Development of the Shooting Quality Assessment Tool (SQAT) for measuring field goal shooting efficiency in elite men's basketball

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ABSTRACT

The present paper written was within the realm of practical performance analysis. The core purpose was to develop a performance indicator to measure the efficiency of field goal shooting in basketball and to provide results that could be used to enhance the shooting performance of a team. Because of this core purpose, it was necessary to also establish a statistical framework within which the results of the performance indicator mentioned could be interpreted correctly. It was found out that when measuring field goal shooting efficiency, previous researchers systematically used biased samples: they excluded missed field goal shots where a shooting foul occurred. To avoid this bias, a new performance indicator called Shooting Quality Assessment Tool (SQAT) was developed. SQAT takes into account not only whether a shooting foul occurs or not but also whether the offense or the defence gets the rebound. SQAT was applied to data gathered from 22 games of club team Honka in the Finnish men's basketball league. An important result was that close range two-point field goal shots proved to be more effective than three-point shots only because close range two-point shots led to a higher free throw frequency and to a higher offensive rebounding percentage. The statistical framework within which SQAT was used was Six Factors, or a modification of Four Factors, an influential method of basketball performance analysis developed by Oliver (2004). In the context of the present paper, Six Factors was more relevant because – unlike Four Factors – Six Factors differentiated between a team's ability hit

field goal shots where there is shooting foul and where there is not and between the team’s ability to earn free throw attempts and to hit them. The main limitation of the paper was the smallness of the sample size. Future research is needed to test the reliability, validity and applicability of SQAT and Six Factors in different contexts.

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LIST OF ABBREVIATIONS

2P	Two-point field goal
2PA	Two-point field goal attempt
2PS	Two-point field goal shot
3P	Three-point field goal
3PA	Three-point field goal attempt
3PS	Three-point field goal shot
DRB	Defensive rebound
DRB%	Defensive rebounding percentage
eFG%	Effective field goal percentage
eFG%+	Effective field goal percentage+
FBA	Finnish Basketball Association
FG	Field goal
FGA	Field goal attempts
FGS	Field goal shooting
FGSE	Field goal shooting efficiency
FIBA	Fédération Internationale de Basketball
FT	Free throw
FT%	Free throw percentage
FTA	Free throw attempts
FTM	Free throws made
NBA	National Basketball Association
Opp.	Opponents
ORB	Offensive rebound

ORB%	Offensive rebounding percentage
PPP	Points per play
PPS	Points per shot
PTS	Points
SQAT	Shot Quality Assessment Tool
Tm	Team
TOV	Turnover
TOV%	Turnover percentage
TS%	True shooting percentage

1. INTRODUCTION

Performance analysis is a process of objectively recording and analysing what takes place during a sports performance (Bampouras et al 2012). It may have two goals: theoretical and practical (Letzelter and Letzelter 1982). The predominant goal of theoretical performance analysis is to reveal the structure or logic of a given sport in general (Lames and McGarry 2007; Garganta 2009). The predominant goal of practical performance analysis is to enhance the improvement of the performance of a particular athlete or group (Lames and McGarry 2007). When athletes and coaches try to improve the athletes' performance, it is important that they have feedback available (Maslovat and Franks 2008), especially objective and quantitative feedback (Hughes and Bartlett 2008). Practical performance analysis may be used to provide this type of feedback (Maslovat and Franks 2008).

An elementary part of building a performance analysis system is selecting the performance indicators (Lames and McGarry 2007), or indicators that are used to measure a certain facet or facets relevant to the outcome of a performance (Lago and Martin 2007). In other words, choosing performance indicators determines what gets measured when applying the performance analysis system. Also, these measurements should reflect the quality of the performance (Csataljay 2009).

Since sports are different, performance analysis systems will differ from sport to sport (Maslovat and Franks 2008). However, the more similar sports are to each other, the more similar will be the performance analysis systems applied to them (Hughes and Bartlett 2002). Basketball belongs to the category of game sports, or sports where two individuals, pairs or teams attempt to score points or goals and at the same attempt to stop the opponent(s) from scoring (Lames 2006). Game sports may in turn be divided into four categories: net and wall games (e.g. volleyball and squash); striking and fielding games (e.g. cricket and baseball); rival target games (e.g. curling and boccia); and invasion games (e.g. football and basketball) (Mitchell et al 2013; Zhao 2013). Invasion games that are played by two teams are also referred to as invasion team sports (Lamas et al 2014).

Invasion team sports share at least three features: 1) There is a playing area of two halves and each team has its own half; 2) Each team defends its own half and attacks the other team's half; and 3) Players of both teams occupy common ground (James 2008; Lamas et al 2014). A theoretical framework known as ecological dynamics emphasizes that in invasion team sports, an individual's decision-making is always based on and constrained by the interaction with his teammates and with the players of the opposing team (Araujo et al 2006). Within these constraints, a player acts in order to achieve certain goals (Araujo et al 2006). Players' actions are also constrained by the rules of the game (Williams 2008).

According to the ecological dynamics framework, an invasion team sport athlete's performance should not be observed, measured or analysed independently (like it can be in e.g. 100m run), but the aforementioned constraints should be considered (Lames and McGarry 2007; Garganta 2009). Table 1 lists general issues that originate from the common features of invasion team sports and that add to the complexity of performance analysis in those sports. Table 1 also lists basketball-specific examples of those general issues.

Table 1: Issues adding to the complexity of invasion team sports

Issues adding to the complexity of invasion team sports (Gerrard 2007)	**Basketball-specific examples**
Occupying common ground with opponents adds to the variety of possible actions	Screening; fouling; stealing the ball.
Actions may be executed together with a teammate	Setting double screens; double teaming the ball handler.
Players specialize in different tasks, i.e. they have different roles on team.	Centres usually block more shots than guards and forwards; guards and forwards usually make more steals than centres; guards usually make most assists (Ibanez et al 2008).
Offence affects defence and vice versa.	The number of players that a team sends after an offensive rebound affects the probability of the opponents scoring off the fast should they get the rebound (Wiens et al 2013). Offensive plays that start with a steal produce more points than plays that start with a defensive rebound or by inbounding the ball (Lehto et al 2010).

Often performance indicators used in invasion team sports are what Vilar et al (2012, p.2) referred to as "scoring indicators", i.e. indicators that have to do with scoring opportunities, the rate of conversion of scoring opportunities into scoring, and scoring (Gerrard 2007). That emphasis is not surprising, because in the hierarchy of the game, scoring indicators are the ones most directly connected to scoring and thus to wins and losses (Gerrard 2007).

