men's sports and 12 women's sports. The fact that women could increase predictability at all while approaching 90% is noteworthy.

In summary, higher-seeded men's teams lost predictiveness in all four of their post-COVID competitions while women gained in all five of theirs. The sports are varied and the pre-COVID male-female differences are also varied, providing a wide context for the female-male differential results. In the next section we seek to

understand what differences in activities by the men and women during the war on COVID are consistent with the results.

Discussion

During 2020 when COVID-19 was rampant, athletes were deprived of practice time and of full team activity. We examine the literature regarding effective training to maintain physical and tactical skills while having to train in smaller numbers. It is particularly important to identify methodologies that would be consistent with the differential post-COVID percentage of wins earned by higher-seeded men's and women's teams.

In rugby union, training for defense and for tackling can be attained by small groups of players who work on head position and proper tackle leg drive, depending on playing situation (Sewry et al. 2015). A study with youth rugby league players showed that technical skills may be improved by modifying the number of players experiencing various game situations (Morley at al. 2016). In that methodology, small numbers of players can gain skills that will aid them when full playing conditions return.

For rugby league, training for explosiveness on contact and leg drive on contact can increase tackling effectiveness (Tierney et al. 2018). That training can be achieved with small numbers of players. Elite female netball and volleyball players improved their vertical jump clearances by improving their force-velocity profiles while executing loaded and unloaded counter-movement jumps (Petridis at al. 2021). Although that training was intended for netball and volleyball, the same training could aid various required movements in other team sports.

When youth academy soccer players engaged in small-sided games, their faster-than-normal activity mimicked the faster pace shown by older, professional players (da Costa and Silvino 2023). When professional players had to follow an online training regimen during severe COVID-19 restrictions, they maintained their previous physical testing levels (Anderson et al. 2023).

Although the above studies show that physical strength and individual skill can be retained and even enhanced by women and men training in the smaller groups that would have been seen during COVID-19 restrictions, these drills would not retain the same level of coordinated team performances that higher-rated teams had acquired pre-COVID. Higher-rated women's and men's teams would both be expected to lose more games post-COVID, which is not consistent with Table 4. Instead of physical training, we now examine psychological effects.

Comprehensive questionnaires were given to 400 young soccer players of various ages. Their indicated psychological attributes were compared with their sports abilities. Those athletes that indicated that they possessed personal integrity such as honesty and responsibility also demonstrated social cohesion which linked to what was called task cohesion, meaning team cohesion in this case (Berengui et al. 2022). It was expected that team cohesion would continue as athletes aged and continued to take part in sports. For elite college athletes in basketball and soccer,

increased team cohesion was found to correlate with increased team success, (Carron et al. 2002).

Eyes and Kim (2017) reviewed 30 years of research which dealt with various aspects of cohesiveness, the underlying psychological attributes, and the effects on team performance. In soccer, netball and other sports studied, it was shown that increased team cohesiveness linked with greater team success. The authors formed a panel of 22 coaches each of whom had extensive experience coaching both men and women in various countries and sports. The coaches believed that cohesiveness was more important to women than to men. They also agreed from their experiences, that while it was true that there is a link between team cohesiveness and team success, that relationship was different for women and men. Their opinion was that for women, increased team cohesiveness drove greater team success, while for men, increased team success drove greater team cohesiveness. That observation is consistent with the results in Table 4.

Consistent with the studies above, the onset of many COVID-induced disruptions to their sports would have caused women to be increasingly sensitive to the turmoil of their teammates. Their sense of responsibility and friendship would have moved them to greater levels of social cohesiveness, leading to greater team cohesiveness as condition got worse. That increased team cohesiveness would improve the team's level of play, especially for higher-rated teams. That scenario is consistent with the increased post-COVID fraction of games won by higher-rated women's team in all five of their sports in Table 4. According to the coaches' experiences, the COVID-induced compromised quality of team play would likely have reduced men's team cohesiveness, consistent with post-COVID higher-rated men's teams winning less often in all four of their sports in Table 4.

Conclusions

The higher-rated women's teams in all five of the carefully-chosen and widely-variable post-COVID sports won more games than pre-COVID, likely due to greater team cohesiveness than pre-COVID while higher-rated men's teams won less often in all four of their sports, likely due to reduced team cohesiveness enhancing the detrimental restrictions imposed by anti-COVID activities. These conclusions suggest that coaches in team sports should not only train athletes to develop physical strength and tactical skill, they ought also to create social cohesiveness. An associated increase in team cohesiveness can improve team play, while it can also improve the enjoyment of the players in competition, out of competition and as they look back on their sports experiences in the years to come.

References

Anderson L, Flannigan C, Polychronopoulos P, MacKenzie R, Drust B, Milso J (2023) Lessons from the COVID-19 pandemic: insights into effective training strategies for physical development in football. *International Journal of Sports Science & Coaching* 18(2): 402–413.

Berengui R, Carralero R, Castejon M, Campos-Salinas J, Canton E (2022) Values, motivational orientation and team cohesion amongst youth soccer players. *International Journal of Sports Science & Coaching* 17(5): 1049–1058.

Carron B, Bray S, Eys M (2002) Team cohesion and team success in sport. *Journal of Sports Sciences* 20(2).

Da Costa I, Silvino M (2023) Analysis of tactical behavior in full- and small-sided games: Comparing professional and youth academy athletes to enhance player development in soccer. *International Journal of Sports Science & Coaching* 18(1): 132–142.

Eyes M, Kim J (2017) *Team building and group cohesion in the context of sport and performance psychology*. Oxford Research Encyclopedia of Psychology.

IOC (2023a) *International sports federations*. Available at: https://olympics.com/ioc/international-federations.

IOC (2023b) *Recognized federations*. Available at: https://olympics.com/ioc/recognised-international-federations.

Morley D, Oglivie P, Till K, Rothwell M, Cotton W, O'Connor D, et al. (2016) Does modifying competition affect the frequency of technical skills in junior rugby league? *International Journal of Sports Science & Coaching* 11(6): 810–818.

Petridis L, Palinkas G, Troznai Z, Beres B, Utczas K (2021) Determining strength training needs using force-velocity profile of elite female handball and volleyball players. *International Journal of Sports Science & Coaching* 16(1): 123–130.

Sewry N, Lambert M, Roode B, Mathews B, Hendricks S (2015) The relationship between playing situation, defence and tackle technique in rugby union. *International Journal of Sports Science & Coaching* 10(6): 1115–1127.

Stefani R (2011) The methodology of officially recognized international sports federations. *Journal of Quantitative Analysis in Sports* 7(4): Article 10.

Stefani R (2023) Chapter 12: Rating systems and other determinants for the predictability of world team championships. *Statistics Meets Sports, Cambridge Scholars Publishing* ISBN(10): 1-5275-9273-1.

Tierney G, Denvir K, Farrell G, Simms C (2018) The effect of technique on tackle gainline outcomes in elite rugby union. *International Journal of Sports Science & Coaching* 13(1): 16–25.

Wikipedia (2023) *List of international sports federations*. Available at: http://en.Wikipedia.org/wiki/List_of_international_sport_federations.

Athens Journal of Sports - Volume 10, Issue 4, December 2023 – Pages 215-234

A Mathematical Analysis of Team Impact and Individual Player Contribution in Football

By Jeffrey Leela[*], Donna M. G. Comissiong[±] & Karim Rahaman[°]

In this paper, we present an important application of the Hungarian Method - a well-known combinatorial optimization tool for solving assignment problems. For our purposes, we consider the assignment of players to specific roles in a football team. It involves the broad classification of team players as defensive, midfield or attacking, while assigning the main roles associated with each of these positions. This provides insight on specific role of each individual player, thereby facilitating an optimal team selection. To illustrate this method, we utilize the average player statistics per game for two teams from the 2016/2017 Premier League Season. In addition, a team rating index is created by identifying six sub-indices. The first is called team contributions - which includes set piece goals, percentage tackles won, percentage take-ons won, percentage aerial duels won, number of interceptions, number of blocked shots, number of clearances, number of red and yellow cards. To visualize the method, a multiple correlation is carried out on team data for the 2016/2017 Premier League season to generate a correlation coefficient for each contribution. The resulting team index can be a useful tool for measuring the overall strengths of competing teams in a football league.

Keywords: *Hungarian method, football, team rating index, multiple correlations, team comparisons*

Introduction

It is a well-known fact that the most successful teams are the ones that are best balanced, not necessarily those comprised of the best collection of available players. Nevertheless, each player's individual contribution is vital for the overall team performance, and coaches are continually seeking the most effective techniques for identifying the most outstanding players. Modern-day football scouts can make use of data-driven analysis techniques to assess any player's potential based on the available performance metrics. After recruiting the players with the best ratings, it is then up to the coaching staff to conduct appropriate training sessions to get the players to work together, harnessing each individual player's strengths to optimize overall team performance.

One of the most important tasks of a football coach is team selection, according to the match being played, and after careful consideration of the

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opposing team's strengths and weaknesses. While is not necessarily true that a collection of players with the best individual performance ratings would be the optimal choice for the selected team, once these players have trained together and have a well-defined game plan, it is not unreasonable to expect a favourable match outcome. The difficulty lies with the process of team selection when the available players have similar attributes. In such cases, it would be beneficial for coaches to have a scientific method to distinguish between closely matched players with similar abilities. Given the large sums of money on offer for winning professional football leagues and national team titles, the ability to select the most suitable team players has become an indispensable skill (Qadar et al. 2017).

The Hungarian method can be employed for the effective solution of assignment problems, where a set of tasks must be assigned to workers who each have a different level of ability. The problem is solved by creating the cost matrix associated with each worker-task pair, and consequently finding the optimal assignment of workers to tasks through a series of iterative steps. The objective is to minimize the total cost or to maximize the total benefit associated with the completion of the assigned jobs. As the Hungarian method guarantees an assignment solution that is both feasible and optimal, it can conceivably be employed to determine the optimal team selection for any team sport. The method was successfully applied by Britz and Maltitz for the optimal selection of baseball players for the most effective team (Britz and Maltitz 2010). After assessing a group of novice baseball players to determine their abilities in key practical aspects of the game, they successfully employed the Hungarian method to determine the optimal team, according to these metrics. This same approach could conceivably be adapted for team selection in football, utilizing the available player performance metrics freely available on online football data repositories.

In this paper, we utilize these player performance metrics – available for free download from Whoscored.com – to create an efficiency matrix for key players in a football team. We do this by classifying players according to their specific role on the team, and extracting the relevant statistical data associated with the jobs typically allocated to defenders, midfielders and strikers. Subsequently, we apply the Hungarian algorithm to the efficiency matrix to determine the maximal defensive, midfield and striking scores for the team. This facilitates an unbiased comparison of competing teams in a professional football league using summarised player statistics obtained from a recently completed season. Given that large sums of money are spent each year on recruiting new players, it would be very helpful to have another scientific tool to analyse immediate past team results to effectively identify problem areas where player recruitment might be opportune.

Next, we present a general method for the overall rating of teams in a professional football league, using the Premier League to illustrate this objective. To formulate our team rating system, we establish a set of criteria which characterizes all-round team play. Inspired by the player ranking methodology presented by McHale et al., we introduce an appropriate number of sub-indices, the first being called "team contributions" which is sub-divided into set piece goals, duels won percentage, defensive actions and discipline (McHale et al.

2012). The required data for each registered team for the 2016/2017 Premier League season was sourced from Squawka.com (Squawka 2017). A multiple correlation analysis is performed with points achieved by each team as the reference variable, with the other variables being set piece goals, tackles, take-on, aerial duels won, interceptions, blocked shots, clearances, red and yellow cards.

As football fans around the world will attest, the final result of a match does not often represent the actual performance of a football team. Our proposed team index is a single score that effectively rates the collective contributions of all team players. While there are several predictive tools that are available for use in team football, our analysis will provide an avenue for evaluating the overall team performance after the season has ended. A quick comparison with the overall team standings at the end of the playing season can easily demonstrate the effectiveness of the method, lending credibility to its usefulness for coaching staff when planning for future seasons.

Literature Review

The mathematical foundation for the Hungarian algorithm was established by the Hungarian mathematicians Konig (1913) and Egevary (1931). Harold Kuhn later devised a computational algorithm that efficiently employs the Hungarian method for the solution of an assignment problem (Kuhn 1955). The algorithm was studied independently by James Munkres in 1957, and for that reason, it is sometimes referred to as the Kuhn–Munkres algorithm or the Munkres assignment algorithm (Munkres 1957). The method reduces the associated cost matrix in such a manner that at least one zero in each row and column will be obtained. The positions of these zeros in the matrix are representative of the optimal assignment solution, thus facilitating the calculation of the minimal opportunity cost.

Britz and Maltitz utilized the Hungarian algorithm for team selection in baseball, by assigning the most effective player to respective positions on the field (Britz and Maltitz 2010). They considered different weighted combinations of player roles on a baseball field, while considering the overall balance that must be achieved between offensive and defensive plays. They then tested their proposal on a group of novice baseball players by conducting skill tests to determine the relevant ratings for the associated efficiency matrix. They then employed the Hungarian algorithm to identify the optimal team. To the best of our knowledge, this methodology has not yet been adopted for team selection purposes in football.

As explained by McHale et al., “performance assessment is a fundamental tool for quantitative analysts and operational researchers” (McHale et al. 2012). Rating systems are often utilized to measure team or player performance, and there are well-established rating systems for ranking opposing teams in competitive sports competitions. In individual sports such as tennis, it is relatively straightforward to analyse recent results of player competitions to generate an ordered list of the top ranked players. As these official rankings are often used to seed players in a tournament, this can also affect the overall outcome of the tournament, as top seeded players are effectively guaranteed an easier route to the

final rounds of matches. It is true however that there are limitations to any ranking system, and absolute trust cannot be placed on rating systems that rely only on past player performances. Even the official rankings provided by the well-established Association of Tennis Professionals (ATP) might prove somewhat deceptive for sports enthusiasts placing bets on the top ranked tennis players (McHale and Morton 2011).

Tennis is not the only sport to have used officials' rankings to predict future performance. Forrest and McHale found that for men's professional golf, increased forecasting power can be achieved by incorporating up-to-date results with an established forecasting model which utilizes world rankings as a predictor (Forrest and McHale 2007). In a similar study for football, McHale and Davies determined that recent match results of international teams can add much value to the forecasting model (McHale and Davies 2007). Thus, the evidence from tennis, golf and football suggests that although official rankings of players and teams are useful as predictors, they do not determine match outcomes with absolute certainty. Reliable team ratings are required for the calculation of betting odds, and substantial funds are generated when sports fans place bets on their preferred teams. The availability of methods for the evaluation of team performance is therefore of great interest not only to players and coaching staff, but also to the wider community of sports enthusiasts.

Methodology

Individual Player Contribution

In assignment problems, the main objective is the allocation of jobs to an equal number of persons at a minimum cost for maximal profit. Let us suppose that there are 'n' jobs to be performed and 'n' persons available to take these jobs. We assume that each person can complete an assigned job in a specified time with a varying level of efficiency. Let c_{ij} be the cost associated with the i^{th} person being assigned to the j^{th} job. Our goal is to determine the optimal job assignment such that the total cost for performing all the jobs is minimized. Typical examples of assignment problems include the allocation of machines to jobs, classes to classrooms, players to a team, etc.

Basic Mathematical Formulation

Cost matrix: $c_{ij} = c_{11} \quad c_{12} \ldots\ldots\ldots\ldots\ldots\ldots c_{1n}$

$c_{21} \quad c_{21} \ldots\ldots\ldots\ldots\ldots\ldots c_{2n}$

$\ldots \quad \ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots$

$c_{n1} \quad c_{n2} \ldots\ldots\ldots\ldots\ldots\ldots c_{nn}$

We wish to minimize cost: $z = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij}$ $\quad i = 1, 2,\ldots, n \;\; ; \;\; j = 1, 2,\ldots, n.$

subject to the conditions

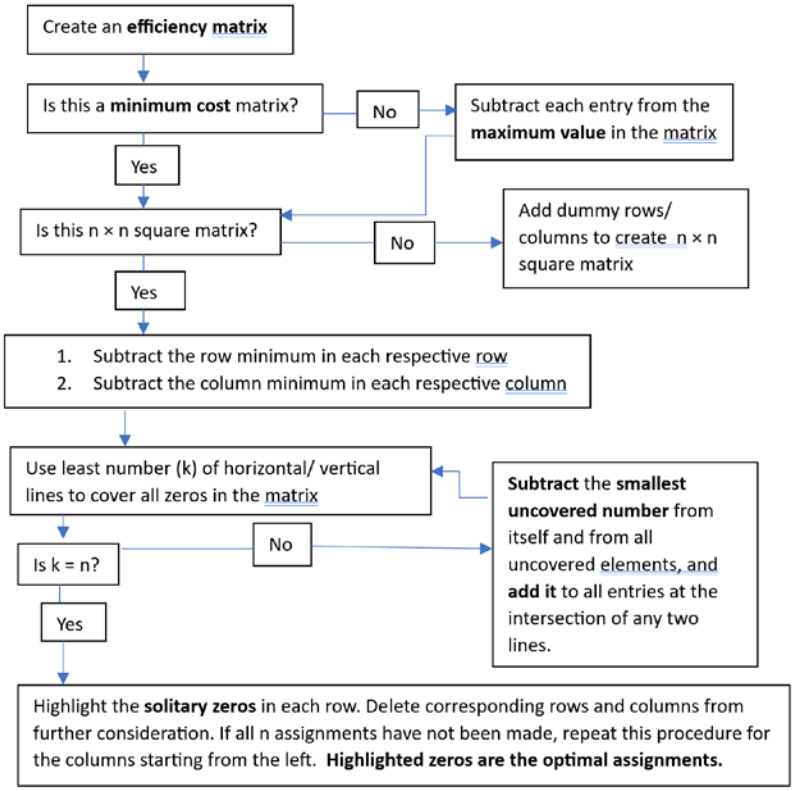
$$x_{ij} = \begin{cases} 1 \text{ if } i^{th} \text{ person is assigned to } j^{th} \text{ job} \\ 0 \text{ otherwise} \end{cases}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \text{ (one job is done by the } i^{th} \text{ person } i = 1, 2, \ldots, n)$$

$$\sum_{i=1}^{n} x_{ij} = 1 \text{ (only one person should be assigned the } j^{th} \text{ job } i = 1, 2, \ldots, n)$$

where x_{ij} denotes the j^{th} job to be assigned to the i^{th} person.