Yet it is safe to say that emphasizing scoring indicators introduces the risk of performance analysis being reductionistic and less fruitful than it could be. That is because emphasizing scoring indicators may make one overlook the inherent complexity of invasion team sports (Garganta 2009; Vilar et al 2012; Lamas et al 2014). Scoring indicators alone will not reveal how and why scoring opportunities arise because scoring opportunities are always affected by ecological dynamics (Vilar et al 2012). From the point of view of theoretical performance analysis, ignoring those dynamics will lead to incorrect or at best deficient descriptions of the structure and logic of an invasion team sport (Vilar et al 2012). From the point of view of practical performance analysis, this reductionism will hinder the process of improving a team's performance because it unduly highlights the biomechanical and technical aspects of a performance at the expense of tactical ones (Garganta 2009). This does not imply that scoring indicators should be ignored but rather that they should considered jointly with other performance indicators (Garganta 2009).

In recent years, technological development regarding automatic tracking systems has made gathering and analysing data for performance analysis a less and less work-intensive process (Travassos et al 2013), although not necessarily a more reliable one (Dogramac et al 2013). This development has made it more convenient to consider ecological dynamics when selecting performance indicators (Duarte et al 2012). Performance indicators now more often concern such tactics-related actions (e.g. passing and moving) that are outside the scope of scoring indicators (Duarte et al 2012).

However, technological development will not automatically lead to theoretical or practical advances in performance analysis, because a prerequisite for these advances is selecting performance indicators appropriately (Garganta 2009). In order to advance performance analysis optimally, there should be an understanding of what to look for, i.e. which actions are meaningful from a tactical point of view (Garganta 2009). This process of selecting performance indicators is made difficult by the ecological dynamics' important role in invasion team sports (Garganta 2009). In spite of these difficulties it has been shown that British football teams in the Premier League have been able to make practically valuable use of modern performance analysis (Gerrard 2007). Reliably evaluating the amount of competitive edge created with the help of performance analysis is a tall order, because often organizations keep their performance analysis procedures out of the public eye in order to maintain their competitive edge (Gerrard 2007; Reed 2011).

The evolution of performance analysis in basketball has followed the same lines as the evolution of performance analysis in invasion team sports in general (Bourbousson et al 2010). Performance indicators have often been derived from standard basketball game statistics, known as a box score (e.g. Sporic 2006; Csataljay 2009; Lorenzo et al 2010; Martinez 2012; Garcia et al 2013). Box score statistics put a heavy emphasis on scoring-related actions and on other actions that have to do with a change of ball possession (Garcia et al 2013). Box scores include statistics such as shooting percentages and the number of rebounds captured (Garcia et al 2013). Most statistics are attributed to individuals, and they do not reflect the interactions amongst the players (Maymin et al 2013).

Along the lines of Garganta's (2009) aforementioned suggestion, recently in basketball performance analysis scoring indicators and other performance indicators derived from box scores have been used jointly with performance indicators that are based on the data collected through more advanced forms of technology. Recent peer-reviewed research of this kind has looked into e.g. the synergic effect of a team of players with different skill sets (Maymin et al 2013), the effect that an offensive player's use of his dominant or non-dominant hand has on his team's offensive efficiency (Bartholomew and Collier 2012); and how the stressfulness of the situation affects players' shooting efficiency (Cao et al 2011). Also, there have been non-peer-reviewed articles that have used the same approach. Several of those articles have been published in the annual MIT Sloan Sports Analytics Conference, and a few have used data gathered though SportVU player tracking system from National Basketball Association (NBA) games. Such articles include studies on the effect of defensive pressure on the efficiency of shooting (Chang et al 2014), optimizing the number of players who try to get the offensive rebound (Wiens et al 2013), and assessing the quality of shooters based on the variety of locations they shoot from

(Goldsberry 2012a). SportVU, owned by STATS LLC, is now used by all 30 NBA teams (STATS LLC 2013), and the tracking system records the location of the ball and every player 25 times a second (STATS LLC no date). However, SportVU has not yet contributed much to the improvement of scientific basketball performance analysis, since, to the best of the knowledge of this paper's author, there is not a single peer-reviewed article on NBA basketball that has used SportVU as the data source.

As mentioned above, in spite of remarkable technological advancements regarding data collection and management, performance indicators that may be derived from box scores are still being used frequently in basketball performance analysis. That kind of basketball performance analysis may only be valid if the box score performance indicators are valid. A lot of those performance indicators are scoring indicators (e.g. 2-point field goals made (2P), 3-point field goals attempted (3PA) and free throw percentage (FT%)) (Csataljay 2009). It has been well documented that the efficiency of field goal shooting (FGS) is an important performance indicator (e.g. Ibanez et 2008; Lehto et al 2010; Zambova and Tomanek 2012). This makes it of uttermost importance that the performance indicator chosen to measure field goal shooting efficiency (FGSE) is valid, i.e. that it validly reflects how certain types of FGS affect the offensive team's chances of winning a game (Oliver 2004).

The core purpose of the present paper was to suggest a performance indicator that would measure FGSE reliably and validly and that would provide applicable information, “applicable” meaning that it should help enhance the improvement of the performance of a particular player or team (Lames and McGarry 2007). This performance indicator was called SQAT (Shot Quality Assessment Tool). The aforementioned core purpose placed the present paper in the realm of practical performance analysis (Maslovat and Franks 2008).

In order to correctly interpret the results produced by any performance indicator, one must review those results within their proper context (Alamar 2013). Thus, considering the core purpose of the present paper, one had to first theoretically present a statistical framework that covered both a team’s offensive performance and its defensive performance, because a team’s defensive performance affects its offensive performance and vice versa (Oliver 2004). Because a field foal shot (FGS) by definition leads to the ending of a play (Oliver 2004), it was justified to refer to a statistical framework designed to analyse different types of endings of plays. That framework was the well-known theory of Four Factors, originally presented by Oliver (2004). To better meet the purposes of the present paper, Four Factors was modified and re-named Six Factors.

Secondly, one had to determine which kind of performance indicator was theoretically optimally suited for measuring FGSE on its own, yet in synergy with the framework of Six Factors. This performance indicator was called Shooting Quality Assessmant Tool or SQAT. The synergy of Six Factors and SQAT implied that it was possible to use Six Factors and SQAT in question jointly to enhance the performance of a team, i.e. the information provided by one source complemented the information provided by the other one. Also, the data required were derived from the same data set since that limited the labour-intensity of the data gathering and thus enhanced the practical value of the methods. Thirdly, the applicability and the practical value of the Six Factors-and-SQAT combination was tested by applying them to the data derived games of Tapiolan Honka in the Finnish men's league. Fourthly, still because the present paper was within the realm of practical performance analysis, the results of the statistical analysis were used to discuss how to best enhance the performance of Honka or some other team. And finally, the generalizability and implications of the findings were discussed.

2. LITERATUTE REVIEW

2.1 PHASES OF CREATING A NEW PERFORMANCE INDICATOR

According to Alamar (2013), there are four phases in creating a new performance indicator, or metric, as he called it. Those four phases are "opportunity, survey, analysis, and communication" (Alamar 2013, p.65).

1) Opportunity phase. In this phase it is recognized that present performance indicator do not provide all information presently or potentially useful to stakeholders (Alamar 2013). An opportunity of this kind is often indicated by the emergence of questions that the present performance indicators do not provide answers to (Alamar 2013). The opportunity, or the need, may be met by creating a new performance indicator or by enhancing one already in existence (Alamar 2013). In the present paper the opportunity phase was addressed in the introduction (Chapter 1).

2) Survey phase. Performance indicators that have tried to answer the same or similar questions before are reviewed and scrutinized (Alamar 2013). It is recognized if and how they have failed to provide the information needed (Alamar 2013). Simultaneously, the goal and the context of the new performance indicator are defined in ever more detail (Alamar 2013). The survey phase of the present paper took place in Chapters 2 through 4.

3) Analysis phase. A new performance indicator is put together so that it meets the goals previously set (Alamar 2013). If need be, new data are gathered (Alamar 2013). The performance indicator is tested by applying the equation to relevant data, and the results are analysed and assessed (Alamar 2013). Chapters 5 through 7 of the present paper were the analysis phase.

4) Communication phase. The creator of the performance indicator presents the indicator to people in the organization he represents or to the public, and its usefulness is discussed and assessed (Alamar 2013). The scale of the performance indicator should be chosen so that it makes the indicator as comprehensible and easy-to-use as possible (Alamar 2013). The communication phase was mainly outside the scope of the paper, yet the future research section (Chapter 7.3) was relevant from this point of view.

2.2 FOUR FACTORS

2.2.1 FOUR FACTORS IN GENERAL

Four Factors is a wide spread concept in basketball performance analysis that was first presented by Oliver (2004) and further developed by Kubatko et al (2007). Four Factors has been quoted and discussed quite frequently in peer-reviewed articles (e.g. Bazanov and Vohandu 2009; Eldridge 2010; Strumbelj and Vracar 2012) as well as in popular articles (e.g. Scribbins 2011; Lawhorn 2012; Toppmeyer 2013). Four Factors has even been called “the backbone of advanced statistical analysis in basketball” (de Peuter 2013, p.1). Four Factors are the same on offense and on defense, yet the goal is obviously opposite (Oliver 2004). The offense will attempt to maximize the offensive redounding percentage (ORB%), while the defense will attempt to minimize it (Kubatko et al 2007).Table 2 shows Four Factors’ independent variables and their indicators as presented by Kubarko et al (2007).

Table 2: Four Factors, their indicators and equations

Variable	Indicator	Equation
Field goal shooting	eFG%	FG / FGA
Rebounding	ORB%	ORB / (Tm ORB + Tm Opp DRB)
Turnovers	TOV%	TOV / Possessions
Free throws	FT frequency	FTM / FGA

eFG%=Effective field goal percentage, FGA=FG attempts, ORB=Offensive rebounds, DRB=Defensive rebounds, Tm=Team, Opp=Opponents, TOV=Turnover, FTM=Free throws made. Source: Kubatko et al 2007. Abbreviations: Basketball Reference 2014.

Oliver (2004) and Kubatko et al (2007) suggested that Four Factors should be discussed jointly with offensive rating, i.e. how many points a team on the average scores in 100 possessions, and defensive rating, i.e. how many points a team on the average scores in 100 possessions. Kubatko et al (2007) suggested using offensive rating and defensive rating to reflect the overall efficiency of a team's performance and using Four Factors to more closely assess the details of both offensive and defensive performance. Baghal (2012) turned this train of thought around by claiming that offensive Four Factors are variables of a latent variable he calls offensive quality and that defensive Four Factors are variables of a latent variable he calls defensive quality. In short, Kubatko et al (2007) claimed that a team is good if it executes Four Factors efficiently, while Baghal (2012) claimed that if a team is good it executes Four Factors efficiently. From the standpoint of basketball performance analysis applied in the present paper, the logic used by Kubatko et al (2007) is more fruitful since it helps bring about more concrete goals for a development process within a team. In other words, it is easier to figure out how to affect certain performance-related variables and indicators than how to affect a very general characteristic of a team – say, whether it is a good team or a bad one.

A possession is defined as an “uninterrupted control of the ball” (Oliver 2004, p.27). Thus, according to this definition, an offensive rebound will not start a new possession because the offensive team maintains control of the ball (Lee and Berri 2008). However, an offensive rebound starts a new play, using Oliver’s terminology (2004). That is the only difference between a possession and a play (Kubatko et al 2007). Consequently, in any given game, the teams will have the same or almost the same number of possessions because by they by definition will have possessions in reciprocal succession (Oliver 2004). However, the number of their plays may differ a lot, depending on the teams’ rebounding efficiency (Oliver 2004).

Even though Oliver (2004) emphasized possessions rather than plays, Four Factors is precisely designed to cover all possible endings of plays, which are TOV, FG, FTA, DRB and ORB (Maymin et al 2013). This is not the case with possessions since, as mentioned, an ORB will not end a possession (Lee and Berri 2008). Covering all possible endings of play gives credence to Oliver’s bold claim about Four Factors (2004, p.63): “There really is nothing else in the game”. Through regression analysis it has been shown that Four Factors does predict a team’s success when the success is operationalized as the percentage of the games that a team wins, or won-lost percentage (Teramoto and Cross 2010). Four Factors explained 94% of the variance in won-lost percentage in the NBA regular season and 69% in the NBA playoffs (Teramoto and Cross 2010). All offensive and defensive Four Factors predicted won-lost percentage significantly (Teramoto and Cross 2010). Any of the correlations between the variables in Four Factors did not exceed .500, so there should not be any multicollinearity issues involved (Teramoto and Cross 2010). Table 3 shows how much of the variation in won-lost percentage Four Factors indicators explained according to squared semipartial correlation coefficient (Teramoto and Cross 2010).