The Hungarian Algorithm (Britz and Maltitz 2010)



The position that a player occupies on the field defines the role and responsibility of that particular player. There are three main positions for outfield players in a football team: defender, midfielder or striker. Players may be asked to perform multiple tasks/jobs in accordance with the team formation/tactical directives provided by the coaching staff. These jobs include passing, tackling, blocking, intercepting, clearing, shooting, assisting, and dribbling. Most football players are better at mastering one or two of these jobs, although there are a few exceptional players who exhibit extraordinary levels of talent and can therefore perform multiple functions with equally high levels of competence. In general, regardless of the position that they occupy, players must be able to perform all these jobs effectively - since football is a team sport, and successful teams are comprised of players who can adapt quickly to changing situations on the pitch.

To illustrate the method, we utilize the average player statistics per game for two teams from the 2016/2017 Premier League Season (Whoscored 2017). We select the team that placed first that year: Chelsea, and the team that placed sixth: Manchester United. Our main objective is to investigate the roles performed by the players from each team, and in so doing, to provide reasons for the gulf in class between these two teams. This type of critical analysis can help the coaching staff to identify what is working well for their team, and what needs to be improved.

We begin by classifying the players on each team according to their main roles – as defender, midfielder or striker. Defenders are given five major jobs while midfielders are given seven and strikers four. As midfielders must perform both defensive and offensive duties, there is some overlap in the tasks to be performed by defenders and midfielders as well as by midfielders and strikers. We use the available data to assign the players to jobs, noting that whenever there are more players than jobs, the resulting matrix is not square. As the Hungarian Algorithm requires a square matrix, in such cases, "dummy jobs" must be created to facilitate the analysis. Although not all the players will be given a legitimate job as a result, the analysis will still allow us to identify the most efficient combination of players on the team to perform all the tasks outlined. Our objective is to maximize each team's defensive and offensive statistics, based on the available data. This will allow important comparisons to be made between the two teams. Our results will provide reasonable justifications for the gap in points scored between the teams and for the overall performance of each team as a unit.

We will illustrate the method by considering the defensive statistics for Manchester United. The nine defenders used for the majority of the 2016/2017 Premier League season by Manchester United are listed in Table 1 with their associated averages for the five defensive jobs considered crucial for their position. Note that each number indicates the average for that particular job per game, and that passing data is based on quoted pass percentages. For example, Smalling has an 89% successful passing rate.

Table 1. *Defenders for Manchester United*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	0.7	2.0	2.4	1.4	1.5	2.4	1.1	2.4	2.1
Clearing	6.9	4.7	2.1	6.8	2.1	5.0	2.5	4.1	7.6
Blocking	0.5	0.4	0.3	0.3	0.2	0.9	0.1	0.1	0.8
Intercepting	0.7	1.9	1.5	1.6	1.3	2.5	1.1	2.3	1.6
Passing	0.89	0.86	0.86	0.86	0.83	0.86	0.86	0.81	0.89

Our problem is to maximize the defensive statistics for the team - by identifying the combination of five selected players that results in the maximum overall defensive score for the team with respect to the five tasks identified: talking, clearing, blocking, intercepting, and passing. Now, to turn this into a maximization type problem for the Hungarian algorithm we must first develop the effective matrix. To do this, we must first subtract the largest entry (7.6) from each other entry of the matrix. The resulting matrix is shown in Table 2.

Table 2. *Subtract the Smallest Entry from Each Row from all other Entries in that Row*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	6.9	5.6	5.2	6.2	6.1	5.2	6.5	5.2	5.5
Clearing	0.7	2.9	5.5	0.8	5.5	2.6	5.1	3.5	0
Blocking	7.1	7.2	7.3	7.3	7.4	6.7	7.5	7.5	6.8
Intercepting	6.9	5.7	6.1	6.0	6.3	5.1	6.5	5.3	6.0
Passing	6.71	6.74	6.74	6.74	6.77	6.74	6.74	6.79	6.71

Next, we add dummy jobs to make the number of rows to equal the number of columns. The dummy jobs are denoted as F, G, H and I, as illustrated in Table 3.

Table 3. *Effective Matrix – After Addition of Dummy Jobs F, G, H and I*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	6.9	5.6	5.2	6.2	6.1	5.2	6.5	5.2	5.5
Clearing	0.7	2.9	5.5	0.8	5.5	2.6	5.1	3.5	0
Blocking	7.1	7.2	7.3	7.3	7.4	6.7	7.5	7.5	6.8
Intercepting	6.9	5.7	6.1	6.0	6.3	5.1	6.5	5.3	6.0
Passing	6.71	6.74	6.74	6.74	6.77	6.74	6.74	6.79	6.71
F	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0

We can now proceed with the steps listed in the Hungarian algorithm. Subtract the minimum element in each row from each element in that row. As there are zeros in every column, there is no need to subtract the minimum element from each column from all elements in that column. The result is shown in Table 4.

Table 4. *Modified Matrix – After Subtraction of Minimum Element from all Rows*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	1.7	0.4	0	1	0.9	0	1.3	0	0.3
Clearing	0.7	2.9	5.5	0.8	5.5	2.6	5.1	3.5	0
Blocking	0.4	0.5	0.6	0.6	0.7	0	0.8	0.8	0.1
Intercepting	1.8	0.6	1	0.9	1.2	0	1.4	0.2	0.9
Passing	0	0.03	0.03	0.03	0.06	0.03	0.03	0.08	0
F	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0

As there are zeros in every column, there is no need to subtract the minimum element from each column. We must now cover all the zeros with the minimum number of horizontal and vertical lines. This yields eight lines, as shown in Table 5.

Table 5. *Cover all Zeros with Minimum Number (8) of Horizontal/Vertical Lines*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	1.7	0.4	0	1.0	0.9	0	1.3	0	0.3
Clearing	0.7	2.9	5.5	0.8	5.5	2.6	5.1	3.5	0
Blocking	0.4	0.5	0.6	0.6	0.7	0	0.8	0.8	0.1
Intercepting	1.8	0.6	1	0.9	1.2	0	1.4	0.2	0.9
Passing	0	0.03	0.03	0.03	0.06	0.03	0.03	0.08	0
F	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0

As the order of the matrix is nine, the optimal assignment cannot be made. We proceed by subtracting the minimum uncovered element from all uncovered elements and add this minimum uncovered element to the covered elements at the line intersections only. From Table 5, we see that the minimum uncovered element is 0.03. To cover all the zeros with the minimum number of horizontal and vertical lines in the resulting matrix, we will again require eight lines (as shown in Table 6), so once again, the optimal assignment cannot be made.

Table 6. *Zeros Covered with the Minimum Number (8) of Horizontal/Vertical Lines*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	1.73	0.4	0	1.0	0.9	0.03	1.3	0	0.33
Clearing	0.7	2.87	5.47	0.77	5.47	2.6	5.07	3.47	0
Blocking	0.4	0.47	0.57	0.57	0.67	0	0.77	0.77	0.1
Intercepting	1.8	0.57	0.97	0.87	1.17	0	1.37	0.17	0.9
Passing	0	0	0	0	0.03	0.03	0	0.05	0
F	0.03	0	0	0	0	0.03	0	0	0.03
G	0.03	0	0	0	0	0.03	0	0	0.03
H	0.03	0	0	0	0	0.03	0	0	0.03
I	0.03	0	0	0	0	0.03	0	0	0.03

We must repeat the steps of the Hungarian algorithm. The smallest uncovered number is 0.17, so we subtract 0.17 from all uncovered numbers, and we add 0.17 to the covered numbers that are located in any position where two lines intersect. Nine lines can be used to cover all zeros in the resulting matrix, as shown in Table 7. The optimal assignment can now be determined.

Table 7. *Zeros Covered with the Minimum Number (9) of Horizontal/ Vertical Lines*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling	1.73	0.4	0	1.0	0.9	0.2	1.3	0	0.5
Clearing	0.53	2.7	5.3	0.6	5.3	2.6	4.9	3.3	0
Blocking	0.23	0.3	0.4	0.4	0.5	0	0.6	0.6	0.1
Intercepting	1.63	0.4	0.8	0.7	1	0	1.2	0	0.9
Passing	0	0	0	0	0.03	0.2	0	0.05	0.17
F	0.03	0	0	0	0	0.2	0	0	0.2
G	0.03	0	0	0	0	0.2	0	0	0.2
H	0.03	0	0	0	0	0.2	0	0	0.2
I	0.03	0	0	0	0	0.2	0	0	0.2

Zeros are then eliminated to leave one zero in each row and column, thus ensuring that each player is assigned to one job. The resulting matrix is presented in Table 8, where the symbol ⊗ indicates an eliminated zero while (0) indicates the assigned player in the respective column with the corresponding job in the respective row.

Table 8. *Matrix Displaying the Optimal Assignment Solution*

	Smalling	Blind	Valencia	Rojo	Young	Bailly	Shaw	Darmian	Jones
Tackling			(0)					⊗	
Clearing									(0)
Blocking						(0)			
Intercepting						⊗		(0)	
Passing	(0)	⊗	⊗	⊗			⊗		
F		(0)	⊗	⊗	⊗		⊗	⊗	
G		⊗	⊗	(0)	⊗		⊗	⊗	
H		⊗	⊗	⊗	(0)		⊗	⊗	
I		⊗	⊗	⊗	⊗		(0)	⊗	

For verification purposes, we utilized the MATLAB Hungarian Algorithm for linear assignment problems (V2.3) developed by Yi Cao (Yi 2023). Deployment of the program "munkres.m" with the effective matrix (see Table 3) yielded the same result displayed in Table 8, which effectively confirms our manual calculations. The optimal team defensive score is subsequently calculated by adding the original performance scores by the players selected for the optimal solution (refer to Table 1). This type of analysis facilitates a comparison of defensive systems employed by different teams in the Premier League, with the highest overall defensive team score expected to correspond with the team with the most effective defensive records.

A similar analysis can be carried out for midfield players and strikers, for their respective jobs. For brevity, our calculations for the two football teams under consideration will be summarized in the results section.

Analysis of Team Impact

In formulating a system for rating, we must first establish a number of criteria which constitutes the all-round play of each registered team in the league under consideration. The necessary data for each team for the 2016/2017 Premier League Season was collected from Squawka (Squawka 2017). A multiple correlation analysis was then carried out with 'number of points obtained' as the reference variable with the other variables being 'number of set piece goals', 'tackles percentage won', 'take-ons percentage won', 'aerial duels percentage won', 'number of interceptions', 'number of blocked shots', 'number of clearances', 'number of red cards' and 'number of yellow cards'. The results are presented in Table 9.

Table 9. *Multiple Correlation Analysis Results*

Multiple Correlation Analysis	**Correlation Coefficients**
# Set Piece Goals & # Points	0.4844
Tackles % Won & # Points	0.4239
Take-ons % Won & # Points	0.1644
Aerial Duels % Won & # Points	0.0333
# Interceptions & # Points	−0.4651
# Blocked Shots & # Points	−0.7879
# Clearances & # Points	−0.6562
# Red Cards & # Points	−0.2820
# Yellow Cards & # Points	−0.2411

As positive correlation coefficients are indicative of a relationship between two variables that tends to move in the same direction, our results indicate that the more set piece goals scored by a team, the more points will be obtained. This is also the case for tackles percentage won. We note that take-ons percentage won and points are positively correlated but only distantly so, while aerial duels percentage won and points have almost no correlation. This indicates that there may be other underlying factors that we have not considered for those two variables.

As expected, defensive actions and points are all negatively correlated, i.e., more of these actions is indicative of fewer points attained by the team. We note that teams with a larger number of interceptions, blocked shots and clearances are constantly under attack. As a result, those teams will be defending frantically to stay in the game, with much less focus on offensive play. Discipline also impacts

on the team, so it is no surprise that red/ yellow cards and points are negatively correlated.

We are now ready to establish the first sub-index of the rating system by multiplying the number of actions of each team by the correlation coefficient obtained for that action and then summing these products. As the number of set piece goals, tackles won, take-ons won and aerial duels won will be significantly less than the number of defensive actions (namely blocked shots, clearances and interceptions), we expect that the associated index will be negative. In general, team data for the number of set piece goals and the percentages of tackles, take-ons and aerial duels won is in the tens, while the data corresponding to defensive actions is markedly higher, often measuring in the hundreds or thousands. To compensate for this imbalance, we multiply set piece goals by one hundred - since the number of goals scored decides the match outcome and the number of points awarded to the team. The percentages associated with tackles, take-ons and aerial duels won will also be multiplied by one hundred. This will allow for a better balance in terms of the tabulated offensive and defensive actions of each team.

Sub-Index 1

Team Contributions Index

$$I_1 = 100\ [0.4844(x_1) + 0 \cdot 4239(x_2) + 0 \cdot 1644(x_3) + 0 \cdot 0333(x_4)] \\ - 04651(x_5) \quad - 0 \cdot 7879(x_6) - 0 \cdot 6562(x_7) - 0 \\ \cdot 282(x_8) - 0 \cdot 2411(x_9)$$

where x_1 = number of set piece goals, x_2 = tackles % won, x_3 = take-ons % won, x_4 = aerial duels % won, x_5 = number of interceptions, x_6 = number of blocked shots, x_7 = number of clearances, x_8 = number of red cards, x_9 = number of yellow cards.

Sub-Index 2

Goal Difference Index

This sub-index awards points to a team based on net goals. The specific number of points awarded has been calculated by converting goals into points. Over the 2016/2017 Premier League Season, there was a total of 1064 goals scored, and 1056 points won. Therefore, we can estimate how many points one goal is worth as $\frac{1056}{1064} = 0 \cdot 9925$ points for each goal. This means that on this index, a team receives 0.9925 points for each goal the team scores. The points awarded to a team for goal difference is simply points per goal multiplied by a

team's goal difference scaled by a factor of ten - to keep in line with the weight of the first sub-index, as well as not to outweigh it.

$$I_2 = 10 \times \text{goal difference}_i \times 0 \cdot 9925$$

where $i = 1,2,3,\cdots,20$ denotes the each of the 20 teams in the Premier League Season 2016/2017.

Sub-Index 3

Assists Index

An assist is defined as a pass which leads to a goal. Therefore, from our previous estimate a goal is worth $0 \cdot 9925$ points. We can place an assist on this same scale. Hence, each assist by a team is worth $0 \cdot 9925$ points. The points awarded for the assist for each team is simply the number of assists multiplied by the points for each assist. As for the previous sub-index, we scale by a factor of ten to get:

$$I_3 = 10 \times \text{assists}_i \times 0.9925$$

where $i = 1,2,3,\cdots,20$ denotes the each of the 20 teams in the Premier League Season 2016/2017.

Sub-Index 4

Key Pass Index

A key pass is defined as a pass that creates a goal scoring opportunity. At times, a key pass leads to an assist. The total chances created by each team is a combination of the key passes and assists of each team. From the 2016/2017 Premier League Season Data there were a total of 7067 chances created. 717 of these chances created were assists, therefore:

$$\frac{717}{7067} \times 100 = 10 \cdot 146\%$$

From this analysis we can conclude that approximately 10% of the chances created resulted in goals. This leads to approximately 90% of the total chances created to be classified as key passes. Therefore, a chance created is nine times more likely to not result in a goal as to result in a goal. The points awarded per assist are $0 \cdot 9925$. As a result, the points awarded per key pass should be

$\frac{0 \cdot 9925}{9}$ which is close to one ninth of the value of an assist, i.e., $0 \cdot 1103$. As before, we scale by a factor of ten to obtain

$$I_4 = 10 \times \text{key passes}_i \times 0 \cdot 1103$$

where $i = 1,2,3,\cdots,20$ denotes the each of the 20 teams in the Premier League Season 2016/2017.

Sub Index 5

Work Rate Index

The seasonal points obtained per team based on distance covered which again is scaled by a factor of ten (10).

$$\text{Work rate: } I_5 = \frac{\text{distance covered}_i \times \text{points}_i \times 10}{\sum_{i=1}^{20} \text{distance}_i}$$

where $i = 1,2,3,\cdots,20$ represents the each of the 20 teams in the Premier League Season 2016/2017.

Work rate is a measure that contributes significantly less than the other sub-indices. This is mainly because players in general tend to run more and cover more distance when they are not in possession of the soccer ball. This could translate to being under pressure from opposing teams. Hence, absorbing such pressure takes a high level of concentration and should be merited. In terms of team rating this would not place a team at the summit by any means. However, it could separate teams with fine margins in ratings.

The final index is calculated by taking the sum of the five sub-indices calculated previously:

$$\text{The Final Index} = I_1 + I_2 + I_3 + I_4 + I_5 .$$

Note that some of the ideas in creating this index were utilised and modified from (McHale et al., 2012).

Results

a. Hungarian Method Results:

The optimal defensive assignment (jobs → player) of Manchester United in the 2016/2017 Premier League season was as follows:

Passing → Smalling; **Tackling** → Valencia; **Blocking** → Bailly;
Intercepting →Darmian; **Clearing** → Jones.

To determine the maximum defensive assignment score for Manchester United, we combine the initial average data for the specific job that is assigned to each of these five defenders as follows:

$$0.89 + 2.4 + 0.9 + 2.3 + 7.6 = 14.09$$

The same analysis can be carried out for the midfielders and strikers from Manchester United, resulting in the following assignments.
Midfield assignment for Manchester United:

Passing → Lingard; **Shots per Game** → Pogba; **Through Balls** →Mkhitarian;
Key Passes → Mata; **Tackling** →Fellaini; **Assists** → Herrera; **Intercepting** → Carrick.

The associated maximum midfield assignment for Manchester United is calculated to give

$$0.88 + 3.1 + 0.2 + 1.8 + 2 + 6 + 1.9 = 15.88$$

Striker assignment for Manchester United:

Assists → Martial; **Successful Dribbles** → Rashford;
Shots per Game → Ibrahimovic; **Fouled per Game**→ Rooney.

The maximum assignment for the strikers of Manchester United tallies to:

$$6 + 1.3 + 4.1 + 0.5 = 11.9$$

The same analysis on the Chelsea team for defense is as follows:

Intercepting → Azpilicueta; **Blocking** → Cahill; **Clearing** → Luiz;
Passing → Terry; **Tackling** → Aké.