Table 3: Variance in won-lost percentage explained by the Four Factors indicators

Indicator	Regular Season	Playoffs
Off. eFG%	23%	31%
Off. ORB%	4%	5%
Off. TOV%	9%	3%
Off. FT frequency	2%	3%
Def. eFG%	29%	30%
Def. ORB%	2%	3%
Def. TOV%	6%	5%
Def. FT frequency	2%	5%

Off.=Offensive, Def.=Defensive, eFG%=Effective field goal percentage, ORB=Offensive rebound, TOV=Turnover, FT=Free throw. Source: Teramoto and Cross (2010). Abbreviations: Basketball Reference 2014.

Based on the above, it seemed quite probable Four Factors was a well-enough established and justified statistical framework within SQAT could be developed and applied. As mentioned above, that was the core purpose of the present paper. However, it was important that the Four Factors framework was reviewed critically, variable by variable. This importance was due to three different aspects:

1) **Theoretical aspect.** Even though Four Factors' explanatory power regarding won-lost percentage had been shown to be strong, it seemed possible to make it even stronger. Also, despite the fact that the level of multicollinearity was low, it seemed possible to make it even lower through more precise operationalization of the dependent variables (Teramoto and Cross 2010).
2) **Practical aspect.** As mentioned above, the present paper was within the realm of practical basketball performance analysis. From that point of view, it seemed possible to improve a statistical framework no matter how well justified it was from a theoretical point of view. Having said that, it was recognized that Four Factors was most practical when it came to data collecting since all necessary data could be derived from readily-available box score statistics (Kubatko et al 2007). However, if practicality was understood as applicability, i.e. how simple it was to apply the findings to improving a team's performance, there was possibly room for improvement (Kubatko et al 2007).
3) **Contextual aspect.** In the present paper, Four Factors was treated primarily as the context within which field goal shooting efficiency (FGSE) could be analyzed by using SQAT. This emphasis made it necessary to adjust Four Factors so that it presented an optimal context for the use of SQAT.

2.2.2 FIELD GOAL SHOOTING

It has been shown over and over again that field goal shooting efficiency (FGSE) is an important factor in determining the success of a basketball team (Ibanez et 2008; Lehto et al 2010; Zambova and Tomanek 2012). This is consistent with the fact that in invasion team sports in general scoring indicators are most directly connected to won-lost percentage (Gerrard 2007).

Originally in Four Factors FGS was operationalized as FG%, or FG/FGA (Oliver 2004). The problem with this operationalization was that it treated 2P and 3-point field goals (3P) the same, even though 3P produces 1.5 times as many points as 2P (Kubatko et al 2007). In 2007 Kubatko et al replaced FG% in Four Factors with effective FG percentage (eFG%). The equation was:

$$(FG + .5 \times 3P) / FGA.$$

In other words, the relative effect of 2P and 3P on eFG% is now the same as their direct effect on the point total (Kubatko et al 2007). Later applications of Four Factors have continued to use eFG% as the indicator of FGS (Eldridge 2010; Teramoto and Cross 2010; Strumbelj and Vracar 2012). When assessing whether eFG% optimally indicated FGSE within the Four Factors framework, one had to first define both field goal shooting and efficiency.

In the Statisticians' Manual of Fédération Internationale de Basketball (FIBA), the act of shooting is defined as "an upward and/or forward motion toward the basket with the intention of trying for a basket" (FIBA 2012a, p.2). Hence a FGS should be defined as an act that occurs any time a player starts the act of shooting. However, if the shooter gets fouled in the act of shooting and misses the shot, that FGS will not count as FGA in the box score statistics and in the eFG% equation (FIBA 2012a). Hence FGS and FGA are defined differently which was important to notice in the context of the present paper.

A lot of times box score statistics are used to evaluate an individual's overall performance. The most influential ones of the numerous models developed for this purpose include TENDEX (Berri 1999), Wins Produced (Berri 1999), and Player Efficiency Rating (Hollinger 2011). From this particular point of view the aforementioned restriction in the definition of FGA is justifiable: since a missed FGA will lower the calculated value of an individual's performance (Berri 1999; Hollinger 2011), it may seem incorrect, even unjust, to include missed FGA where the shooter has been fouled since, the fouler (instead of the shooter) may be deemed to have caused the miss. From the point of view of Four Factors, however, the aforementioned restriction presents a problem since it systematically and by definition excludes certain types of FGS from the analysis while the stated goal is to indicate the efficiency of *all* FGS (Kubatko et al 2007). This makes the sample biased.

In spite of this, using eFG% as the performance indicator for FGSE may be rationalized in yet another way: the data necessary for calculating eFG% may be derived from the box score (Maymin et al 2013) and hence the procedure is, in a sense, practical. However, from a coaching point of view, the procedure is not practical because it may lead to incorrect conclusions about how to best enhance the team's performance. This may happen because eFG% does not reflect merely FGSE, as it is supposed to, but also the frequency of defensive fouls drawn by the shooter. That is because, within the definition of eFG%, when the shooter gets fouled, he can only make the FGS. So the more frequently the shooter gets fouled, the more frequently he has a chance to make a shot without the risk of a miss.

In the framework of Four Factors that is a problem, because there is supposed to be as little multicollinearity between the four factors as possible, and yet variables "field goal shooting" and "free throws" are clearly multicollinear to some degree. Thus the question becomes which indicator should be used for field goal shooting to lessen its multicollinearity with free throw frequency. One suggestion might be to simply include the missed FGS where the shooter was fouled, in the eFG% equation. This line of thought would lead to this equation for effective field goal shot percentage or eFGS%:

$$eFGS\% = (FG + .5 \times 3P) / FGS.$$

However, from a coaching point of view this simple adjustment would not be practical. That is because eFGS%, would drop the more the more frequently shooters get fouled because getting fouled diminishes the probability of the shot going in (Chapters 6.1 and 6.2). This drop in eFGS% would be misleading since, on the average, shooting fouls are positive occurrences for the offence (Kubatko et al 2007). Hence positive changes in FT frequency should not directly cause negative changes to be deducted by the indicator for FGS.

The same principle should hold true for all Four Factors: a positive change in one variable should not directly cause a negative change in another variable, and a negative change in one variable should not directly cause a positive change in another. This is because of the practical emphasis of the present paper: should one and the same change directly cause positive changes in one indicator and negative changes in another, it would make it difficult for a coach to determine whether the overall effect of the change is actually good or bad, or at least exactly how good or bad it is. In other words, the practical value of the statistical framework would suffer. This principle was called *the principle of unambiguity*.