The maximum assignment for defence in the Chelsea team is therefore:

$$1.9 + 0.5 + 5.3 + 0.92 + 2 = 10.62$$

We now apply the analysis to the Chelsea midfielders. The optimal assignment is as follows:
Shots per Game → Hazard; **Assists** → Fabregas; **Through Balls** → Willian;
Intercepting → Matic; **Key Passes** → Oscar; **Tackling** → Kanté; **Passing** → Loftus-Cheek.

The maximum midfield assignment score for Chelsea is therefore:

$$2.1 + 12 + 0.1 + 1.4 + 1.7 + 3.6 + 0.84 = 21.74$$

The optimal assignment for the strikers of Chelsea produces the following:

Assists → Pedro; **Successful Dribbles** → Hazard;
Shots per Game → Costa; **Fouled per Game**→ Moses.

The maximum striker assignment for Chelsea calculates is therefore given as:
$$3.2 + 8 + 3.9 + 0.9 = 16.$$

b. Performance Rating Results:

Figure 1 presents a scatter diagram displaying the multiple correlations for each variable. These are used in the calculation of the first sub-index 'team contributions'. The four remaining sub-indices are 'goal difference', 'assist', 'key pass', 'work rate'. The five calculated sub-indices are summarized in Tables 10 and 11.

Figure 1. *Multiple Correlations with Reference Variable 'Points'*

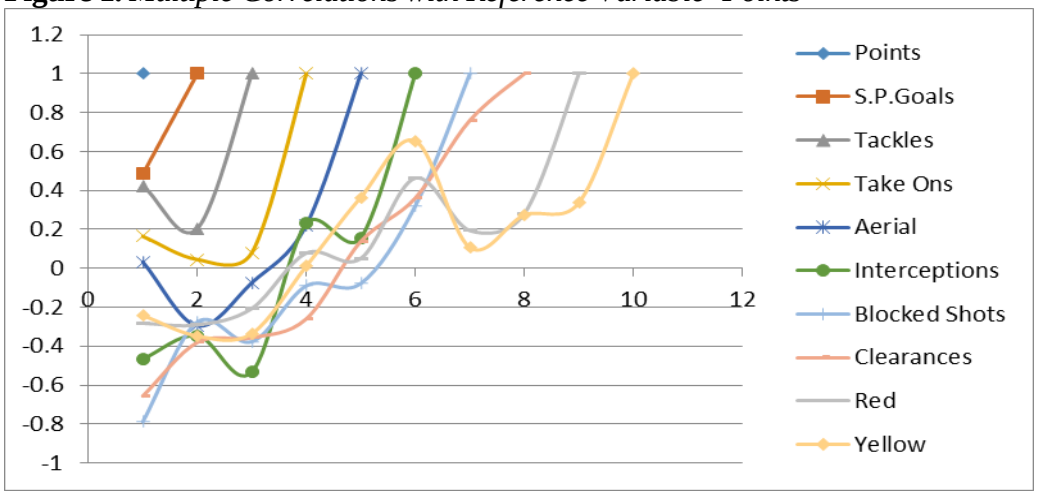


Table 10. *Sub-indices 1 & 2 - Team Contributions & Goal Difference*

Team	Score (Team Contributions Index)	Score (Goal Difference Index)
Chelsea	3258·15	516·10
West Bromwich Albion	2694·62	– 79·40
Tottenham Hotspur	2899·47	595·50
Swansea City	2665.90	– 248·13
Liverpool	2944·11	357·30
West Ham United	2577·96	–168·73
Bournemouth	2629·69	–119·10

Manchester City	2735·41	406·93
Burnley	2214·87	–158·80
Hull City	2431·96	– 426·78
Arsenal	2741·94	327·53
Crystal Palace	2478·15	–129·03
Everton	2518·69	178·65
Watford	2196·54	– 227·90
Stoke City	2424·60	–148·88
Leicester City	2123·46	–148·88
Manchester United	2058·51	248·13
Southampton	2404·40	– 69·48
Sunderland	2073·07	– 397·00
Middlesbrough	2099·02	– 258·05

Table 11. *Sub-Indices 3, 4, 5 - Assist, Key Pass and Work Rate*

Team	**Score (Assist Index)**	**Score (Key Pass Index)**	**Score (Work Rate Index)**
Chelsea	555·80	430·17	47·35
West Bromwich Albion	337·45	276·85	23·18
Tottenham Hotspur	585·58	490·84	44·18
Swansea City	317·60	283·47	20·65
Liverpool	545·88	486·42	39·996
West Ham United	287·83	355·17	22·18
Bournemouth	357·30	330·90	23·48
Manchester City	516·10	474·29	40·38
Burnley	228·28	262·51	20·47
Hull City	535·95	269·13	17·08
Arsenal	496·25	415·83	37·88
Crystal Palace	337·45	302·22	19·79
Everton	456·55	380·54	29·99
Watford	258·05	295·60	19·38
Stoke City	228·28	296·71	21·53
Leicester City	327·53	285·68	21·51
Manchester United	406·93	447·82	32·96
Southampton	258·05	403·70	22·57
Sunderland	119·10	269·13	11·58
Middlesbrough	208·43	247·07	14·29

The data on average distance (km) covered per game by each team and the total distance covered by each team for the season was obtained from the Express UK online (Express UK 2017). We found that the work rate index is substantially smaller than the assist and key pass indices. Also, the goal difference index can be either positive or negative. It can therefore add to or subtract from a team's rating. It is quite clear that the team contributions index carries the greatest weighting in the overall rating index. Table 12 presents the overall rating calculated for the twenty Premier League teams for the 2016/ 2017 season, arranged in order from the highest to the lowest rating.

Table 12. *Final Team Ratings*

Position	Team	Team Rating
1.	Chelsea	4807
2.	Tottenham Hotspur	4616
3.	Liverpool	4374
4.	Manchester City	4173
5.	Arsenal	4059
6.	Everton	3445
7.	West Bromwich Albion	3253
8.	Bournemouth	3222
9.	Manchester United	3194
10.	West Ham United	3074
11.	Swansea City	3039
12.	Southampton	3019
13.	Crystal Palace	3009
14.	Stoke City	2822
15.	Hull City	2788
16.	Leicester City	2609
17.	Burnley	2567
18.	Watford	2542
19.	Middlesbrough	2311
20.	Sunderland	2076

Discussion

Recapping the optimal assignments for both teams, we observe that Chelsea's entire round total was higher that Manchester United's. However, Manchester United's average defensive assignment was higher that Chelsea's. As a result, Manchester United conceded fewer goals than Chelsea, twenty-nine as opposed to

thirty-three. Note that Chelsea scored significantly more goals than Manchester United i.e., eighty-five to fifty-four. Chelsea also had a goal difference which was more than twice that of Manchester United. Chelsea's midfield and attack scored approximately five and four more assignment points per game respectively. This tells the story of how effective the link between midfield and attack worked for Chelsea. The midfield also helped martial the defence by creating a formidable barrier in front of the defence. We can see that the combined average assignment per game in defence and midfield for Chelsea was 32.36 as opposed to 29.97 for Manchester United. This shows how superior the midfield of Chelsea was in supporting the defence and linking up the attacks.

This type of analysis can inform the manager and coaching as to the best players for various roles. It will in fact aid in the selection of the team from the available players - depending on the team formation adopted for a particular game. For example, suppose that Chelsea was playing the (3-4-3) formation with three defenders, having identified that the three most important roles to counteract the opposition's weaknesses were to intercept, clear and pass optimally to neutralize the opposition's attack. In such a case, Azpilicueta, Luiz and Terry would have been the three best available options in that particular season.

It is interesting to observe that the top two and bottom two teams in our rating index placed exactly the same as the final league table for 2016/2017. The top five teams were also the same as the final league table, but with Manchester City and Liverpool switching positions. We note that in our final team rating index, Everton, West Bromwich Albion and Bournemouth all finished above Manchester United, however this did not happen in the final league table for 2016/2017. This was because offensively, their contributions on our ratings index were higher than that of Manchester United.

Conclusion

The selection of individual football players to function as a cohesive unit can be a very daunting task for coaches. Getting the right balance of strikers, midfielders and defenders is critical to the team's all-round performance. By using data from previous games on how players perform the various roles, coaches can explore the best combinations to use for upcoming matches. We have demonstrated how this can be achieved via the application of the Hungarian Algorithm. Web sources provide data on football statistics such as blocking, clearing, tackling, intercepting, dribbling, shooting, assisting, passing, etc. We are able to divide these attributes into defensive and offensive together with a combination of both to pick the best defence, midfield and offence to perform optimally as a unit.

We have also described how to use player statistics to create a ranking system for all registered teams in a football league. This can be achieved through the creation of a team index by way of a combination of five sub-indices. The first sub-index is called team contributions, and it accounts for the number of set piece goals, shots, blocks, tackles won, aerial duels won, clearances, red and yellow cards obtained by the players. For each team, the total number for each component

is multiplied by an estimated correlation coefficient and the resulting values are added to determine the overall score that is representative of these contributions. The four remaining sub-indices are called goal difference, assist, key pass and work rate. Each of these sub-indices contributes a score to the overall team index, based on the overall numbers that the team amasses in each respective aspect of team play. The score for the five sub-indices is then totalled to produce the team index score, and the teams are ranked from highest to lowest based on the final index score.

We have used the 2016/2017 Premier League data to demonstrate the similarities between our team ranking index and the eventual position of each team in the league table at the end of the season. This suggests that our proposed team index can be used as a league predictor for future seasons and to set up betting odds for teams. Further analysis could be carried out to determine what proportion each sub index contributes to the all-round team index. This would allow conclusions to be drawn on the effectiveness of the various sub-indices and their relative importance in predicting the outcome of the league.

The ratings index that we have presented in this paper provides an additional tool for the comparison of teams. It allows us to analyse the overall performance, and subsequently to determine the best and worst teams in the league. Some of the ideas in creating this index were utilised and modified from (McHale et al. 2012). The team index is a single score used to rate the collective player contributions that directly influence overall team success. It provides a quantitative way to measure the differences between teams.

References

Britz SS, Maltitz MJ (2010) *Application of the Hungarian algorithm in baseball team selection and assignment.* Available at: https://www.ufs.ac.za/docs/librariesprovider 22/mathematical-statistics-and-actuarial-science-documents/technical-reports-docu ments/teg419-2070-eng.pdf?sfvrsn=383cf921_0.

Express UK (2017) *Premier League distance covered.* Available at: https://www.express. co. uk/sport/football/794607/Premier-League-distance-covered-sportgalleries.

Forrest D, Mc Hale I (2007) Anyone for tennis (betting)? *European Journal of Finance* 13(8): 751–768.

Kuhn WH (1955) The Hungarian method for the assignment problem. *Naval Research Logistics Quarterly* 2(1–2): 83–97.

McHale I, Davies S (2007) Statistical analysis of the effectiveness of the FIFA world rankings. In *Statistical Thinking in Sports*, 77–90. 1st Edition. Chapman and Hall/ CRC.

McHale I, Morton A (2011) A Bradley-Terry type model for forecasting tennis match results. *International Journal of Forecasting* 27(2): 619–630.

McHale I, Scarf P, Folker D (2012) On the development of a soccer player performance rating system for the English Premier League. *Interface Science* 42(4): 339–351.

Munkres J (1957) Algorithms for the assignment and transportation problems. *SIAM Journal on Applied Mathematics* 5(1): 32–38.

Qadar MA, Zaidan BB, Zaidan AA, Ali SK, Kamaluddin MA, Radzi WB (2017) A methodology for football players selection problem based on multi-measurements criteria analysis. *Measurement* 111: 38–50.

Squawka (2017) https://www.squawka.com/en/comparison-matrix/#avg.

Whoscored (2017) *Premier League 2016/2017*. Available at: https://www.whoscored.com/statistics.

Yi C (2023) *Hungarian algorithm for linear assignment problems (V2.3)*. Available at: https://www.mathworks.com/matlabcentral/fileexchange/20652-hungarian-algorithm-for-linear-assignment-problems-v2-3.

Athens Journal of Sports - Volume 10, Issue 4, December 2023 – Pages 235-260

Olympic Public Transportation Investments, Legacy, and City Prosperity: An Empirical Look at the 2000-2016 Summer Games

By Kennedy Magee[*] & W. James Weese[±]

The complexity of hosting the Olympic Games has grown throughout its history. The financial risks to cities vying for the hosting rights are often viewed as excessive and consequently, fewer bids are being submitted in modern times. Critics suggest that public funds would be better spent supporting other social programs. However, history has demonstrated that host cities can use the Games to expand and modernize public transport systems to efficiently move people, increase accessibility, reduce personal travel and garner environmental benefits like improved air quality and less noise pollution. The authors examined the five Summer Olympic Games host cities between 2000-2016 using the City Prosperity Index (CPI) to measure city performance across six indexes to determine the accrued public transit benefits of hosting the Games. The authors hope this paper can provide a clear path forward for future Olympic bidders and city officials.

Keywords: *Olympic Games, City Prosperity Index, public transportation, investments*

Hosting Olympics as the Stimulus for Urban Development

The first Olympic Games were constrained by financial limitations and held in venues that were only upgraded as needed (Liao and Pitts 2006). The first Games resulted in minimal urban development legacies. For example, the first Olympic Games staged in Athens in 1896 resulted in restoring a 2000-year-old stadium and the refurbishing a downtown building. Paris hosted the Games in 1900 and used natural settings, which led to situations like swimmers competing in the muddy Seine River. The Olympic Games were still in their infancy, and financial support for major public infrastructure upgrades was not considered a priority.

The second era of Olympic urbanization was marked by the building the White City Stadium for the 1908 Olympic Games in London (Liao and Pitts 2006). The stadium was the first example of Olympic urbanism. The example showed the world the kind of infrastructure change that hosting the Olympics could bring to a city. Stadia development seemed to be the significant infrastructure benefit of hosting the Games. The inclusion of an Olympic Village for the 1932 Olympics marked a new era of Olympic urbanization development due to hosting the Games. The Olympic Village was envisioned as a temporary structure in these Games, designed exclusively for male competitors. However, the most significant

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change in Olympic urbanization was evident in the 1936 Games staged in Germany. The 1936 Olympic Games, while staged for political gain, showcased the transformative powers of hosting the event. Significant governmental support was invested in creating venues, parks, and public spaces designed to remain in place long after the Games were concluded. This trend continued through the 1960 Olympic Games held in Rome. Infrastructure improvements tied to hosting these included upgrades to the water supply system, construction of new hotels, improved street lighting, and upgrades to urban landscaping. According to Liao and Pitts (2006), this host became the first to use the Games to enrich their public transit system (e.g., a new highway system to connect sites and the construction of a new airport). The trend continued. Gordon (1983) noted that the organizers of the 1964 Olympic Games in Tokyo used the Games to address its transportation issues with significant infrastructure investments (e.g., a new multi-hierarchy transportation system consisting of roadways, 73km of subway line, 13.2km of monorail, and access to a 500km bullet train line which connected several major cities across Japan). The trend was in place, and one of the major selling points for bidding for the Games became the influx of resources that would help cities address their public transportation issues.

For example, the 1968 Games held in Mexico City resulted in a new metro system for the city (Liao and Pitts 2006). The Munich Olympic Games in 1972 resulted in upgrades to the city's public transportation system and other urban upgrades. The 1976 Olympic Games held in Montreal forced the city to build 20km of new metro lines, construct a new airport terminal, and upgrade many highways in addition to a new Olympic Stadium. Significant cost overruns resulted in significant municipal, provincial and national debt. The lessons were learned, and the following two host cities (i.e., Moscow and Lake Placid) proposed and spent much less on urban development and civic infrastructure as part of their Games hosting strategy. Host cities such as Seoul (1988) and Barcelona (1992) altered this trend. They used the hosting of the Games to clean up targeted areas of the city, regenerate their urban landscape, and showcase their cities to the world as attractive tourist destinations. This trend changed four years later, as evidenced by the 1996 Olympic Games staged in Atlanta. New and refurbished sports infrastructure was the focus, which came at the cost of reduced urban development. The underinvestment in public transit emerged as the most criticized part of the Games experience.

Urban transformations and upgrades to public transit became a higher priority for potential host cities. Cities and countries took notice of this opportunity, so the number of bids for the right to host the Games soared. Civic leaders knew that hosting the Games would provide the resources to address this need, and on a schedule that would only be possible with the pressure of hosting the Games. The 2010 Games held in Vancouver is a sterling example of this scenario. The Canada Line rail system was constructed for the Games and designed to link the airport with the downtown region. The Canada Line continues to serve the city well and provides cost-efficient and environmentally responsible transportation to 112,000 people daily (City of Vancouver n.d.).

Public transit has long been used in urban areas to increase the efficiency of moving large groups throughout the same densely populated area. Transportation habits and patterns since the end of the 19th century have influenced Europe and North America's sprawling land use tendencies (Arbury 2005, Brueckner 2000). Brueckner (2000) commented on the negative impacts of excessive expansion by noting the adverse effects of farmland open spaces, promoting long commutes which increase pollution, the erosion of downtown centres, and the weakening of social bonds facilitated by proximity. Urban sprawl isolates those who do not own a car from participating meaningfully in society.

Cities planners must shift their focus toward creating viable and sustainable transportation options, and increasing public transit is the solution. Finding the funding to build the infrastructure is usually the barrier. Public transit is needed in urban settings. Hosting the Olympic Games is a strategy that can be used to access new sources of revenue to build more public transit quickly and economically (Kassens-Noor 2013, Richter 2012). However, is this a realistic outcome? Is hosting the Summer Olympic Games worth the risk? Bid Committees and advocates tend to cherry-pick examples that support the benefits and minimize the risk. A more empirical analysis is warranted and serves as the justification for this research.

The researchers studied the situations that transpired at the Summer Olympic Games held from 2000-2016. Were public transit issues addressed through the hosting of the Games? Do citizens have better access and public transportation service due to these investments? The researchers set out to analyze the situation and draft their conclusions. They analyzed the host cities before hosting the Games, and after the Games to determine if significant, sustainable change was realized. They measured social good using the City Property Index (CPI). The CPI was created by the UN-Habitat in 2012 to analyze a city's prosperity performance and guide future policy decisions (Martinez 2012, UN-Habitat n.d.). This metric is different from others in that it exclusively looks at city performance instead of country performance, and it analyzes cities along various indexes that measure aspects beyond traditional economic analysis.

The CPI is measured across six indexes, all provided as values out of a maximum of 100. The six indexes are (a) productivity; (b) infrastructure development; (c) environmental sustainability; (d) quality of life; (e) equity and social inclusion; and; (f) urban governance and legislation. Within each index is a series of measures aggregated and averaged to provide a single score for the index. The CPI has a list of essential and extended actions; the extended measures offer a deeper analysis of the city and should be used when possible.

Case Studies: 2000-2016 Summer Olympic Games - 2000 Sydney Olympics

Sydney: Before the Olympics

Sydney is the biggest city in the state of New South Wales (NSW), Australia. It has been considered the centre of finance, marketing, and commerce in Australia

since the early 1900s (Pringle n.d.). The area was established as a penal colony with the arrival of Lord Sydney in 1788, who described the area as having the finest harbour in the world. Sydney is now one of the most ethnically diverse cities in the world, containing people from more than 180 nationalities.

Early in its history, when the population was relatively low, much of the travel within the area was done over water on the harbour, with competition emerging between private and public modes of transport (Wotherspoon 2008). The first railway to Sydney opened in 1855, designed to connect the city to Parramatta in the west, spurring suburban developments along the line. Eventually, residents started to become frustrated with the limitations of the line and the fact that it only went some of the way into Sydney, making commuting and commerce rather tricky.

At one point in its history, Sydney had one of the largest tramway networks in the world, servicing over 400 million journeys per year on 291km of dedicated track (*Sydney's transportation history*, 2022). The tramway peaked in 1923 and eventually gave way to the bus system, which was introduced alongside the tramway in 1905 (*Sydney's transportation history* 2022). Despite the popularity of these systems, Sydney remained mostly a walking town, evidenced by the 56% of trips taken to work by foot, compared to the 19% by tram/bus and 11% by train (Wotherspoon 2008). Sydney tried to modernize its tram system in early 1900, but beyond WW1, it saw little expansion and did not grow beyond 1922. Eventually, in 1917, the government began construction on new sections of underground rail for the city. Planners included the option for extensions to the northern and eastern suburbs, and the lines would eventually be fully electrified. The trams were eventually overtaken and replaced by the motorbus. Many Sydney residents soon turned to the rising popularity of cars and abandoned other forms of travel, which altered planning decisions in Sydney for years. As a result, Sydney had an underdeveloped and underutilized public transit system. Hosting the Olympic Games was seen as a way of addressing the issue. The Sydney Bid Committee understood that traffic congestion would be a weakness in their bid (Hensher and Brewer 2006) and that the city needed to modernize its public transit system.

Sydney: Investments in Public Transit

Unfortunately, Sydney officials did not significantly invest in public transit upgrades for the Games. The only significant investments in their transit system were a 10km rail line between the Central Business District (CBD) and the airport, a 5.3km rail link, and a brand-new Olympic Park station to serve the venues (Bovy 2019). The rail link provided access to the main Olympic site from the Olympic Park Line and opened a few years before the games while costing A$95 million (Richter 2008). One kilometre of the link was installed underground and was connected to the four-platform Olympic Park station. A $12 million interchange was created to shuttle passengers between the new link and the western line, which became a transport hub.

Freight train traffic necessitated a A$31 million flyover junction to separate freight and passenger trains (Richter 2008). A central rail line to the airport opened

in 2000 and had five total stations (four underground). The four underground stations were privately owned and operated. Securing private investment for these projects allowed Sydney to offset some of the cost of their investment. Given the level of car ownership in the city, it is surprising that they bypassed this opportunity to invest significantly in their transportation system.

Sydney: Olympic Public Transit Legacy

The Sydney Olympics left behind a questionable transport legacy due to their lack of long-term planning around their infrastructure investments. Sydney officials hoped that showing how well the transport system could perform would convince more residents to switch permanently to public transit for their average daily trips (Kassens-Noor 2010). In her analysis, Kassens-Noor questioned the impact of the poorly planned rail infrastructure. The infrastructure left residents wanting to understand due to the chronic low ridership of the Olympic loop. Government officials justified its existence with the once-a-year Royal Easter Show, which takes place on the Olympics site.

The Sydney Olympic Games witnessed high use of the public transit system and multi-modality during the Games, but they were not sustained. During the Games, all public transit was free for 24 hours for ticket holders and accredited individuals (Bovy 2019, Mulley and Montou 2015), and 95% of spectators used the service (Bovy 2019).

Mulley and Montou (2015) noted that the Sydney suburban rail network was the backbone of their transportation system, while the bus network sought to fill in the gaps between rail lines. Unfortunately, the trains still did not cover the whole city, leaving entire areas that had to rely on a bus network. At the time of the Olympics, all these modes were planned by separate organizations, which resulted in different timetables, fare scales, and tickets not being transferrable between the different modes. This made mobility very difficult for those who relied on public transit.

Mulley and Montou (2015) monitored public transit use following the 2000 Games and found disappointing results. Much of the issue with the Sydney transportation system lay in its focus on single-seat journeys. They noted that an integrated "fare" system was required. Sydney civic leaders and transportation advocates highlighted this while the bid was being prepared, but it was not realized until 2010, 10 years after the Games were staged. When the "MyZone" program was launched (since replaced by the "Opal" integrated smart card (Dixon et al. 2018b, Mulley and Montou 2015). However, the payment system remains disjointed for passengers transferring between travel modes, a requirement for many who live in Sydney. Greater coordination and symmetry remain an issue, although there seem to be recent changes implemented to help eliminate the issue (Shakibaei 2022).

Analysis by Dixon et al. (2018b) from Deloitte Insights showed how bus and rail use increased by 36% and 24%, respectively, from 2009 to 2018 while private vehicle miles only increased by 6%. A follow-up analysis done by Dixon et al. (2020b) on Sydney's transportation system outlined many of the upgrades made to

the system between 2018 and 2020 resulted in public transit mode share increasing (i.e., up 2% from 2018 to 27%) but this volume remains comparatively low. A reduction in the cost of the monthly transit pass was also seen as a stimulus that worked to increase use patterns (Dixon et al. 2020b). The city has areas to improve. The high car ownership in Sydney and the convenience that automobiles provide continue to be a barrier to enhancing the share of public transit (Nguyen 2019). Although Sydney has invested heavily in public transit, it still sees a modest percentage of only 25% which is relatively low (Dixon et al. 2018b).

The public transit legacy of hosting the 2000 Olympics in Sydney was comparatively small compared to other Olympic hosts. Like other host cities, civic leaders could have addressed the transportation issues plaguing the city through hosting the Games. One can conclude that the Sydney Games of 2000 had a minimal transport legacy.

2004 Athens Olympics

Athens: Before the Olympics

Athens is a tourist destination attracted by its rich history, Greek architecture, museums, and culture (WorldData.info n.d.). Each year millions of tourist travel to the historical city of Athens, they knew that it was the first city to host the modern Olympic Games in 1896. Athens won the bid to host the Olympic Games again in 2004. Modernizing their public transportation systems was a high priority for the city, and hosting the Games was seen as a strategic step in addressing the need. Bovy (2004) discussed how Athens' public transit was substandard for a capital city of 4.5 million people and a private car ownership rate of 415 vehicles per 100 inhabitants. Frantzeskakis and Frantzeskakis (2006) noted that only 30 percent of daily transportation in Athens was done using public transit. Athens urgently needed an upgraded public transit system to support the Games and everyday life in Athens following the Games. Securing the Games provided that opportunity.

Athens: Investments in Public Transit

Athens officials used the hosting of the Games to stimulate significant upgrades to its aging public transit system. The city doubled its metro and high-performance rail system in less than five years (Bovy 2004). The Games provided the impetus. Athens officials also significantly used the Games to upgrade their road infrastructure and added 140km of main roadways to prepare for the Games. Civic leaders focussed on upgrading/extending three metro lines, building a new suburban rail line, and building a new coastal tramway (Bovy 2004, Frantzeskakis and Frantzeskakis 2006). The first upgrade was Isap Metro Line 1, which connected Piraeus to the city center and the suburb of Kifissia (Bovy 2004). The oldest line in Athens, Metro Line 1, was significantly upgraded and modernized, making it safer for patrons and increasing the capacity to 26,000 passengers per hour in each direction. The Attiko Metro Line 2 and Line 3 were also extended to some of the

suburbs of Athens (Line 2 was developed by 2.5km with two new stations, and Line 3 was extended by 6km with an additional two stations). Part of the new suburban rail line allowed Line 3 to connect to the newly constructed airport, shortening the 38km commute to 20 minutes. A new 32km section of suburban rail linked an airport with Greece's central railway station. The final piece of the Athens public transit upgrade was the 27 km tramway system (i.e., Athens Light Rail System) which was constructed with two lines connecting Glyfada, the city centre, and the Faliro area. At the time, the plan was to have these two lines be the building blocks for a more extensive tramway system in the years following the Olympics.

The operation budget for the Olympic transportation system operation was €105 million (Bovy 2004). The upgrades to the metro system were estimated to cost €2 billion due to complications with legal settlements and archaeological finds (Martinet and Allaire 2012). The upgrades to the public transit system cost an estimated $2.45 billion USD (Kassens-Noor 2015). However, these significant investments made into public transit infrastructure were a huge step forward for the city. The staging of the Games helped the city leaders significantly upgrade an area of need by constructing a public transit system capable of moving high volumes of people around the city in a practical, economical, and environmentally responsible manner.

Athens: Olympics Public Transit Legacy

The impact of the new airport or the upgrades made to the road network fall beyond the scope of this research. It has made a difference, although Athens still struggles with traffic congestion (Kassens-Noor 2015). Some question the state of the Athens public transit system if they had yet to host the Games and access new funding sources. Martinet and Allaire (2012) suggested that Athens would likely only have received its public transit upgrades if it had hosted the Games. Olympics. Critics often point to the exorbitant cost of the Games for Athens as the reason why they should not have hosted. Admittedly, much of the spending was on cost overruns and “white elephant” competition venues which could have been avoided with better planning. However, upon closer examination, their investments in public transit have made a difference and paid long-term dividends.

Kassens-Noor (2015, p. 5) noted that “since the metro’s new line inauguration, the underground train has become an integral part of Athens’ life.” She concluded that there had been no comparable development since hosting the Games despite many grandiose plans. One of the significant purposes of increasing public transit was to induce development along the created lines. The suburban railway is underutilized since it shares the same track going to the airport that one of the metro lines uses, which in her view, makes that section redundant.

Kassens-Noor (2015) further delved into the intangible transport legacies left by hosting the Olympic Games. She discussed foremost the additions to the pre-existing bus network; four new bus lines, expanding the express bus lines, eleven new feeder lines servicing the suburban rail, and the overall bus network expansion by 180km. This has left a legacy in the inner city, where 50% of people are

transported by bus (and only comprises 3% of the city traffic). Public transport modes improved in downtown Athens due to the Olympic-expanded bus lanes used both day and night. A new bus and trolley fleet will serve the city for years. Kassens-Noor (2015) reported a 13% increase in ridership across all modes of public transit, and rider share reached 38% in 2007 (three years after the Olympics) before rising to 43% in 2011. While these data are promising, very little change in car ownership and usage has transpired due to the habits of Athenians and the public's stigma surrounding public transit.

Hosting the Games stimulated the integration and coordination of the transport agencies during the Olympics, but the change has not been sustained. An integrated Athens-central transport agency should have resulted. It worked during the Games when many people needed to be efficiently transported around the city. Still, unfortunately, city officials sat idle when public transit officials returned to the ways of the past following the Games (Kassens-Noor 2015). This has proven to be a lost opportunity for hosting the Games.

Other analysts have been more positive. Martinet and Allaire (2012) suggested that the new infrastructure increased public transit mode share by 10% from 2003-2006. Hosting the Games and investing in public transit made a difference. This researcher pointed to other positive developments to the transit system due to hosting the Games (e.g., the extension of dedicated bus lanes, city centre tram lines, and metro lines combined with the renewal of the bus fleet).

In conclusion, Athens maximized the upgrades to their transportation system that citizens and tourists have used since hosting the Games. Naturally, and in hindsight, they could have done more to integrate the systems fully on a long-term basis. However, all told, Athens is considered a success story relative to how the city hosted the Games to modernize and expand its public infrastructure. A more integrated system and a social marketing campaign to get citizens to reduce their dependence on cars could help ensure long-term benefits for the hosting experience.

2008 Beijing Olympics

Beijing: Before the Olympics

One of the largest cities in the world and the capital of China, Beijing was selected as the host of the 2008 Olympics in July of 2001 after a failed bid to host the 2000 Olympics (GamesBids 2022). Beijing is famous for its rapid urbanization at the turn of the 21st century, and the trio of Olympic bids since shows the desire of China leaders to showcase its economic prowess to the world.

Beijing is an industrial city, containing 120 of the 130 national industrial sectors and 67.3% of the city's economic base emerging from heavy industry (Wang 2011, as cited in Yamawaki and Tomaz 2019). Throughout much of the city's history, industrial growth was the primary concern, and little thought was put into housing or transportation standards. These attitudes shifted with China's rapid urbanization in the late 20th and early 21st centuries.

The first subway line was built in 1965, albeit for military purposes (Yamawaki and Tomaz 2019). The line underwent multiple changes and was finally opened to the public in 1981. It was mainly used to transport those who had migrated from the countryside to the city and had settled in cheap suburban housing to and from their jobs in the city center. A lack of coordination between land use and transportation systems made citizens highly dependent on private transportation. A plethora of automobiles on the roads created gridlock, so some bus lines took four times longer to complete their routes. This congestion led to Beijing expanding its ring road system and adding five new highways in 2008 to facilitate traffic.

Before the Olympic bid, Beijing only had two metro lines serving the city's center (Yamawaki and Tomaz 2019), and most public transit occurred via an extensive bus network (Doneliza 2012). This was not acceptable for hosting the Olympic Games or the future development of Beijing. China realized that it needed to make a change, and hosting the Olympic Games of 2008 allowed city leaders to make the change.

Beijing: Investments in Public Transit

Beijing invested heavily in public transit after winning the bid to host the 2008 Olympics. Over $USD20 billion was spent on the total transportation system in the seven years leading up to the Games (Bovy 2009), and a significant portion of USD 9B was spent on public transit (Hays 2010). The public transit system was expanded by 143.61km of new line, and passenger load capacity was expanded to up to 200,000 on the 1,420 vehicles (Yamawaki and Tomaz 2019). Three new lines on the Beijing subway system increased the system's reach by 40% to 200km (Cortes IV 2008). The new lines cost $3.3 billion USD and were constructed on time for the Games (Cortes IV 2008). The Olympic Rail Transit Network Command Centre was installed in July of 2008 for the Games, and a newly constructed rail line to the airport now delivered passengers to the downtown area in 30 minutes (Beijing Organising Committee for the Games of the XXIX Olympiad and Beijing Organising Committee 2008). Ironically, many of the public transit expansions at the time did not serve Olympic venues, despite being included in the financial package for the Olympics.

Beijing: Olympics Transport Legac

Beijing had a long-term plan and put the needs of the city first. They developed and implemented a robust public transit plan to serve the city better with more efficient transportation (Yamawaki and Tomaz 2019) and used the hosting of the Games as the catalyst for change. The urban rail system consolidates access to the new city centre areas. All but one of the SEZs experienced significant growth from 2004 to 2008 over the 2001 to 2004 period when the subway system was expanded. Public transit infrastructure excitement played some role in the development of these zones.

Beijing needed to make public transit an attractive alternative to private transportation. Hosting the Games and investing in more public transit appeared to

work Mao (2008) pointed to increasing the cost of parking in the city center, improving the efficiency of the transit design hubs, giving transit vehicles more priority over private traffic, and enhancing government information about the importance of using public transit were the specific reasons.

Beijing's public transit share of modal transport was 28.2 in 1986, 26.5 in 2000, and 29.8 in 2005 (Mao 2008). This shows a decline in popularity before the commitment to further investment, which led to a modest increase in mode share in the lead-up to the games. This trend continued in the years following the Olympics. However, Dixon et al. (2018a) suggested that despite the significant investments in public transit, mode share remained relatively low (i.e., 36%), and use still commanded 28% of the traffic share.

Were there transportation benefits for Beijing as a result of hosting the Games? Beijing would have undoubtedly upgraded its metro system without hosting the Games. The only investment in public transportation for the Olympics was the Olympic line built to service the Olympic Green SEZ (Doneliza 2012). Legislation has changed use patterns, not access to new transportation services, for example. Beijing bans private cars from entering the 5th Ring road for one of the workdays each week based on the last digit of their license plate (Mao et al. 2016). This makes it hard to compare traffic metrics since the city has built-in artificial governors to control congestion that only exists in other cities. Regardless, Beijing made significant and lasting upgrades to its public transit system that should provide tangible benefits to city residents for decades to come, especially with legislative policies supporting the greater use of public transit.

2012 London Olympics

London: Before the Olympics

Founded by the Romans in 43 AD, London flourished during the Victorian era, its population boomed, and by the end of the nineteenth century, it had become a world city and an important trade hub as the British Empire rose to prominence (Civitatis n.d.). The town historically used omnibuses as the first mode of public transit, which evolved into the use of motorbuses as they rose to prominence in the early 1900s (Transport for London n.d.). The lack of a monopoly over bus services resulted in fierce competition and rapid expansion of bus lines. Through the 20th century, the bus network in London underwent many changes and authority organizations before finally evolving into the current Transport for London (TFL) organization.

London's first underground railway was built in 1863 with six stations (Railway Technology 2006). The following 50 years saw much of the central network completed with shallow tunnels fitted with covers and vents while new technologies allowed for deeper tunnels making the following 50 years marked by the expansion of the lines into suburban neighbourhoods to further connect the city. No new lines were built over 60 years until 1968. The Victoria Line opened for the first time, followed by the Jubilee Line opening in 1979 and expansion to

the docklands in 1999. The Docklands Light Railway (DLR) was opened in 1987 to help redevelop the Docklands area, containing 11 trains along 15 stations. Four extensions were completed along the system between its inception and when London was making its bid for the 2012 Olympics. The railway operates on a private franchise model, with TFL responsible for managing the relationship and the DLR.

London once had an extensive tram network that was phased out in the 1950s in favour of cars and buses (Transport for London n.d.). Trams were re-introduced in Croydon in 2000 to combat congestion and make the city more interconnected. Some of the routes followed old unused rail lines, and the system was run by a private entity which was eventually bought out in 2008 by Transport for London, who purchased more trams to allow for better frequency of service.