The suggestion introduced in the present paper was to split eFGS% into two variables: eFGS% of FGS where the shooter is not fouled in the act of shooting (clean eFGS%) and eFGS% of FGS where the shooter is fouled in the act of shooting (foul eFGS%). This change provided two different types of eFGS%: one measured the eFGS% when the shooter is fouled and one when he is not. Adding to the number of independent variables added to the complexity of the analysis, yet it improved the practical value of the analysis by allowing coaches to assess the FGSE without this assessment being hampered by the bias caused by shooting personal fouls. Following this line of thought, the new equations became:

Clean eFGS% = (Clean FG + .5 x Clean 3P) / Clean FGS

Foul eFGS% = (Foul FG + .5 x Foul 3P) / Foul FGS

Efficiency may be defined as “a measure of the input a system requires to achieve a specified output” (Encyclopedia Britannica 2014). In the context of FGS in Four Factors, the number of FGS is regarded as the measure of the input. The output then is the effect that FGS has on a team’s chances of winning a game. It should be noted, however, that this effect is assessed within the framework of Four Factors, i.e. considering other dependent variables and avoiding multicollinearity. This restriction is important because the type of FGS correlates with the probability of a shooting foul occurring (82 Games no date) and ORB% (Goldsberry 2012b). I.e. in another context these variables should be considered when assessing FGSE (Chapter 6.2). However, the framework of Four Factors includes FT frequency and ORB% as separate dependent variables, and hence those aspects need not and should not affect the assessment of FGSE within Four Factors. So, clean eFGS% and foul eFGS% were deemed to be appropriate and sufficient indicators to be used jointly to assess FGSE within Four Factors.

The following fictional example will demonstrate the difference between eFG% on one hand and the combination of clean eFGS% and foul eFGS% on the other hand. Let us assume that both Player #A and Player #B only shoot 2FGS. When #A is not fouled, his accuracy is 26/64 (clean eFGS% .41), and when he is fouled, the accuracy is 12/36 (foul eFGS% .33). #B’s respective numbers are 39/84 (clean eFGS% .46) and 6/16 (foul eFGS% .38). So, according to both clean eFGS% and foul eFGS% #B is the more effective field goal shooter of the two. Yet #A and #B have the same eFG%, .50. The apparent anomaly is caused by #A's being fouled more frequently than #B. Since the missed FGS where the shooter gets fouled do count as FGA, eFG% is affected not only by the accuracy of shooting but also by the shooting foul frequency. Jacas (2013) calls this phenomenon "shooting foul bias". Hence in the example, #A has 100 FGS but only 76 FGA because he missed 24 FGS where he was fouled. The calculations for #A's and #B's eFG% are:

1) *Player #A's eFG% = (26 + 12) / (64 + 12) = 38 / 76 = .50*
2) *Player #B's eFG% = (39 + 6) / (84 + 6) = 45 / 90 = .50*

2.2.3 REBOUNDING

A rebound is "the controlled recovery of a live ball by a player after a shot has been attempted" (FIBA 2012a, p.41). In other words, a rebound always starts a new play and determines which team may score next. That is obviously important regarding the outcome of the game.

In Four Factors, ORB% is used as the indicator for rebounding (Kubatko et al 2007). It is a more proper indicator for rebounding efficiency than the total number of rebounds, because FGS and pace will affect that total number. That is for two reasons:

1) The less efficient FGS is, the more total rebounds both teams are likely to get (Kubatko et al 2007).

2) Pace is defined as the number of possessions per game (Kubatko et al 2007). The quicker the pace, the more shots will be taken, the more shots will probably be missed, and the more total rebounds both teams are likely to get (Kubatko et al 2007).

2.2.4 TURNOVERS

A turnover is an action where the defensive team gains “possession of the ball without the offensive team having attempted a field goal or free throw” (FIBA 2012a, p.44). TOV affects the outcome of the game in at least two ways. First, a play ends without a score. Second, a play initiated after a TOV will be more efficient for the offense than a play initiated after a defensive rebound (Lehto 2010).

In Four Factors, TOV% is used as the indicator for turnovers (Kubatko et al 2007). It reflects the share of possessions that end without the offensive team taking a FGS or a FTA (Kubatko et al 2007). As was partly the case with rebounds, TOV% is used instead of the total number of TOV in order to neutralize the effect of the pace (Kubatko et al 2007). Four Factors as presented by Kubatko et al (2007) used this equation:

$$TOV\% = TOV / Possessions$$

When considered within the context of the present paper, this TOV% equation presented a problem. Since the core purpose of this paper was to suggest a performance indicator to measure FGSE (SQAT), it was appropriate to analyse a game as fragments that would not include more than one FGS. However, a possession may include any number of FGS, since an ORB will start a new possession (Kubatko et al 2007). Hence, within this context, it seemed more appropriate to fragment a game into plays since they by definition include no more than one FGS (Kubatko et al 2007). Given this, the equation for TOV% in the present paper was:

$$TOV\% = TOV / Plays$$

2.2.5 FREE THROWS

A team may earn FTA as the results of the other team a) fouling a player in the act of shooting, b) committing more that four fouls in a quarter, causing a team foul penalty situation, and c) committing a technical foul (FIBA 2012b). Generally, earning FTA is considered advantageous for the offensive team because on the average they produce points at a higher rate than FGA (Jacas 2013). Also, FTA indicate that fouls have been called on the opponent, and the opponents' fouls are advantageous for additional reasons besides the FTA directly resulted by them. First, most fouls add to the number of team fouls (FIBA 2012b) and thus they enhance the total number of FTA not only directly but also indirectly, via team fouls. Second, under the FIBA rules (2012b), a player is disqualified after committing five personal fouls which may affect the outcome of the game. The number of personal fouls may be important even if a player does not eventually foul out of the game because the fouls accompanied with the risk of fouling out may hamper the player's performance or make his coach substitute for him when it would be advantageous for the team to leave him on the court if not for the fouls (Maymin et al 2011).

Originally Oliver (2004) used this equation to measure FT frequency:

FT frequency = FTA / FGA

An obvious problem with this equation was that FT frequency was not affected by whether a team made or missed its FTA even though that affected its offensive rating (Lopez-Gutierrez and Jimenez-Torres 2013). Later the equation was modified into (Kubatko et al 2007):

FT frequency = FTM / FGA

In this edited version of the equation, making the FTA does raise FT frequency. Yet the new equation is still theoretically problematic since happenings, that are negative for the team, may cause FT frequency to rise. I.e. if the shooter misses a FGS where he gets fouled (foul FGS) it affects the FT frequency more positively than if he makes the shot. That is because a missed foul FGS will not add to the number of FGA, as a made foul FGS does, and because a missed foul FGS provides the offense with two FTA, whereas a made foul FGS will only provide one. This phenomenon goes against the principle of unambiguity.