However, only some people paint the same optimistic picture of the state of the London transportation system. When London was making its bid for the 2012 Games, its public transit system was described as "obsolete" (Bovy 2013). Wolmar (2004) described the pre-Games transportation system as overcrowded and plagued by poor planning and route scheduling. The city lacked transport lines that Londoners desperately needed, including the East London Line. London needed more public transit infrastructure and needed it on a short timeline. This was a perfect time to bid for the Games and access revenue sources to improve the system.

London: Investments in Public Transit

London undertook a bold plan to bolster their public transit systems, specifically their rail network. Stratford received a new international station with a high-speed Javelin stop seven minutes from St Pancras station (Bovy 2013). The Stratford regional station was vastly improved along with the King's Cross-St Pancras station (Bovy 2013, Transport for London n.d.). The Dockland Railroad was extended to Woolwich and Stratford International and saw a 50% increase in capacity. They added capacity to the Central and Jubilee Lines and upgraded to 30 trains per hour at peak times. The "orbital" London rail network was completed, and London Overground (the above-ground rail network in London) was refurbished on the East London and North London lines. Southfields and Green Park were given step-free stations to aid in accessibility. Refurbished piers, simplified maps and timetables, and Oyster pay-as-you-go fares aided commuter services along the Thames. Rail transport was extended throughout London, and all the venues were accessible by at least one metro station (Bovy 2013). The Crossrail project was in its planning stages at the time of the Olympics but was not deemed essential in the transportation plan, though it is being completed now (Railway Technology 2006). London placed a high priority on its public transit system and used the opportunity of the Olympics well to provide the city with a once-in-a-generation upgrade to the system.

London: Olympics Transport Legacy

Congestion and the need for an upgraded public transit system remained an issue as the city assembled its bid to host the 2012 Games. Significant public transportation upgrades were weaved into the bid documents. The strategy paid off. The public transport system, updated and expanded for the Games, performed admirably and remained a legacy of hosting the Games. Branded as the "Public Transport Games," the host planners ensured that the hosting of the Games resulted in a public transit legacy. The mayor was committed to reversing the trend of underinvestment in East London and providing tangible benefits to the city's most disadvantaged residents. The legacy plan included the proposal of the Mayoral Development Commission (MDC), which would absorb power from many Olympic planning bodies to become the sole authority for catalyzing regeneration in the area (Dept. for Culture, Media and Sport 2010). There were many actionable items presented in the plan. However, many of them lacked specificity and would have easily confused the level of commitment being made by London city officials.

London officials ensured that East London gained a rail system that proved its efficiency during the Olympics and long after the completion of the Games (Bovy 2013). The system was designed with growth in mind; planners ensured reserve capacities for medium- and long-term development. It was vital to recognize that the community's needs will sometimes be dynamic, requiring a system that can adapt alongside them. The trains purchased for the Olympic Games will still be in use in 2042, and the lines extended to support travel during the Olympics will still be in use in 2112, a century after they were installed (IOC 2021).

Despite the significant infrastructure improvements, London has yet to experience the spiked public transit usage that it anticipated. The 29% mode share of public transit is still relatively low, given the investments made into the system (Dixon et al. 2020a). The monthly cost of a transit pass has increased from $159 in 2018 to $190 in 2020 (Dixon et al. 2020a). London could have scored better in the affordability of public transit score on the CPI with a 67.14 out of 100. They were the highest-scoring city studied for the length of mass transport network (48.95/ 100), though the mediocre score on the metric shows that they still have a way to go. If the system is not affordable, it does not matter how much infrastructure there is. Public Transit mode share has continued to rise throughout the years. Mode share statistics show that by Q4 in 2019, public transit mode share had increased to 35.6% compared to the 29% in 2015 (Mayor of London and Khan 2020). Continued investments into the system allowed it to improve steadily, while the commitment to maintaining the MDC has allowed the city officials to continue with infrastructure and neighborhood developments (Law Insider n.d.). Overall, London hosted the Games to address underserved areas of the city with sound public transit investments.

2016 Rio de Janeiro Olympics

Rio de Janeiro: Before the Olympics

Before the Olympics, Rio de Janeiro had an overstretched and disconnected transit system. The geography of the city makes planning for public transit very difficult. Rio de Janeiro contains the world's largest urban park -Tijuca National Park, in the city's centre (Bovy 2017). The park extends for 105 square kilometres of sprawling mountainous sub-tropical forest, with mountainous topographical features dividing the city into four distinct areas. Serving the residents through public transit has proven to be a challenge.

According to the bid committee officials (Rio 2016 Bid Committee, The Olympic Studies Centre 2009), when organizers began assembling their bid in 2008, they concluded that Rio de Janeiro lacked public transport infrastructure for a city of its size and geographic characteristics (e.g., 37 km of metro, 225km of suburban rail, and 749km of roadways and arterial roads). A lack of system integration was also problematic and led to low ridership. Rio de Janeiro officials hoped to transform their public transit system by hosting the Games. Planning decisions made for the Olympics helped catalyze the public transit connections that now exist across the city. Civic leaders decided to locate the Olympic venues across all four city centers to encourage development across the whole city, which led to the necessitation of transport development between all four areas (Bovy 2017).

Rio de Janeiro: Investments in Public Transit

Rio prioritized public transit in their Olympic bid and made significant investments in the system to add many new lines and higher capacities. The candidature files for Rio for the World Cup and the Olympics showed a plan to create a high-capacity transport ring that would connect critical areas in the city and benefit "low-income workers" the most: the group most likely to live on the edges of the city and have long commutes in to work (Pereira et al. 2019). They spent $4.5 billion in the years leading up to the games on public transit infrastructure and programs. Cost overruns and political corruption drove up this significant figure.

For the most part, Rio over-delivered on most of the public transportation promises outlined in their bid. The rapid rail line (RRL) connecting Barra to the South Zone was one exception (Bovy 2017, Rio 2016 Bid Committee, The Olympic Studies Centre 2009). It was replaced by the rapid bus line (i.e., RBL) that extended an additional 79km of lines from the promised rail line. The light rail system was developed after the original bid, and the new metro line extended 11km in 2016.

The primary public transit upgrades were centred around four systems, namely: (a) a new BRT system; (b) an extension of the metro; (c) suburban rail upgrades, and; (d) a new light rail system (Bovy 2017). The new BRT system was extensive, covering 122 km and composed of three lines. There were plans to have

the system extended to 150km by 2018, making the system one of the largest under centralized control. They developed 15km of new metro line to connect Barra da Tijuca with the South Zone of Rio. A 30km stretch of the suburban rail significantly improved service and mobility, while six new stations underwent significant renovations. The final upgrade to the city's infrastructure was the new 15km light rail system built to link the airport with the city's central bus terminal; there were plans to put in a second line in 2017-18 to double capacity.

Rio de Janeiro: Olympics Transport Legacy

Rio made significant investments in their public transit infrastructure, but questions remain about the impact of the assets and subsequent policy decisions. A severe economic downturn resulted in a 70% drop in the budget of the Secretary of Transport (Pereira et al. 2019). A significant decline in the ridership of the public transit system followed (France 2016). In 2016, there needed to be more clarity about the status of the public transit system. Fifty-one lines were removed while 25 new ones were added, and 26 more had their lines shortened or altered (France 2016). Pereira reported a darker picture, with 70 bus lines being eliminated (out of 485), 41 rerouted or shortened, and only 16 new lines created (Pereira et al. 2019). The economic challenges and commensurate impacts on public transit investment led to widespread criticism of the government and civil unrest. Some experts claim increased violence in Rio has led to more people avoiding busses due to heightened security threats (France 2016).

Only a year after hosting the Games, there were widespread criticisms of the cost overruns of the infrastructure projects and the corruption within contracted companies and politicians that decide who gets the construction bids (Sandy 2016). A criminal probe named "Operation Car Wash" investigated many of the firms contracted to build the infrastructure projects for the Olympics. The results determined that a cartel of construction companies offered significant bribes to hundreds of politicians across the political spectrum, leading to substantial cost overruns. Internal documents released by Odebrecht, the company contracted to work on the new subway line- showed that bribes were made to 316 politicians across 24 parties. It also found that Odebrecht had a specialized department specifically mandated to handle the bribe payments.

Quieroz and Legroux (2014) discussed how the "transportation revolution," as labelled by the Rio government, is a one-sided focus that ignores the other issues surrounding the issue of urban mobility, often overestimating the benefits of limited mobility projects. Quieroz & Legroux highlighted one of the principal problems with how planners and city officials handled the 2016 Olympics. They were too focused on the short term and tended to ignore the main issues plaguing the city and their root causes. Rio was beset by traffic congestion and did little outside of the public transit investments to stimulate public transit solutions. Car use rose from 1.6 million vehicles in 2000 to 2.5 million in 2011.

One of the significant points of criticism came from the modal choice that was made when the Rio government decided to do most of its public transit upgrades through a bus rapid transit (BRT) system. Interviews done by Jean

Legroux (Queiroz and Legroux 2014) indicated that public opinion did not favour the BRT system due to its low capacity and lack of ability to match the needs of a developing city. Kassens-Noor et al. (2016) concluded that the BRT planning did not take the origin and destination studies into account, which were based on urban densities and employment centers (Governo do Rio de Janeiro 2013, as cited in Kassens-Noor et al. 2016). The BRT that was implemented was used to promote road widening and ultimately created more space for cars in areas where expropriation was necessary for construction (Quieroz and Legroux, 2014). In many cases, these researchers noted that additional lanes were not needed for the BRT system, and the expropriation of people living alongside the road was carried out to create room for cars and not the BRT system.

Pereira et al. (2019) suggested that average access to schools and jobs by public transit fell by 4.5% to 6.1% between 2014 and 2017 in Rio. They found that the investments alone should have improved access and rationalized that the drop was likely due to the rationalization of using bus lines and recent cuts/changes in service. Additional analysis found that schools were more adversely affected by the policies than jobs were and that most of the accessibility losses were in poorer neighbourhoods, while most of the accessibility gains were in wealthier neighbourhoods. A cluster analysis showed how the light-rail system did not significantly improve access to jobs or schools, while the new metro line in the south of the city improved access for various poor and wealthy neighbourhoods. The results of this study show that there is still hope for Rio. The infrastructure upgrades improved access independently, but they also needed to be followed with sound policy decisions that ensure accessibility and affordability for all users.

Ribeiro and Almeida (2021) painted a dim picture of the public perceptions of the public transit system. They conducted cross-sectional surveys before and after the 2016 Olympic Games on citizens who lived in Rio de Janeiro to assess their perceptions of the transport legacy left by the Olympics. Resident perceptions were measured against five main factors concerning the public transit system, namely: (a) planning; (b) infrastructure; (c) insecurity; (d) public transit information, and; (e) urban mobility. The results showed that the Olympics negatively impacted resident perceptions of the public transit system, decreasing across every factor except public transit information. Perceptions can vary widely based on innumerable complex and interconnected factors. However, when combined with other research echoing the same sentiments, the criticisms against the Rio public transit system appear to be justified.

Rio has a costly public transit system concerning average wages, which makes it burdensome for those lower on the socioeconomic ladder; Rio scored 0 on the CPI index for transport affordability. While the total infrastructure was added significantly, Rio still needs more public transit infrastructure for a city of its geographic size; it scored 31.54 on the CPI index for the length of the mass transport network.

However, it is not all of the results are negative. The hosting of the Olympics and the World Cup resulted in significant upgrades to Rio's transportation system in a very short period of time (Pereira et al. 2019). Bovy (2017) noted that in 2011 1.1 million daily trips were made on public transit, and this level rose to 2.3

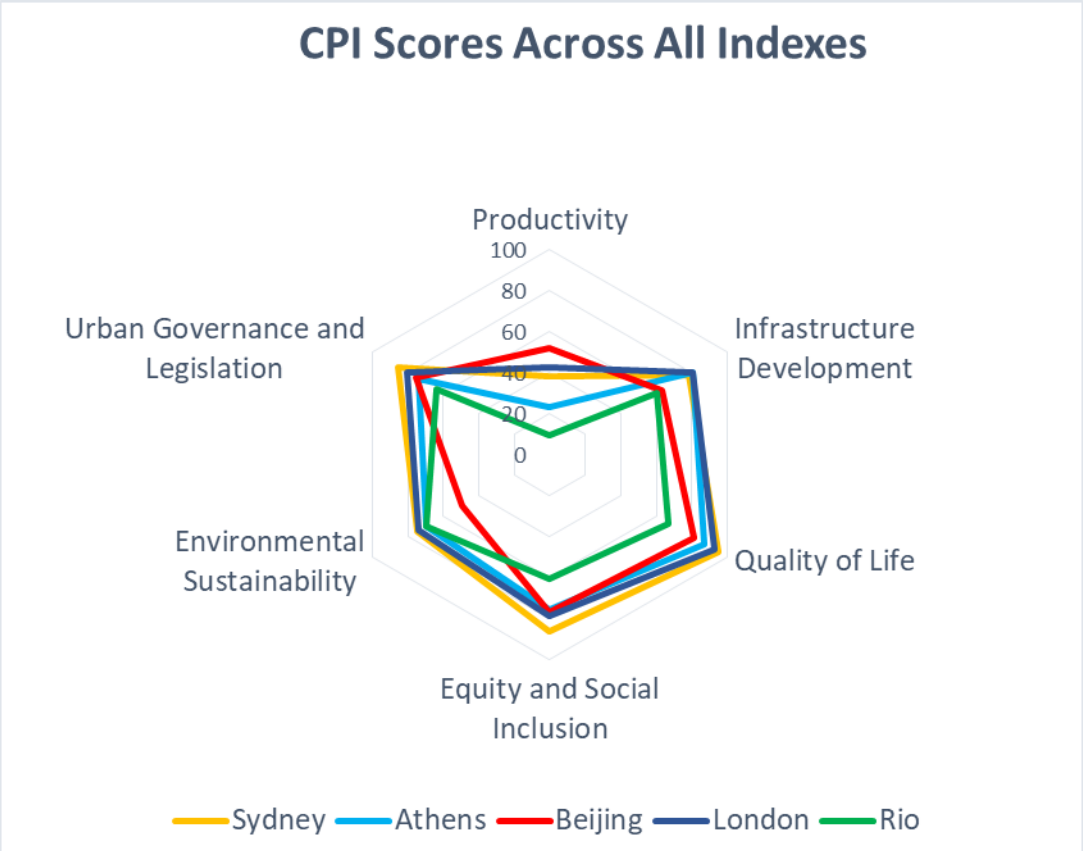
million in 2016. Rio has a reasonably functional public transit mode share compared to other cities; 48% of trips are taken on public transit. All the trains in the city are electrified, which is critical to reducing transport emissions for the city (Rio 2016 Bid Committee, The Olympic Studies Centre 2009). Rio has established a much more competent system than it had in the past, and it should allow the city to continue to develop and improve quality of life so long as competent planning and policy decisions support the system.

Overall City Performances

Comparing the Scores of All Cities

All the scores for the individual indexes were summated and averaged to provide each of the five host cities with a CPI score out of 100. Sydney had the highest cumulative CPI score of (76.04) followed by London (74.78), Athens (68.19), Beijing (66.14), and Rio de Janeiro (54.97). The total CPI score and the score for each index were compared against the spending on public transit investments for the Olympics. The comparison of the total CPI scores is presented in Figure 1.

Figure 1. *CPI Scores for Olympic Games Hosts After They Have Hosted*



Discussion

Public Transit Spending and System Performance

There is not a noticeable relationship between public transit spending for the Olympics and overall city prosperity. Increased spending did not necessarily result in better overall prosperity. A larger urban redevelopment strategy was taking place in Beijing at the time of planning for the Olympics, evidenced by the highest spending of any host studied. Meanwhile, Beijing did not have top scores for any index except for the Productivity Index, which showed Beijing outscoring all the other cities by a significant margin. However, the rest of the data do not support a connection between the CPI and public transit spending. This relationship was also shown in the Infrastructure Development Index, the sole index that should be influenced most heavily by investments into public transit. Many of these indexes suggest that public transport spending has little impact on the prosperity of a city.

This lack of connection raises questions since literature shows that public transit can provide innumerable benefits to communities and their residents. So why does this relationship fail to appear in these data? Each city had its own history and unique circumstances, while only taking post-event data assumes a similar starting point. Additionally, many circumstances can impact the efficiency of spending dollars, including labour costs, planning efficiency, and political corruption.

Olympic public transport projects often only impact some of the city but focus on a small area needing improvement which leads to an unequal distribution of benefits which lessens any relationship that appears in the data. New research should work to find a way to measure policy decisions and convey their importance quantitatively while taking spending efficiency into account. These data suggest that policy decisions are as crucial as infrastructure spending.

Best Practices for Public Transit and the Olympics

By identifying best practices for public transit investment and planning, cities can maximize the efficiency of their transportation systems while making transportation more easily accessible to all residents. Proper planning results in numerous benefits, such as lower congestion, better air quality, economic prosperity, and improved physical fitness.

A successful public transit system that meets the needs of the city's residents will contain multiple modes of transport. Research by Mulley and Montou (2015) discussed multi-modality, which is when someone uses more than one mode of public transit to get where they need to go. Nielson et al. (2005, as cited in Mulley and Montou 2015) argued for multimodality to build more efficient networks, which allows cities to offer service more frequently to individual users. They mention how the cities that have embraced multi-modal trips have also focused on making interchanges between modes as fast and easy as possible. A multi-modal system can connect places in ways that a direct system cannot, so making connections fast and easy for the user allows a city to become very accessible and connected, assuming that the city has an appropriate amount and placing of public

transit infrastructure. Without proper organization and coordination, the multiple modes will have difficulty complementing each other, resulting in a disconnected service. The first recommendation is that cities create a complimentary hierarchy of public transit modes that services the needs of different areas and corridors and strives to make connections between modes as easy and convenient for the user as possible.

Historically, when building public transit projects for the Olympics, the focus has been on satisfying the short-term needs of the Olympic spectators and officials. Planners must start thinking differently when planning public transit infrastructure projects. The thinking must shift towards the long-term needs of the cities, which are not the temporary transit patterns experienced during the Olympics, but rather the long-term established practices that have been developed over time and represent where people travel regularly (Kassens-Noor 2010). The second recommendation is that host cities look at the established movement patterns and then develop transit solutions that meet the current needs of the city with room for the city to continue to grow and add capacity if needed. By focusing on the residents over short-term event spectators, cities can maximize their investment and reduce the likelihood of investing further to fix poor design choices.