From a practical point of view, another problem in the FT frequency equation was FTM's being included. If a team has a relatively low FT frequency in Four Factors, that frequency alone will not tell in which aspect the biggest room for improvement lies – i.e. whether the team should concentrate on enhancing

FT% or the number of FTA. As Kubatko et al (2007) themselves pointed out, earning FTA and making them are two separate issues. That is necessarily so because FT shooting is a closed skill, a rarity in basketball as well as in any invasion team sport (Czech et al 2004).

Ezekowitz (2011) suggested that, within the Four Factors framework, FTM/Possessions ratio should be used instead of FT frequency to measure the overall effectiveness of a team's FT shooting. He managed to find evidence that FTM/Possessions predicted a team's offensive rating better than FT frequency did (Ezekowitz's 2011). Ezekowitz's (2011) suggestion was also a theoretical improvement over FT frequency since in FTM/Possessions, contrary to FT frequency, a made foul FGS did not add to the divisor (possessions) any more than a missed foul FGS did. However, since FTM was included in FTM/Possessions as well, the aforementioned practicality issues, that hampered FT frequency, hampered FTM/Possessions, too.

Another solution was hinted at by Kubatko et al (2007): since earning FTA and making them were two separate issues, the two could also be two separate independent variables. This solution was chosen in the present paper.

The efficiency of making FTA was operationalized as FT% since all FT's are worthy of one point and since there are no shooting fouls involved in the act of shooting FT. These two features set FT shooting apart from FGS and make it easier to assess its efficiency. (See Chapter 2.2 for complications concerning assessing FGSE.) This left open the question of how one should operationalize a team's efficiency when earning FT.

The simple solution seemed to be to use FTA as the dividend in the FT frequency equation. Yet it was shown above that neither FTA nor FTM should be the dividend since missing a foul FGS would lead to more FTA and FTM than making a foul FGS will, even though making a foul FGS was a more positive happening for the offensive a foul FGS. Hence using either FTA or FTM in the free throw frequency equation would have made the results misleading regarding the overall efficiency of a team's offense.

The only options left for the dividend were the number of number defensive fouls or the number of FT sets. As mentioned above, the results produced by a performance indicator must be reviewed within a proper context (Alamar 2013). The context here was Four Factors where the independent variables cover all endings of plays (Maymin et al 2013). Since a defensive foul will not necessarily be the ending of play but a FT set will be, it was justified to choose the number of FT sets as the dividend in the FT frequency equation. Also, obviously, FT sets were more directly linked to FT frequency than the total number of defensive fouls was.

The options for the divisor were possessions and plays. Plays were chosen for the same reasons they were chosen for the TOV% equation (Chapter 2.2.4). Hence the equation became:

FT frequency = FT Sets / Plays

2.3 EFFICIENCY OF FIELD GOAL SHOOTING

As mentioned as above, the importance of field goal shooting efficiency (FGSE) to the outcome of a basketball game has been unanimously accepted (Chapter 1). Yet a consensus regarding the operationalization of FGSE has not been reached but a variety of performance indicators have been used (Martinez 2010). Table 4 shows some of them.

Table 4: Examples of performance indicators for calculating FGSE

Performance indicator	**Equation**	**Reference**
Field goal percentage (FG%)	FG / FGA	Oliver (2004)
Effective field goal percentage (eFG%)	(FG + .5 x 3P) / FGA	Kubatko et al (2007)
Effective field goal percentage+ (eFG%+)	eFG% – Effective shot quality	Chang et al (2014)
True shooting percentage (TS%)	(PTS / 2)/(FGA + .44 × FTA)	Kubatko et al (2007)
Points per shot (PPS/Kubatko)	PTS / (FGA + .44 x FTA)	Kubatko et al (2007)
Points per shot (PPS/Neyer)	(PTS – FTM) / FGA	Neyer (1996) as explained by Berri and Scmidt (2010)
Gross-offensive efficiency	PTS / (Possessions – (*Bonus FT sets* + TOV))	Goldman and Rao (2013)

FGA=Field goal attempts, FG=Field goals made, 3P=Three-point field goals made, PTS=Points, TOV=Turnover, FTA=Free throw attempts, FTM=Free throws made, eFG%=Effective field goal percentage. Abbreviations: Basketball Reference 2014.

It was shown that jointly clean eFGS% and foul eFGS% indicate FGSE properly within the framework of Six Factors (Chapter 3). However, the core purpose of the present paper was to suggest a performance indicator that was suited for measuring FGSE *per se* though in synenergy with the framework of Six Factors (Chapter 1). This made it necessary re-evaluate the issue since all results of performance analysis must be reviewed within a proper context (Alamar 2013). In other words, clean eFGS% and foul eFGS% could not be taken out of the context of Six Factors and be assumed to properly indicate FGSE standing alone simply on the grounds of their so doing within the context of Six Factors.

Most often, FGSE is measured by how many points a certain type of FGS on the average produces directly, i.e. through points received from FG (Maheswaran et al 2012). However, the type of FGS correlates with the frequency of a shooting foul occurring (82 Games no date) and with ORB% (Goldsberry 2012b). Since those variables correlate with a team's W–L% (Teramoto and Crossa 2010), they should be considered when assessing FGSE. I.e. they had to be a part of the equation of the performance indicator that the present paper aimed to suggest: an indicator that was suited for the measuring FGSE.

Also, since the context of the present paper was practical basketball performance analysis, it added to the value of the sought-after performance indicator that it produced, not just one FGSE figure, but three separate figures:

one for the resultant FG point production, one for the value of the resultant shooting fouls, and one for value of the resultant ORB. Then the comprehensive FGSE could be calculated based on those three separate figures. This characteristic added to the practical value of the performance indicator because it made it easier to diagnose the FGS performance of a team and then implement the consequent intervention. I.e. one comprehensive FGSE figure may correctly demonstrate a team's FGSE, yet it may leave it up to the coach to judge whether the weakest link is direct point production, the frequency of shooting fouls, or ORB%. Having a separate figure for each of these factors helps the coach determine which factor the intervention should try to affect first or foremost.