When investing in public transit, cities need to fully understand the different modes of public transit and the benefits and drawbacks of each. Beyond having this understanding, they need to match the modes they choose with the city's long-term needs. A poor example of planning was seen in Rio de Janeiro for the 2016 Games, where planners and city officials decided to implement 100km of dedicated BRT lines as the primary form of mass transit. As a result, Rio has locked itself into a fixed capacity system in a rapidly growing city. Planners need to do extensive research on the travel patterns of city residents while combining those patterns with growth forecasts for the city. By looking at the current and long-term needs of residents, planners can select better modes that fit what the city needs. The third recommendation is that city planners make mode choices based on the circumstances and long-term needs of the city, outside of pressure from stakeholders to choose the cheapest and least intrusive option; in many cases, cities require bold solutions to their transportation issues, but there is always pressure to reduce costs.

The area that needs to be addressed by Olympic hosts is the integration of transport entities and the creation of a single transportation authority that carries on knowledge from the hosting of the Olympics. These authorities already exist during the staging of the Games, working to coordinate different agencies to provide a seamless experience for the end user (Kassens-Noor 2010). However, once the Games finish, these authorities are usually dissolved, giving power back to the respective agencies and returning to a normal state where change processes are much more bureaucratic and drawn out. Often, the knowledge gained by the management of Olympic transport officials is lost through the split. She identified how cities can encourage institutional change by planning for a post-Olympics integrated transport system and by establishing “guardians” to exist past the Olympics are gone, and in doing so, ensuring that the set goals and vision are being met. Mulley and Montou (2015) echoed this sentiment, discussing how it is

easier to provide a better interconnection and multi-modal experience when there is coordination between the organizations responsible for providing public transit. They caution that a single organization is not the only route to developing an efficient system, so there is good communication and cooperation between the parties responsible for providing the service. The fourth recommendation is that cities work to keep the planning and coordination power gained during the hosting of the Olympics; this power allows changes to happen much more quickly and efficiently compared to traditional bureaucratic processes.

Kassens-Noor (2015) offered three recommendations for Olympic host cities relative to their transportation system. Cities should emphasize creating a strategic planning approach that will outline the actions that need to be taken and the goals for the city to leave a positive transport legacy. She recommended the establishment of an "entity" that will watch over the progress during and after the Olympics to ensure that goals are being met and the legacy is being upheld while making strategic adaptations when different circumstances arise. Finally, cities should commit time, resources, and personnel to improve the transport system after the Olympics to avoid any post-Games developmental slump. This recommendation follows those given by Kassens-Noor (2015). She called for the establishment of a long-term strategic plan that exists outside of the Olympics. She suggested the appointment of someone who will monitor the progress compared to the project both before and after the Olympics and maintain a focus on infrastructure improvement after the Games have drawn to a close.

Areas of Criticism/Recommendations

Sydney needed to effectively address their public transit needs due to hosting the 2000 Olympic Games. The completed projects did not match the city's needs, evidenced by their chronic low ridership (Kassens-Noor 2010). Though they can be commended for not overspending on expensive upgrades, Sydney missed out on an incredible opportunity to reshape its public transit system for the better. The city should have spent more time studying the travel patterns of its citizens to identify high-capacity corridors where public transit could alleviate pressure from the road network. Sydney did not eliminate financial penalties for mode transfers until 2022 in a city that often requires multiple modes to get from one place to another (Mulley and Montou 2015, Shakibaei 2022). This significantly hampered the desire for residents to switch from private automobiles to public transit, shown in the perpetual high car ownership and low mode share for public transit. Now that Sydney has improved the multi-modal experience, the focus should remain on adding capacity and reach to the system while promoting public transit over private cars.

While Athens should be commended on the amount of infrastructure that it built in the lead-up to the Olympics, it should be equally criticized for the planning of the construction and the post-Olympic period. The lack of assigned responsibilities in the early stages led to cost overruns from the frantic building pace that was required to catch up to the Olympic timeline (Kassens-Noor 2015). Poor infrastructure planning led to multiple trains running along the same section

of track to the airport, making one of them redundant. A lack of foresight saw the ATHOC dissolved after the conclusion of the Olympics, with no central agency destined to take its place, resulting in much of the gained knowledge being dispersed and eventually lost. The Traffic Management Center saw a need for more investment post-Olympics. The Olympic tram line chronically suffers from long travel times and underdevelopment. Athens needs to develop a centralized agency to coordinate multiple institutions and make operations and upgrades much easier to implement.

Citizens of Beijing must deal with an expensive transportation system that, while extensive, places financial strain on the lowest members of society. In the CPI analysis, Beijing scored 15.45/100 on the index for affordability of public transit. Mao et al. (2016) criticized Beijing for the lack of attractiveness of its public transit system in 2008, who cited too much parking in the city center, low efficiency of the system and the hubs, and poor access to transit information as the main causes. Public transit modes showed the lowest ride satisfaction of the five modes studied in 2016. Beijing should focus on increasing the experience for public transit users, making the system more efficient and affordable for the average person. They should also continue to seek opportunities to add to the system, increasing interconnectivity between city districts.

There are a few areas of criticism for the London 2012 Games. The focus on making necessary upgrades and creating a transport legacy for the Games ensured that there were real benefits brought to the residents of London. London had a relatively low score on the CPI index for affordability of transport (67.14). In contrast, the length of the mass transport network index score (48.95) indicated that London needs to continue investing in the size of its public transit network. London needs to keep improving the size and accessibility of the system to present it as a more viable alternative to private cars while working to keep the system affordable for everyone.

Much of the planning and building for the Rio de Janeiro Olympics was rife with corruption and bribes for lucrative contracts, leading to significant cost overruns on public transit projects. While Rio de Janeiro added significant infrastructure and connected areas that were previously only accessible by congested roadways, the mass transport they chose to implement did not fit with the city's long-term goals. Rio locked itself into a fixed capacity system (BRT) that is less efficient than rail and needs to be equipped to deal with a growing population and demand for transport (Quieroz and Legroux 2014). Only some other initiatives were taken on to tackle the problem of congestion, and new transportation lines were used as an excuse to cut existing lines and make changes to the system with poor information relay to residents. The BRT system was used as an excuse to widen roadways and add lanes, increasing the total space devoted to motor traffic under the veil of public transit. The BRT should have considered established movement patterns and the lack thereof limited the lines' effectiveness. Finally, the cost of the public transit system is burdensome to residents, evidenced by a score of 0 on the CPI index for affordability of transport. Rio planners and officials should study origin-destination studies to determine the best places to invest in further public transit infrastructure. When the best locations have been

decided, higher capacity modes than BRT should be chosen due to their ability to adapt to the city's growth. Rio should make information about the system more easily accessible and should work to reduce the cost of use for residents.

Conclusion

Through examining five modern Olympic host cities and the improvements made to their transportation systems in the name of the Olympics, one of the most significant factors influencing the legacy of an Olympic host is the post-event planning set out in the bidding process. Most of the cities studied should have taken advantage of the hosting opportunity to develop a futuristic and integrated public transportation network for their city. This is a lost opportunity and a shame.

Sydney did not maximize the opportunity of the Olympics, barely adding to its public transit infrastructure and abandoning support for multi-modality after its success during the Olympic period. They can be commended for not creating unmanageable debt for the city, but they should have taken advantage of an opportunity to create a substantial legacy.

Athens had its share of problems but found a way to develop a significant amount of needed public transit infrastructure, leaving the city with the tools to create prosperity in the near and distant future. Unfortunately, many promised developments alongside public transit lines never came to fruition, and a lack of post-event planning led to underutilization and inefficiency of the public transit system. Athens is famous for the debt it incurred from the 2004 Games, but its financial position should be balanced with the incredible physical legacy that was left.

Beijing invested significantly in infrastructure, more than any city studied in this paper. They expertly married the needs of the residents with the needs of the Olympics, mainly using a plan that would be put in place regardless of whether they hosted the Olympics. Though they followed Athens by creating a physical legacy for the city, they made the same mistake of ignoring the importance of policy. The result is that some have seen the public transit in Beijing as inefficient, expensive, and unattractive as a transportation option. Beijing has work to do regarding the attractiveness of its public transit system, but the genuine investments that have been made make improvements possible through policy.

London created a lasting transportation legacy for the city by focusing on a legacy plan and implementing the Mayoral Development Corporation, which oversees the progress of the city’s development and can buy/develop land to meet city goals. London improved areas in dire need of public transit upgrades and expansions, emphasizing the entire experience for public transit users. As a result, London has arguably left the best transportation legacy in the history of the Olympics.

Rio de Janeiro made the most significant expansions to its public transit system, surpassing the plans outlined in its bid. Unfortunately, corruption and poor policy decisions have negated the benefits to the city. Public transit in Rio is seen as expensive and unsafe, and information about the system is not easily accessible.

Rio has a long way to go before realizing the expected benefits of their public transit upgrades.

The CPI analysis shows that public transit spending does not necessarily correlate with city performance, even in the infrastructure development index, which contains several measures on public transit. This suggests that other factors influence prosperity, one of which could be policy decisions by city planners and officials. An analysis of best practices suggests that cities need to change the focus from the Olympic user to the city's residents, and that data surrounding their habits and movements should be used to guide public transit decisions and policies. Cities must establish a long-term plan flexible enough to adapt when required but rigid enough to withstand time and the potential for dwindling attention. Individuals should be identified to uphold these plans and ensure that transport legacies are being met. Once the Olympics are gone, cities should establish centralized agencies that retain the coordination and power that the Olympic planning organizations used to develop Olympic projects. All these practices lead toward creating a tangible legacy for a host city that can be measured in the performance of its public transit system. By maximizing legacies, the Olympics can continue to grow, and attention can shift away from problems with hosts to the incredible events and athletic achievements on display.

References

Arbury J (2005) *From urban sprawl to Compact City: an analysis of urban growth management in Auckland*. Thesis. Greater Auckland. Available at: https://www.greaterauckland.org.nz/wp-content/uploads/2009/06/thesis.pdf.

Beijing Organising Committee for the Games of the XXIX Olympiad, Beijing Organising Committee B (2008) *Preparation for the Games, New Beijing Great Olympics: official report of the Beijing 2008 Olympic Games (2008).* Beijing Organising Committee. Available at: https://stillmed.olympic.org/. Documents/Reports/Official%20Past%20Games%20Reports/Summer/ENG/2008-RO-S-Beijing-vol3.pdf.

Bovy P (2004) Athens 2004 Olympic Games transport. *Road and Transport* 7(8): 45–48.

Bovy P (2009) Beijing 2008 Olympic Games success: massive public transportation developments and major road traffic reduction. *International Association of PT* 58(3): 52–55.

Bovy P (2013) *London 2012: best public transport Olympics ever*. ms, Chexbres.

Bovy P (2017) *Rio 2016 Olympic Games public transport outstanding legacy and mobility*. Mega Event Transport and Mobility. Available at: https://www.mobility-bovy.ch/page1/page1.html.

Bovy P (2019) Institute for Transport Planning and Systems: IVT Seminar. In *Mega Event Transport and Mobility*. Zurich. Available at: https://www. mobility-bovy.ch/.

Brueckner JK (2000) Urban sprawl: diagnosis and remedies. *International Regional Science Review* 23(2): 160–171.

City of Vancouver (n.d.) *Population*. City of Vancouver. Available at: https://vancouver.ca/news-calendar/population.aspx.

Civitatis (n.d.) *History of London. The evolution of UK's Capital City*. Civitatis London. Available at: https://www.londoncitybreak.com/history#:~:text=London's%20foundation,influence%20of%20its%20major%20port.

Cortes IV C (2008, July 19) *Beijing opens new subway lines for Olympics*. Reuters. Available at: https://www.reuters.com/article/us-china-subway-beijing-idUSSHA30 105120080719.

Dept. for Culture, Media and Sport (2010) *Plans for the legacy from the 2012 olympic and Paralympic Games*. London, Greater London.

Dixon S, Hecker M, Ma CJL (2018a) (Rep.) *Deloitte City Mobility Index: Beijing*. Deloitte Insights. Available at: https://www2.deloitte. com/content/dam/insights/us/ articles/4331_Deloitte-City-Mobility-Index/Beijing_ GlobalCityMobility_WEB.pdf.

Dixon S, Irshad H, Spanjaard L (2018b) (Rep.) *Deloitte City Mobility Index: Sydney*. Deloitte Insights. Available at: file:///C:/Users/kenne/ Downloads/deloitte-au-about-city-mobility-index-sydney-310518.PDF.

Dixon S, Milligan T, Smith V (2020a) (Rep.) *Deloitte City Mobility Index 2020: London*. Deloitte Insights. Available at: https://www2.deloitte. com/content/dam/insights/us/ articles/4331_Deloitte-City-Mobility-Index/London _GlobalCityMobility_WEB.pdf.

Dixon S, Siddall M, Houghton L (2020b) (Rep.) *Deloitte City Mobility Index 2020: Sydney*. Deloitte Insights. Available at: https://www2.deloitte. com/content/dam/insi ghts/us/articles/4331_Deloitte-City-Mobility-Index/Sydney_GlobalCityMobility_ WEB.pdf.

Doneliza J (2012) *Olympic Transportation Planning: the legacies of Barcelona and Beijing*. Thesis. Columbia University Libraries. Columbia University. Available at: https://academiccommons.columbia.edu/doi/10.7916/D80R9 WG2.

France R (2016, December 11). *Ônibus Perdem Passageiros Durante a crise*. (Buses lose passengers during the crisis). O Globo. Available at: https://oglobo.globo.com/rio/ onibus-perdem-passageiros-durante-crise-20625497.

Frantzeskakis JM, Frantzeskakis MJ (2006) Athens 2004 Olympic Games: Transportation planning, simulation and traffic management. *Institute of Transportation Engineers. ITE Journal* 76(10): 26–32.

GamesBids (2022, February 28) *Past bid results*. Available at: https://gamesbids.com/eng /past-bid-results/.

Gordon BF (1983) *Olympic architecture: building for the Summer Games*. Wiley.

Hays J (2010) *Venues and infrastructure for the 2008 Olympics in Beijing: facts and details*. Available at: https://factsanddetails.com/china/cat12/sub79/item1009.html.

Hensher DA, Brewer AM (2004) *Transport: an economics and management perspective*. Oxford University Press.

IOC (2021, September 2). *Transport improvements and behavioural shifts - Olympic news*. International Olympic Committee. Available at: https://olympics.com/ioc/lega cy/london-2012/transport-improvements-and-behavioural-shifts.

Kassens-Noor E (2010) Sustaining the momentum. *Transportation Research Record: Journal of the Transportation Research Board* 2187(1): 106–113.

Kassens-Noor E (2013) Transport legacy of the Olympic Games, 1992–2012. *Journal of Urban Affairs 35*(4): 393–416.

Kassens-Noor E (2015) The legacy of the 2004 Olympics for the Athens Transport System. In *Routledge Handbook of Sport And Legacy*, 131–141. Routledge.

Kassens-Noor E, Gaffney C, Messina J, Phillips E (2016) Olympic transport legacies: Rio de Janeiro's bus rapid transit system. *Journal of Planning Education and Research* 38(1): 13–24.

Law Insider (n.d.) *Mayoral development corporation definition*. Law Insider. Available at: https://www.lawinsider.com/dictionary/mayoral-develop ment-corporation.

Liao H, Pitts A (2006) A brief historical review of Olympic urbanization. *The International Journal of the History of Sport* 23(7): 1232–1252.

Mao B (2008) Analysis on transport policies of post-Olympic times of Beijing. *Journal of Transportation Systems Engineering and Information Technology* 8(6): 138–145.

Mao Z, Ettema D, Dijst M (2016) Commuting trip satisfaction in Beijing: exploring the influence of multimodal behavior and modal flexibility. *Transportation Research Part A: Policy and Practice* 94(Dec): 592–603.

Martinez C (2012) *Un-habitat launches the City Prosperity Index: HUD USER*. UN-Habitat Launches the City Prosperity Index | HUD USER. Available at: https://www.huduser.gov/portal/pdredge/pdr_edge_hudpartrpt_100512.Html.

Martinet C, Allaire J (2012) (Rep.) *Restructuring the transport network for the Olympic games*. Cooperation for urban mobility in the developing world (CODATU). Available at: http://www.codatu.org/wp-content/uploads/Ath%C3%A8nes_en.pdf.

Mayor of London, Khan S (2020) *Transport modal share in London after coronavirus*. London Assembly. Available at: https://www.london.gov.uk/que stions/2020/3302.

Mulley C, Montou CJ (2015) Not too late to learn from the Sydney Olympics experience: opportunities offered by multimodality in current transport policy. *Cities* 45(Jun): 117–122.

Nguyen K (2019, October 24). *'it's efficient, it's regular' and it will never be Sydney's PT system*. ABC News. Available at: https://www.abc.net.au/news/ 2019-10-24/sydney-will-never-have-world-class-public-transport-says-expert/116 32664.

Pereira RHM, Banister D, Schwanen T, Wessel N (2019) Distributional effects of transport policies on inequalities in access to opportunities in Rio de Janeiro. *The Journal of Transport and Land Use* 12(1): 741–764.

Pringle JD (n.d.) History of Sydney. *Encyclopædia Britannica*. Available at: https://www.britannica.com/place/Sydney-New-South-Wales/History.

Queiroz RLC de, Legroux J (2014) From discourse to reality: impacts of Rio's "transportation revolution" on socio-spatial justice. In *The Metropolis of Rio de Janeiro: A Space in Transition*, 343–367. essay, FAPERJ.

Railway Technology (2006, October 5) *London Olympics Transport upgrade*. Railway Technology. Available at: https://www.railway-technology. com/projects/london-olympics/.

Ribeiro T, Almeida V (2021) The Rio's transport legacy: pre- and post-Games resident perceptions. *International Journal of Sports Marketing and Sponsorship* 22(1): 32–52.

Richter R (2008, April 1). *Transportation investments in Olympic host cities*. Transport Nexus. Available at: https://view.officeapps.live.com/op/view. aspx?src=http%3A%2F%2Fwww.transportnexus.com%2Fwp-content%2Fuploads%2F2012%2F04%2Fmastersproject.doc&wdOrigin=BROWSELINK.

Richter R (2012, April 19) *Olympic Games and transport infrastructure: an analysis*. Transport Nexus. Available at: https://transportnexus.com/olympic-games-4/#:~:text=All%20of%20these%20infrastructure%20improvements,development%20was%20similar%20to%20Sydney.