Shooting foul frequency and ORB% could be and had to be ignored when assessing FGSE within the framework of Six Factors because in Six Factors they are considered through other performance indicators, namely FT frequency and ORB% (Chapter 3). However, when FGSE is assessed *per se*, outside the framework of Six Factors, those two variables had to be considered by the performance indicator, since they correlate with the type of FGS and they affect on a team's chances of winning a game (Chapter 3). Hence clean eFGS% and foul eFGS% alone were not the optimal performance indicators to assess FGSE *per se*. In the context, of Six Factors, turnovers and free throw efficiency could be left unconsidered since it was not possible that either should correlate with the type of FGS. For turnovers this was true because, by definition, it was not possible that TOV and FGS of any type should take place in the same play. Free throw efficiency is indicated by FT%, and FTA is an action isolated from other actions – including FGS – in the game (FIBA 2012b).

Table 4 showed six other performance indicators used to assess FGSE: FG%, eFG%, eFG+, TS%, PPS and Gross-offensive efficiency. As the list below shows, none of these performance indicators may be used to validly assess FGSE.

1-2) FG% and eFG%. The rationale behind FG% and eFG% was explained in Chapter 2.2.2. Neither one could serve as the FGSE performance indicator because shooting fouls and ORB are ignored in the equations.

3) eFG%+. Aims to measure the shooting skills of a player or a team by taking into consideration the average difficulty of the shot. This is done by subtracting the expected eFG% from the actual eFG% (Chang et al 2014). Chang et al (2014) referred to the expected eFG% as effective shot quality. It was calculated using NBA game data from SportVU player tracking system (Chang et al 2014). The independent variables were shot location, distance between the shooter and the defender, and the number of dribbles by the shooter before the shot (Chang et 2014). eFG%+ is an example of the aforementioned trend in basketball performance analysis scoring where data from advanced forms of technology is combined with the traditional box score statistics (Chapter 1). However, the fact that eFG% ignores shooting fouls and ORB was enough to make it an invalid performance indicator for measuring FGSE in the context of the present paper.

4-5) TS% and Points Per Shot / Kubatko. TS% aims to measure the success rate of all shots, both FGS and FTA. In order to achieve that, the success rates of 3FGA and FTA are made commensurable with that of 2FGA (Eldridge 2010). PPS/Kubatko aims to measure the average point production of all shots, both FGS and FTA. Thus it uses almost the same equation as FG%, but since the scale is points (PTS) instead of percentage, PTS is not divided by 2:

$$TS\% = (PTS / 2) / (FGA + .44 \times FTA)$$

$$PPS/Kubatko = PTS / (FGA + .44 \times FTA)$$

In the equations .44 is the estimated probability of a given FT leading to the ending of a possession (Kubatko et al 2007). This estimation is based on statistics derived from NBA games (Kubatko et al 2007). Because of the aforementioned similarities, the following criticism applied to both TS% and PPS/Kubatko.

In the present context TS% and PPS/Kubatko were invalid for measuring FGSE. That was for at least three reasons. First, they ignored the probability of OR. Second, in their equations, FTA caused by shooting fouls and FTA caused by other types of fouls were treated equally. That made it impossible to accurately measure FGSE. Third, besides FGSE, also FT efficiency affected total points scored and thus both TS% and PPS/Kubatko.

6) Points Per Shot / Neyer. Neyer's definition of PPS was different from Kubatko's definition of PPS (Berri and Schmidt 2010; Kubatko et al 2007).:

PPS/Neyer = (PTS – FTM) / FGA

The difference between PPS/Kubatko and PPS/Neyer seemed to stem from the difference in their implicit definitions of S (shot) in PPS (Points Per Shot). The PPS/Kubatko equation treats all FGS as shots, e.g. all foul FGS, where the shot is missed, are also implicitly defined as shots. Conversely, by using FGA as the divisor, PPS/Neyer excludes all foul FGS where the shot is missed, from the category of shots. This exclusion takes place since that type of foul FGS are not included in FGA (Chapter 2.2.2). Analogously, the dividend in the PPS/Neyer equation is the total points produced by FG, or total points minus points from free throws.

In other words, the relationship between PPS/Neyer and eFG% is analogous to the relationship between PPS/Kubatko and TS%: PPS/Neyer and eFG% measure exactly the same thing but the scale is different. Whereas PPS/Neyer and PPS/Kubatko use point production as the scale, eFG% and TS% use success rate. On the other hand, PPS/Neyer and eFG% exclude missed foul FGS from their definition of FGS, and, conversely, PPS/Kubatko and TS% include missed foul FGS.

Since the only difference between PPS/Neyer and eFG% is the scale, PPS/Neyer was deemed an invalid instrument to measure FGSE in the present context for the same reasons that eFG% was deemed invalid: because it ignored shooting fouls and ORB.

7) Gross offensive efficiency. Gross offensive efficiency measures the amount of points scored in a possession after a FGS (Goldman and Rao 2013), i.e. the possessions, where no FGS takes place, are excluded from the equation. The equation is (Goldman and Rao 2013):

Gross offensive efficiency =

PTS / (Possessions – (Bonus FT sets + TO))

PTS in the equation does not refer to the total amount of the points scored, but to the points scored in the possessions included in the divisor (Goldman and Rao 2013).

In a certain way Gross offensive efficiency does manage to consider the effect of both shooting foul frequency and ORB% on FGSE. That is because the equation includes not only points from FG but also the points from FTA that the shooting fouls result in and the points scored after resultant offensive rebounds (Goldman and Rao 2013).

Yet in the context of the present paper, Gross offensive efficiency was not the optimal performance indicator for measuring FGSE, either. That was for at least three reasons:

1) There was multicollinearity because FT efficiency affected the number of FTM and thus the number of PTS or the dividend in the equation. This should not have been the case (Chapter 2.2.1).
2) Gross offensive efficiency ignored the shooting fouls' other positive consequences besides the resultant FTA. These other consequences included possible bonus FT sets that the team is awarded after the opponents have fouled four or more times during a quarter (FIBA 2012 b).
3) Gross offensive efficiency was one comprehensive figure, i.e. it did not reveal the proportional contributions of FG, shooting fouls drawn, and ORB. This was problematic considering the practical nature of basketball performance analysis practiced in the present paper.

3. SIX FACTORS

Based on the suggestions above, Four Factors as presented by Kubatko et al (2007), was modified into Six Factors for the purposes of the present paper. Table 5 shows Six Factors' independent variables and their indicators and equations. The addition of two factors was caused by two of Kubatko et al's (2007) independent variables, namely field goal shooting and free throws, being split into two. It should be emphasized that these modifications were made for the purposes of this paper. They helped to achieve the core purpose of the paper, or to suggest a performance indicator that could be used to measure FGSE within Four Factors (or Six Factors) and the realm of practical performance analysis. Whether those modifications should be maintained when using Four Factors/Six Factors in other contexts, remained an open question.