Rio 2016 Bid Committee, The Olympic Studies Centre (2009) *Rio 2016 Bid Committee*. Available at: https://library.olympics.com/Default/doc/SYRA CUSE/38508/rio-2016-candidate-city-dossier-de-candidature-de-rio-de-janeiro-a-l-accueil-des-jeux-olympiques-et-?_lg=en-GB#.

Sandy M (2016, March 24) *Brazil corruption: Olympic projects could be connected*. Time. Available at: https://time.com/4271376/brazil-corruption-scandal-olympics/.

Shakibaei B (2022, February 11) *A recent history of Sydney's frequent PT*. Transport Sydney. Available at: https://transportsydney.wordpress.com/ 2022/02/11/a-recent-history-of-sydneys-frequent-public-transport/.

Transport for London | Every Journey Matters (n.d.) *London's transport - A history*. Transport for London. Available at: https://tfl.gov.uk/corpo rate/about-tfl/culture-and-heritage/londons-transport-a-history.

Transport NSW Blog (2022, April 4) *Sydney's transport history*. Available at: https://trans portnswblog.com/category/sydneys-transport-history/.

UN-Habitat (n.d.) *CPI. UN-Habitat: a better urban future*. Available at: from https://data. unhabitat.org/pages/city-prosperity-index.

Wolmar C (2004, July 2) *Tackling the problems of London's transport system*. Available at: https://www.christianwolmar.co.uk/2004/07/tackling-the-problems-of-londons-transport-system/.

WorldData.info (n.d.) *Development and importance of tourism for Greece*. Worlddata. info. Available at: https://www.worlddata.info/eu rope/greece/tourism.php#:~:text =By%20putting%20the%20tourist%20numbers,in%20the%20tourism%20sector%2 0alone.

Wotherspoon G (2008) Transport. In *The Dictionary of Sydney*. Available at: https://dictio naryofsydney.org/entry/transport.

Yamawaki Y, Tomaz J (2019) The transport infrastructure contribution to the urban legacy of the Beijing Olympic Games. *Urbe. Revista Brasileira De Gestão Urbana* 11(10).

Athens Journal of Sports - Volume 10, Issue 4, December 2023 – Pages 261-274

Basic Psychological Needs Predicting Physical Activity Participation among Young Adults

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It is alarming that despite the numerous accrued benefits of physical activity participation, many young adults in tertiary institutions engage in inactive and sedentary lifestyles, which can be linked to many cases of morbidity and mortality. However, according to the self-determination theory (SDT), individuals have three basic psychological needs (BPNs) that are essential for healthy growth, development and well-being. The necessity to fulfill these BPN's can stimulate and encourage young adults to engage in regular physical activity and enhance their well-being. Therefore, this study examined the role of BPN's in predicting physical activity participation among young adults in Nigerian private university. A total of 735 students, comprising 408 males (55.5%) and 327 females (44.5%), with ages ranging from 16 to 35 years (mean = 22.8; SD = 5.42), were randomly selected from a private university in the South-west, of Nigeria. The Basic Psychological Needs in Exercise Scale (BPNES) and the International Physical Activity Questionnaire–Short Form (IPAQ-SF) were used to collect data. Data analysis was conducted using descriptive statistics, correlation and multiple linear regression analysis. The results of the study showed that the BPN's of autonomy ($r = 0.233$, $p<0.05$); competence ($r = 0.188$, $p < 0.05$), and relatedness ($r = 0.477$, $p<0.05$) positively correlated with physical activity participation. Additionally, the results found that 25% had low, 57.1% had moderate and 17.8% had high levels of physical activity participation among the participants. There was a significant gender difference between males and females' in their levels of participation in physical activity ($t = 2.866$, $p < 0.05$), with males reporting higher mean scores than their female counterpart. Regression analysis showed that BPN's predicted physical activity participation among young adults ($F(3,731) = 73.968$, $p < 0.05$) with 23% of its variance accounted for by the independent variables. Furthermore, autonomy ($ß = 0.071$, $t = 1.970$, $p < 0.05$) and relatedness ($ß = 0.478$, $t = 12.589$, $p < 0.05$) were predictors of physical activity participation with relatedness being reported as the most potent predictor. These findings provide an insight into focus the importance of satisfying the relatedness and autonomy aspects of BPN's in young adults. Developing interventions that target these identified indices can promote continuous and regular participation in physical activity.

Keywords: *basic psychological needs, relatedness, autonomy, physical activity, young adults*

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Introduction

"It has been well established that physical activity participation provides numerous positive health benefits encompassing physical, psychological, and social aspects, leading to enhanced health, improved life satisfaction, and optimum well-being (Lahart et al. 2019, Malm et al. 2019, Vagetti et al. 2014, Ponce de León and Sanz 2014)". Despite these numerous accrued positive health benefits of physical activity participation, many young adults in tertiary institutions engage in an inactive and sedentary lifestyle, which can be linked to various cases of morbidity and mortality. The World Health Organization (WHO) (2018) indicated that two-thirds of premature mortalities in adults are linked to young age conditions and behaviors, including smoking, heavy drinking, and physical inactivity, with a higher number of young adults not getting enough physical activity. The self-determination theory posits that the satisfaction and fulfillment of an individual's basic psychological needs can stimulate, predict, influence, and increase physical activity participation and encourage active behavior (Vansteenkiste et al. 2019, Springer et al. 2013, Deci and Ryan 2000). Therefore, there is a crucial and persistent need to motivate young adults to continuously participate in physical activity in order to promote healthy behaviors from young age to older age.

The Basic Psychological Needs Theory (BPNT, Deci and Ryan 2002) is a sub-theory within the self-determination theory (SDT) framework, which posits that the growth, integration, active lifestyle, and optimal functioning of humans are grounded in the satisfaction of three basic psychological needs: autonomy, competence, and relatedness. Autonomy refers to an individual's ability to make decisions in choosing and performing different tasks and behaviors (Vansteenkiste et al. 2020, Ryan and Deci 2017). Competence is the ability of an individual to master or efficiently relate to the environment and have confidence in achieving positive outcomes on assigned tasks. Lastly, relatedness reflects the extent to which an individual experiences interpersonal relationships, a sense of belonging in society, and connection with significant others (Vansteenkiste et al. 2020, Ryan and Deci 2017). When these three basic psychological needs are fulfilled, individual gains the impetus to maintain optimal well-being, adopt a healthy lifestyle, and experience a high level of happiness by engaging in physical activity (Junior et al. 2019, Ryan and Deci 2017). However, the inability to fulfill these three basic psychological needs may hinder the energy to grow, develop, and maintain healthy habits and resulting into physical inactivity.

Basic psychological needs have been shown to influence physical activity participation, exercise adherence, autonomous regulation toward CrossFit participation, and enjoyment in physical education indirectly enhancing physical health, life satisfaction, relieving stress, and reducing burnout (Gholidahaneh et al. 2020, Fraguela-Vale et al. 2020, Martinez et al. 2013, Kang et al. 2019, Teixeira et al. 2018, Rodrigues et al. 2018, Davies et al. 2016, Mefferd, 2021, Lovell et al. 2016, Matosic et al. 2016, Leisterer and Gramlich 2021). Additionally, a plethora of studies have demonstrated a positive relationship between the three basic psychological needs and physical activity behaviors (McDonough and Crocker 2007, Sánchez and Núñez 2007, Taylor et al. 2010, Peres et al. 2012, Erdogdu and

Öz 2021), enjoyment in physical education (Leisterer and Gramlich 2021), and sportsmanship (Cosma et al. 2021).

Physical activity participation has continued to decline globally, especially among young persons from late adolescence to older adults (Hallal et al. 2012). In Nigeria, the overall physical activity levels of young adults seem to be declining (Adeniyi et al. 2016) and not meeting the recommendation of engaging in at least 150–300 minutes of moderate-intensity PA (MPA) or 75–150 minutes of vigorous-intensity PA (VPA) per week for those aged 18 years or older (World Health Organization (WHO) 2020). Studies have shown that only 37% of young adults participated in 60 minutes of (MVPA) daily, with 59% involved at moderate levels, 3.8% involved in low levels, and 72% participated in PA at least once in a month (Odunaiya et al. 2010, Adeniyi et al. 2011, Senbanjo and Oshikoya 2010). This declining level of PA in the country and the world can be linked to recent technological advancements, modern lifestyles, automation of daily activities, motorization, urbanization, and unhealthy diets, which enhance sedentary lifestyles, unhealthy behaviors, and underline the necessity to address the growing malaise of physical inactivity (Knuth and Hallal 2009, Institute of Medicine 2013, Onyiriuka et al. 2016).

The transition of young adults from adolescence into adulthood that, from secondary school into university, is a stage encompassed with many challenges, including physical and mental health demands, academic stress and difficulties, a lack of time due to cumbersome lesson schedules and assignments, financial burdens, change in residence, and other school environment-related factors (Glascoe 2023, Ting 2009, Hiester et al. 2009, Oluyinka and Endozo 2019, Jaiyeoba 2018, Fawzy and Hamed 2017, Arnett 2000). These challenges affect young adults' overall well-being and behaviors. While the university environment offers substantial opportunities for all-round development and healthy lifestyles for young adults (Niedermeier et al. 2018), there is also a menace of reduced PA participation and increased sedentary lifestyles (Kann et al. 2018, Nelson et al. 2007), making university students vulnerable to many illnesses such as mental health issues, cardiovascular disease, cancer, osteoporosis later in life, overweight and obesity, tiredness, and exhaustion (McMahon et al. 2017, Fawzy and Hamed 2017, Bonevski et al. 2013, Sandu et al. 2018).

Research evidence suggests that gender differences exist and affects participation in physical activities, with males' involvement greater than females in most studies, with males having higher participation records in moderate to vigorous physical activities (Towne et al. 2017, Beltrán et al. 2017, Fraguela-Vale et al. 2020, Ugwueze and Agbaje 2022). Few studies have indicated no gender difference in PA participation (Manzano-Sánchez and Valero-Valenzuela 2018). Studies have shown that fulfilling BPNs increases individuals' impetus to engage in PA with greater commitment and determination, which in turn promotes overall well-being and active lifestyles in various countries (Fraguela-Vale et al. 2020, Gholidahaneh et al. 2020). While most of the studies on PA in Nigeria have focused on sociodemographic, personal, physical, psychological, and environmental factors that influence and associate with PA among different populations, especially among adolescents (Oluwasanu and Oladepo 2017, Oguntuase et al.

2021, Adeniyi et al. 2016, Adeniyi et al. 2011, Ugwueze et al. 2021, Oyeyemi et al. 2016), there is no evidence of a study on BPNs predicting PA participation among young adults in Nigeria. Therefore, this study investigates basic psychological needs predicting physical activity participation among young adults in Nigeria. The current study aims to: (1) examine the relationship between BPNs and PA among young adults in Nigeria, (2) examine whether BPNs would predict PA, and (3) examine whether BPN components would relatively predict PA.

Methods

Participants

A total of 735 university students, comprising 408 males (55.5%) and 327 females (44.5%), whose ages ranged from 16 to 35 years (mean = 22.8; SD = 5.42), were randomly selected from a private university in the South-west, Nigeria. These participants represented various departments across different faculties within the university spanning from 100 Level to 500 Level students. It's worth noting that all participants were registered full-time undergraduate students of the university. Exclusions from the study were made for students with physical or mental (learning) disabilities and those taking medications that limited their participation in physical activity.

Measures

The measures completed by the participants include:

Basic Psychological Needs

The English version (Vlachopoulos et al. 2011) of the Basic Psychological Needs in Exercise Scale (BPNES) (Vlachopoulos and Michailidou 2006) was utilized to assess the extent to which participants' fulfilled the basic psychological needs for autonomy, competence, and relatedness in their physical activity participation. The BPNES consists of 11 – items divided into three subscales: autonomy (4 items, e.g., "The way I exercise is in agreement with my choices and interests"), competence (4 items, e.g., "I am able to meet the requirements of my exercise program"), and relatedness (3 items, e.g., "My relationships with the people I exercise with are very friendly"). Participants rated the BPNES items on a 5 - point Likert-type scale (1 = strongly disagree to 5 = strongly agree). The Cronbach alpha coefficients obtained in this study for the three subscales of BPN were 0.78 for autonomy, 0.73 for competence, and 0.84 for relatedness.

Physical Activity (PA) Participation

The participants' physical activity levels were assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF). This self-reported questionnaire measures the duration of various levels of physical activity over the past seven days or one week. The short form of the questionnaire is organized by dimensions and is structured to capture physical activity in four primary domains: vigorous, moderate, low (walking), and sedentary (sitting). The questions inquire about an individual's physical activity participation in the preceding seven days. The total weekly physical activity level is quantified as metabolic equivalent of task (MET) per hour per week, and it is categorized as high ($\geq$ 3,000 MET-min/week), moderate (600 to 3,000 MET -min/week), or low (less than 600 MET-min/week), serving as an indicator for physical activity, (Craig et al. 2003, WHO 2010). The IPAQ-SF has been validated in a previous Nigerian study (Oyeyemi et al. 2013). In the current study, the Cronbach alpha coefficient for the IPAQ-SF scale was 0.81.

Procedure

Various departments across different faculties were approached to seek permission to access students for the study. The leaders of the students from each level and department were briefed about the research. Participants were randomly selected either as they entered the lecture rooms before the classes or when classes were in progress. Some classes responded after the lectures had started once their consent was obtained. The participants completed self-administered questionnaires. The questionnaire took approximately 10-15 minutes to complete. Participants were assured of the confidential treatment of the collected data. Students from the Department of Physical and Health Education (PHE) at the university were excluded from the study due to their regular participation in various physical activities, exercises, sports, and games. The study achieved a 95.6% completion rate, with735 out of 769 participants (100%) providing complete responses. Only 34 participants (4.4%) did not provide complete information.

Data Analysis

Data analysis was carried out using descriptive statistics, including frequency counts, percentages, means, and standard deviations. Inferential analysis involved correlation analysis to ascertain the relationship between the dimensions of basic psychological need and physical activity participation, t-test analysis was employed to assess gender differences in levels of physical activity participation, and multiple regression analysis was performed to determine the predictive capability of basic psychological needs and its individual dimensions on physical activity participation.

Results

Descriptive Statistics and Correlation Matrix

Table 1 displays the positive correlations between basic psychological needs of autonomy (r=0.233), competence (r=0.188), and relatedness (r=0.477) with PA participation. This suggests that an increase or enhancement in autonomy, competence, and relatedness would positively influence the physical activity participation among the participants. However, it's important to note that the correlation coefficients for autonomy, competence, and relatedness were relatively weak.

Additionally, the results presented in Table 2 indicate that 25% of the participants had low, levels of physical activity participation, while 57.1% had moderate levels, and 17.8% had high levels. There was significant gender difference levels of participation in physical activity ($t = 2.866$, $p < 0.05$) with males reporting a higher mean score (15.99) compared to their female counterparts, who had mean score of (14.83).

Table 1. *Correlation Matrix, Mean and Standard Deviation of Basic Psychological Needs and Physical Activity Participation*

	Variables Mean	**SD**	**PA participation**	**Autonomy**	**Competence**	**Relatedness**
Participation	15.47	5.51	1			
Autonomy	23.46	4.68	0.233**	1		
Competence	21.42	5.18	0.188**	0.365**	1	
Relatedness	23.00	4.94	0.477**	0.387**	0.467**	1
N=735 Sig.(2-tailed): **Autonomy=0.000** **Competence=0.000** **Relatedness=0.000**						

***Correlation is significant at 0.05 alpha level (p<0.05)*

Table 2. *Levels of Physical Activity Participation*

Levels of Participation	**n**	**%**
Low	184	25.0
Moderate	420	57.1
High	131	17.8
Total	735	100.0

Table 3. *Summary of t-test Analysis on Gender Difference in Physical Activity Participation*

	Gender	**N**	**Mean**	**Std. Dev.**	**t**	**df**	***P***
Physical activity participation	Male	408	15.99	5.98	2.866	733	0.004
	Female	327	14.83	4.80			

Table 4. *Results of Regression on Joint Prediction of Basic Psychological Needs on Physical Activity Participation*

R=.483 R^2=.233 Adj. R^2=.230 Std. Error=4.83793					
Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	5193.762	3	1731.254	73.968	0.000
Residual	17109.471	731	23.406		
Total	22303.233	734			

As shown in Table 4, it was observed that the linear combination of basic psychological needs (autonomy, competence, and relatedness) had a significant impact on physical activity participation among young adults ($F(3,731)=73.968$, $p < 0.05$). The results yielded a multiple regression coefficient of $R=0.483$ and a multiple R^2 of 0.233. Furthermore, the adjusted R^2 was calculated to be 0.230; indicating that approximately 23.0% of the variance was explained by the independent variables. This implies that, there was a significant collective predictive effect of basic psychological needs including autonomy, competence, and relatedness, on physical activity participation among young adults.

Table 5. *Results of Regression on Relative Prediction of Basic Psychological Needs on Physical Activity Participation*

Variables	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	2.661	1.085		2.452	0.014
Autonomy	0.084	0.042	0.071	1.970	0.049
Competence	-0.066	0.040	-0.062	-1.643	0.101
Relatedness	0.533	0.042	0.478	12.589	0.000

Table 5 displays information on autonomy, competence, and relatedness, including the unstandardized regression weight (ß), the standardized error of estimate (SEE), the standardized coefficient, the t-ratio, and the significance level of the t-ratio. As indicated in Table 5, autonomy ($ß=0.071$, $t=1.970$, $p < 0.05$) and relatedness ($ß = 0.478$, $t=12.589$, $p < 0.05$) were found to be independently significant predictors of physical activity participation among young adults. However, competence ($ß=-0.062$, $t=-1.643$, $p<0.05$) did not emerge as a significant predictor. This indicates that autonomy and relatedness were significant relative predictors of physical activity participation among young adults, while competence was not.

Discussion

The present study investigated the prediction of physical activity participation among young adults based on their basic psychological needs. Additionally, the

study examined the relationship between these BPNs and physical activity participation. The results revealed a positive correlation between the components of basic psychological needs and physical activity participation. This finding aligns with previous research (McDonough and Crocker 2007, Taylor et al. 2010). Leisterer and Gramlich (2021) also found that the three components of basic psychological needs were associated with enjoyment in physical education. Regarding gender differences, this study finding are consistent with Towne et al. (2017), indicating that male college students engage more in moderate-to-vigorous physical activity than their female counterparts, who tend to be more involved in heavy sedentary technology use activities, primarily driven by smartphone use. Similarly, Ugwueze and Agbaje (2022) found that boys more likely to meet the total physical activity requirements recommended by the WHO compared to their female peers. Fraguela-Vale et al. (2020) suggested that young girls prefer non-structured types of physical activity, while boys prefer organized forms.

Furthermore, the study demonstrated that BPNs predict physical activity participation among young adults, highlighting the importance of satisfying these needs for healthy growth, development, and well-being (Vansteenkiste et al. 2020, Ryan and Deci 2017). According to self-determination theory, fulfilling BPNs including autonomy, competence, and relatedness is crucial in motivating and encouraging young adults to engage in regular physical activity, promoting desired healthy behaviors (Fraguela-Vale et al. 2020). Kang et al. (2019) also found that these three BPNs components were significant predictors of exercise adherence among recreational sports participants, while Junior et al. (2019) indicated that BPNs contribute to physical development, functional level, and happiness in competitive games among futsal players. The study's results align with Leisterer and Gramlich (2021), who found that autonomy, competence, and relatedness increased students' enjoyment in physical education class, particularly among lower grades

In addition, the study revealed that both autonomy and relatedness were significant predictors of physical activity, with relatedness being the most potent factor. This finding corresponds with Davies et al. (2016), who reported that autonomy and relatedness within BPNs were significant predictors of autonomous participation in CrossFit. Relatedness plays a unique role in physical activity participation as individuals require the presence and involvement of significant others to meet the WHO's physical activity requirements for young adults. The need for relatedness is associated with a sense of belonging and acceptance by others, contributing to overall well-being within the community (Sánchez and Núñez 2007). It serves as a significant motivator for young adults to engage in regular physical activity (Peres et al. 2012). Quality friendship and relatedness were found to be associated with greater enthusiasm for participation in physical activity among adolescent girls (Gholidahaneh et al. 2020). Additionally, the need for relatedness significantly predicted respect for social conventions and opponent's elements of sportsmanship (Cosma et al. 2021).

Regarding the autonomy component of BPNs, the results are consistent with Kang et al. (2019), who reported that autonomy had a stronger impact on predicting longer-term exercise participation and exercise adherence compared to

the relatedness component of BPNs. Individuals with a strong sense of autonomy within BPNs were more likely to adhere to and maintain continuous participation in physical exercise. Similarly, Leisterer and Gramlich (2021) found a moderate to strong association between autonomy and enjoyment in physical education students. They suggested that changes in autonomy support may also impact competence and relatedness in physical education students. Additionally, Fraguela-Vale et al. (2020) noted that the fulfillment of autonomy within BPNs was significantly associated with engagement in unstructured activities in a first-year higher secondary education class.

Overall, these findings underscore the importance of addressing and satisfying basic psychological needs, especially relatedness and autonomy, to promote and sustain physical activity participation among young adults.

Limitations

This study has several limitations. Firstly, it utilized a cross-sectional design which does not allow for the establishment of causal relationships between basic psychological needs and physical activity participation variables. Consequently, the generalizability of the study's findings may be limited. Future research could employ intervention or longitudinal studies to investigate how fulfilling basic psychological needs can positively impact physical activity participation among young adults.

Secondly, data collection took place during the first three weeks of the second semester of the 2021/2022 academic session. This timing might have influenced the study's results, as students may have been particularly motivated to engage in physical activity, make new friends, and establish a sense of belonging by participating in both structured and unstructured activities at the beginning of the school year.

Thirdly, physical activity participation was assessed using self-report questionnaires, which rely on subjective data. This subjectivity limits the conclusions that can be drawn from the research, as they are based on participants' own opinions and perceptions. Future studies could consider incorporating objective measures, such as pedometers and accelerometers, to provide a more and objective assessment of energy expenditure in alignment with the physical activity recommendations outlined by the World Health Organization for young adults.

Conclusion

The present study revealed that the level of participation in physical activity was moderate among young adults in the university. There was a significant gender difference in physical activity participation among young adults, with males' involvement being higher than that of their female counterparts. The findings demonstrated a significant association between Basic Psychological Needs (BPNs) and physical activity participation. Furthermore, BPNs were found

to predict physical activity participation among young adults. Specifically, the study suggested that both relatedness and autonomy play a principal role in predicting physical activity participation.

This study provides valuable insights into the theoretical framework of BPNs (Deci and Ryan 2002), highlighting that the satisfaction of basic psychological needs may serve as a promising motivator for increased participation in physical activity among young adults. These findings are particularly relevant for professionals in the fields of exercise science and public health including sport and exercise psychologists, exercise physiologists, physical educators, health educators, school counselors, and university authorities. It underscores the importance of developing interventions that promote physical activity participation and enhance the overall well-being of university students.

Acknowledgments

The authors would like to express their gratitude to the authorities of the private university that facilitated this study, as well as the various Heads of departments, lecturers, students' course leaders, and the students who actively participated in the research. Your cooperation and support were greatly appreciated.

References

Adeniyi AF, Odukoya OO, Oyeyemi AL, Adedoyin RA, Ojo OS, Metseagharun E, et al. (2016) Results from Nigeria's 2016 report card on physical activity for children and youth. *Journal of Physical Activity & Health* 13(11 Suppl 2): S231–S236.

Adeniyi AF, Okafor NC, Adeniyi CY (2011) Depression and physical activity in a sample of Nigerian adolescents: levels, relationships, and predictors. *Child and Adolescent Psychiatry and Mental Health* 5(May): 16.

Arnett JJ (2000) Emerging adulthood. A theory of development from the late teens through the twenties. *American Psychologist* 55(5): 469–480.

Beltrán Carrillo VJ, Sierra AC, Jiménez Loais A, González-Cutre D, Martínez Galindo C, Cervelló E (2017) Diferenciasse gúngéneroen eltiem poemple adopor adolescentesen actividad sedentariay actividad físicaen diferentes segmentos horarios del día. (Gender differences in the time spent by adolescents in sedentary activity and physical activity in different time segments of the day.) *Retos* 31: 3–7.

Bonevski B, Guillaumier A, Paul C, Walsh R (2013) The vocational education setting for health promotion: a survey of students' health risk behaviours and preferences for help. *Health Promotion Journal of Australia: Official Journal of Australian Association of Health Promotion Professionals* 24(3): 185–191.

Cosma GA, Chiracu A, Stepan AR, Gatzel R, Iancu A, Cosma A (2021) Sportsmanship and basic psychological needs in sports students. *Baltic Journal of Health and Physical Activity* 13(6): 53–65.

Craig CL, Marshall AL, Sjöström M, Bauman A. E, Booth ML, Ainsworth BE, et al. (2003) International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise* 35(8): 1381–1395.

Davies MJ, Coleman L, BabkesStellino M (2016) The relationship between basic psychological need satisfaction, behavioural regulation, and participation in Cross Fit. *Journal of Sport Behavior* 39(3): 239–254.

Deci EL, Ryan RM (2000) The "what" and "why" of goal pursuits: human needs and the self-determination of behaviour. *Psychological Inquiry* 11(4): 227–268.

Deci EL, Ryan RM (2002) *Handbook of self-determination research*. Rochester: University of Rochester Press

Erdogdu M, Öz ND (2021) Evaluation of participation in recreational exercise with basic psychological needs and happiness parameters during the COVID-19 pandemic process. *Turkish Journal of Sport and Exercise /Türk SporveEgzersiz Dergisi* 23(2): 178–184.

Fawzy M, Hamed SA (2017) Prevalence of psychological stress, depression and anxiety among medical students in Egypt. *Psychiatry Research* 255(Sep): 186–194.

Fraguela-Vale R, Varela-Garrote L, Varela-Crespo L (2020) Perfiles de ocio deportivo enjóvenes españoles (15-20 años): un análisis de género. Retos NuevasTendencias Educ. (Sports and leisure profiles in young Spaniards (15-20 years): a gender analysis. New ChallengesEduc Trends .) *Fís. DeporteRecreación* 37: 419–426.

Fraguela-Vale R, Varela-Garrote L, Carretero-García M, Peralbo-Rubio EM (2020) Basic psychological needs, physical self-concept and physical activity among adolescents: autonomy in focus. *Frontiers in Psychology* 11(Mar): 491.

Gholidahaneh M, Ghorbani S, Esfahaninia A (2020) Effects of basic psychological needs satisfaction in the physical education on leisure-time physical activity behavior of primary school students: mediating role of autonomous motivation. *International Journal of School Health* 7(2): 46–53.

Glascoe GR (2023) *A causal comparative study of the effects of physical activity course enrollment on college students' perceived wellness, mental health, and basic psychological needs*. Doctoral Dissertation. University of South Carolina.

Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, (2012) Lancet physical activity series working group. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet (London, England)* 380(9838): 247–257.

Hiester M, Nordstrom A, Swenson LM (2009) Stability and change in parental attachment and adjustment outcomes during the first semester transition to college life. *Journal of College Student Development* 50(5): 521–538.

Institute of Medicine (2013) *Educating the student body: taking physical activity and physical education to school*. Washington, DC: The National Academies Press.

Jaiyeoba OM (2018) Unpleasant life occurrences as determinants of mental health status among undergraduates of the University of Ibadan. *Ibadan Journal of Education Studies* 15(2): 33–42.

Junior JR, Granja T, Silva AA, Fortes LD, Gonçalves MP, Oliveira DV, et al. (2019) Association between basic psychological needs of the self-determination theory and perception of group cohesion among high-performance futsal athletes. *Brazil. J. Kinanthropometry Hum. Perform.* 21: 57369.

Kang S, Lee K, Kwon S (2019) Basic psychological needs, exercise intention and sport commitment as predictors of recreational sport participants' exercise adherence. *Psychology & Health* 35(8): 916–932.

Kann L, McManus T, Harris WA, Shanklin SL, Flint KH, Queen B, et al. (2018) Youth risk surveillance - United States, 2017. *Surveillance Summaries* 67(8): 1–114.

Knuth A.G, Hallal PC (2009) Temporal trends in physical activity: a systematic review. *Journal of Physical Activity and Health* 6(5): 548–559.

Lahart I, Darcy P, Gidlow C, Calogiuri G (2019) The effects of green exercise on physical and mental wellbeing: a systematic review. *International Journal of Environmental Research and Public Health* 16(8): 1352.

Leisterer S, Gramlich L (2021) Having a positive relationship to physical activity: basic psychological need satisfaction and age as predictors for students' enjoyment in physical education. *Sports* 9(7): 90.

Lovell GP, Gordon JA, Mueller MB, Mulgrew K, Sharman R (2016) Satisfaction of basic psychological needs, self-determined exercise motivation, and psychological well-being in mothers exercising in group-based versus individual-based contexts. *Health Care for Women International* 37(5): 568–582.

Malm C, Jakobsson J, Isaksson A (2019) Physical activity and sports-related health benefits: a review with insight into the public health of Sweden. *Sports* 7(5): 127.

Manzano-Sánchez D, Valero-Valenzuela A (2018) Differences between students according to physical activity and their motivation, basic psychological needs and responsibility. *Journal of Human Sport and Exercise* 13(2proc): S221–S230.

Martinez J, Oberle CD, Nagurney AJ (2013) Basic psychological needs in predicting exercise participation. *Advances in Physical Education* 3(1): 20–27.

Matosic D, Ntoumanis N, Quested E (2016) Antecedents of need supportive and controlling interpersonal styles from a self-determination theory perspective: a review and implications for sport psychology research. *Sport and Exercise Psychology Research* 145–180.

McDonough MH, Crocker PR (2007) Testing self-determined motivation as a mediator of the relationship between psychological needs and affective and behavioral outcomes. *Journal of Sport and Exercise Psychology* 29(5): 645–663.

McMahon EM, Corcoran P, O'Regan G, Keeley H, Cannon M, Carli V, et al. (2017) Physical activity in European adolescents and associations with anxiety, depression and well-being. *European Child & Adolescent Psychiatry* 26(1): 111–122.

Mefferd DL (2021) *Organizational fit, teammate interactions, and psychological needs: why some athletes experience burnout*. Master's Thesis. Texas State University.

Nelson TF, Gortmaker SL, Subramanian SV, Wechsler H (2007) Vigorous physical activity among college students in the United States. *Journal of Physical Activity and Health* 4(4): 495–508.

Niedermeier M, Frühauf A, Kopp-Wilfling P, Rumpold G, Kopp M (2018) Alcohol consumption and physical activity in Austrian college students - A cross-sectional study. *Substance Use & Misuse* 53(10): 1581–1590.

Odunaiya NA, Ayodele OA, Oguntibeju OO (2010) Physical activity levels of senior secondary school students in Ibadan, Western Nigeria. *The West Indian Medical Journal* 59(5): 529–534.

Oguntuase SB, Sun Y, Apata TC, Ogunsanya JO (2021) Socio-demographic and psychological determinants of leisure time physical activity among adolescent in Nigeria. *European Journal of Physical Education and Sport Science* 7(4): 1–20.

Oluwasanu MM, Oladepo O (2017) Effects of a multi-level intervention on the pattern of physical activity among in-school adolescents in Oyo state Nigeria: a cluster randomised trial. *BMC Public Health* 17(Oct): 833.

Oluyinka S, Endozo A (2019) Factors affecting physical activity participation among university students. *Journal of Social Science Research* 14: 3161–3170.

Onyiriuka AN, Umoru DD, Ibeawuchi AN (2013) Weight status and eating habits of adolescent Nigerian urban secondary school girls. *The South African Journal of Child Health* 7(3): 108–112.

Oyeyemi AL, Ishaku CM, Oyekola J, Wakawa HD, Lawan A, Yakubu S, et al. (2016) Patterns and associated factors of physical activity among adolescents in Nigeria. *PloS one* 11(2): e0150142.

Oyeyemi AL, Oyeyemi AY, Jidda ZA, Babagana F (2013) Prevalence of physical activity among adults in a metropolitan Nigerian city: a cross-sectional study. *Journal of Epidemiology* 23(3): 169–177.

Peres JM, Cid LF, Marinho JA, Vlachopoulos SP (2012) Validation of the basic psychological needs in exercise scale in a Portuguese sample. *Spanish Journal of Psychology* 15(1): 399–409.

Ponce de León A, Sanz E (2014) Predictores de la actividadfísica de tiempo libre enuna población universitariaespañola. (Predictors of free-time physical activity in a Spanish university population.) Pedagog. *Soc. Rev. Interuniv.* 24: 183–197.

Rodrigues F, Bento T, Cid L, Neiva H, Teixeira DS, Moutão J, et al. (2018) Can interpersonal behaviour influence the persistence and adherence to physical exercise practice in adults? Systematic review. *Frontiers in Psychology* 9(Nov): 2141.

Ryan RM, Deci EL (2017) *Self-determination theory: basic psychological needs in motivation, development, and wellness*. New York: Guilford Publishing.

Saleem F, Bashaar M, Hassali MA (2018) Assessment of barriers to physical activities among university students in Malaysia. *Phar Pharmacol Int J*. 6(6): 468–473.

Sánchez JM, Núñez JL (2007) Análisispreliminar de las propiedadespsicométricas de la version española de la escala de necesidadespsicológicasbásicasenelejerciciofísico. (Preliminary analysis of the psychometric properties of the Spanish version of the scale of basic psychological needs in physical exercise.) *Revi. Iberoam. Psicol. EjercicioDeporte* 2: 83–92.

Senbanjo IO, Oshikoya KA (2010) Physical activity and body mass index of school children and adolescents in Abeokuta, Southwest Nigeria. *World Journal of Pediatrics* 6(Jun): 217–222.

Springer JB, Lamborn SD Pollard DM (2013) Maintaining physical activity overtime: the importance of basic psychological need satisfaction in developing the physically active self. *American Journal of Health Promotion* 27(5): 284–293.

Taylor IM, Ntoumanis N, Standage M, Spray M (2010) Motivational predictors of physical education students' effort, exercise intentions, and leisure-time physical activity: a multilevel linear growth analysis. *Journal of Sport and Exercise Psychology* 32(1): 99–120.

Teixeira DS, Silva MN, Palmeira, AL (2018) How does frustration make you feel? A motivational analysis in exercise context. *Motivation and Emotion* 42(Mar): 419–428.

Ting S (2009) Impact of non-cognitive factors on first year academic performance and persistence of NCAA Division I student athletes. *Journal of Humanistic Counseling* 48(2): 215–228.

Towne Jr SD, Ory MG, Smith ML, Peres SC, Pickens AW, Mehta RK, et al. (2017) Accessing physical activity among young adults attending a university: the role of sex, race/ethnicity, technology use, and sleep. *BMC Public Health* 17(Sep): 721.

Ugwueze FC, Agbaje, OS (2022) Physical activity domains, levels, and health-related quality of life among Nigerian adolescents during the coronavirus disease 2019 pandemic. *SAGE Open Medicine* 10(Mar): 1–13.

Ugwueze FC, Agbaje OS, Umoke PCI, Ozoemena EL (2021) Relationship between physicalactivity level and psychological well-being among male university students in South East, Nigeria: a cross-sectional study. *American Journal of Men's Health* 15(2): 1–17.

Vagetti GC, Barbosa VC, Moreira NB, De Oliveira V, Mazzardo O, De Campos W (2014) Association between physical activity and quality of life in the elderly: a systematic review, 2000-2012. *Revista Brasileira de Psiquiatria* 36(1): 76–88.

Vansteenkiste M, Ryan RM, Soenens B (2020) Basic psychological need theory: Advancements, critical themes and future directions. *Motivation and Emotion* 44(Jan): 1–31.

Vlachopoulos SP, Michailidou S (2006) Development and initial validation of a measure of autonomy, competence and relatedness in exercise: the basic psychological needs in exercise scale. *Measurement in Physical Education and Exercise Science* 10(3): 179–201.

Vlachopoulos SP, Ntoumanis N, Smith AL (2010) The basic psychological needs in exercise scale: translation and evidence for cross-cultural validity. *International Journal of Sport and Exercise Psychology* 8(4): 394–412.

World Health Organisation – WHO (2010) *Global recommendations on physical activity for health*. WHO. Available at: http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_ eng. pdf.

World Health Organisation – WHO (2018) *Global coordination mechanism on the prevention and control of NCDs: NCD and Youth*. WHO. Available at: http://www. who.int/global-coordination-mecha nism/ncd-themes/ncd-and-youth/ en/2018.

World Health Organisation – WHO (2020) *Facts sheets on daily physical activity*. WHO. Available at: https://www. who.int/news-room/fact-sheets/ detail/physical-activity.