Table 5: Six Factors, their indicators and equations

Variable	Indicator	Equation
Field goal shooting – no shooting foul	Clean eFG%	(Clean FG + .5 x Clean 3P) / Clean FGS
Field goal shooting – shooting foul	Foul eFG%	(Foul FG + .5 x Foul 3P) / Foul FGS
Rebounding	ORB%	Tm ORB / (Tm ORB + Opp DRB)
Turnovers	TOV%	TOV / Plays
Free throw frequency	FT frequency	FT Sets / Plays
Free throw efficiency	FT%	FTM / FTA

eFG%=Effective field goal percentage, FG=Field goals made, 3P=Three-point field goals made, FGS=Field goal shot,, ORB%=Offensive rebounding percentage, Tm=Team, Opp=Opponents, TOV=Turnover FT=Free throw, FTA=Free throw attempts, FTM=Free throws made. Abbreviations: Basketball Reference 2014.

4. SHOT QUALITY ASSESSMENT TOOL SQAT

4.1 PREREQUISITES TO SQAT

As mentioned above, the core purpose of the present paper was to suggest a new performance indicator to measure FGSE. This performance indicator was called SQAT. Based on the opportunity phase and the survey phase or creating SQAT (Chapter 2.1), it was designed to meet these five prerequisites:

1) SQAT measured FGSE, with the concept of efficiency including in addition to direct point production the effect of FGS on FT frequency and ORB.
2) SQAT was calculated from three separate figures, so that it was possible to assess how direct point production, FT frequency and ORB% effected FGSE separately, as well as jointly.
3) It was possible to use SQAT in synergy with the statistical framework of Six Factors.
4) Gathering data for and using SQAT required as little labour as possible.
5) The choice of scale optimized the comprehensibility and usability of SQAT.

As shown above, when measuring FGSE, the scales of choice were percentage of success and average point production. Using average point production as the scale made SQAT more comprehensible and practical since points – not percentages – are what FGS directly produce.

In any SQAT analysis, FGSE will be the dependent variable. The number of potential independent variables is huge since a lot of variables affect the outcome of a FGS. These are some of the possibilities that have been suggested in previous studies: the shooter's distance from the basket (Chang et al 2014), the angle of the shooter's location relative to the basket (Goldsberry 2012c), the amount of defensive pressure on the shooter (Weil 2011), biomechanics of the shot (Lindeman et al. 2000), the shooter's decision making (Skinner 2012), the frequency of pick and rolls (Lehto et al 2010), the frequency of the opponents' turnovers (Sampaio et al 2010), the usage of dribbles (Chang et 2014), and the shooter's movement prior to the shot (Bartlett 2008).

Even if the same independent variables are used, they may be defined and categorized in different ways. One such example is the shooter's distance which was the only independent variable used when SQAT was applied in the present paper. Prior researchers have often categorized the distance into three categories: close range 2PA, mid-range 2PA, and 3PA (Csataljay et al 2013; Goldsberry and Weiss 2013; Maheswaran et al 2012). The difference between 2PA and 3PA is determined by the basketball rules and is obviously relevant to FGSE because 3PA have the potential to produce more points than 2PA. There is evidence that the difference between close range 2PA and mid-range 2PA is also relevant to FGSE because of changes in both shooting accuracy and shooting foul frequency (Csataljay et al 2013; Goldsberry and Weiss 2013; 82 Games no date). However, the fact that the difference between these two types of 2PA is not determined by the official rules has allowed researchers to use their own judgement when drawing the demarcation line (Csataljay et al 2013; Goldsberry and Weiss 2013; 82 Games no date). Because of the difference between FGA and FGS (Chapter 2.2.2), the shot distance categories in SQAT were called close range 2PS, mid-range 2PS and 3PS.

4.2 DIRECT POINT PRODUCTION IN SQAT

Previously, eFGS% was found to be an invalid performance indicator to indicate FGSE within the framework of Six Factors (Chapter 2.2.2). That was because when it came to that context, eFGS% failed to properly reflect the effect of shooting fouls occurring. However, eFGS% does perfectly well reflect the direct point production of FGS. This made it valid for use in SQAT. The equation was:

eFGS% = (FG + .5 x 3P) / FGS.

However, the scale in eFGS% is, obviously, percentage. The equation for direct point production per FGS was:

PTS / FGS = (2 x 2P + 3 x 3P) / FGS

4.3 SHOOTING FOULS IN SQAT

On the average, shooting fouls benefit the offensive team in a variety of ways:

1) If FGS is good, the offensive team is awarded one FTA that may produce an extra point or lead to an ORB (FIBA 2012b).
2) If FGS is missed, the offensive team receives two or three FTA (FIBA 2012b). On the average FT% is better than eFGS% (Chapter 6.1).
3) Shooting fouls add to the total number of the defensive team's team fouls. Once Team #A has committed four fouls in a period, Team #B is awarded two FTA for every non-shooting personal foul by Team #A unless Team #A is "in control of the live ball" (FIBA 2012b, p.44) when

committing the foul. This benefits the offensive team, since, as mentioned, FT% tends to be higher than eFGS% (Chapter 6.1).

4) Shooting fouls add to the number of personal fouls of the player who has committed the foul. This elevated risk of being eventually excluded from the game because of five fouls may either harm the performance of the concerned player or make his coach substitute for him in a less-than-optimal way (Maymin et al 2012). This situation is commonly called “foul trouble” (Maymin et al 2012).

As will be shown shortly, the point value of other advantages that shooting fouls bring to the offensive team may be calculated using proper equations but the value of the aforementioned causing foul trouble was left outside the scope of SQAT. This exclusion was due to the fact that there are an infinite number of variables that affect the severity of foul trouble. Maymin et al (2012, p.20) list some of them: “player fatigue, injury history, team-strategic fouls such as non-penalty end-of-quarter situations, and bench depth”.

Whether a FTA is actually made or not should not determine the point value of a FTA when it comes to SQAT, because if it did, unnecessary collinearity would be created, i.e. FT efficiency or FT% of a particular team or player would be let to affect FGSE. Rather, the value of a FTA should be determined by the average FT% of the context. I.e. when analysing Finnish league games, the Finnish league should be treated as the context. Thus, the point value of FTA should be set as the average FT% in the league. Using a league average as a standard is a common procedure in performance analysis (Berri and Schmidt 2010; Gerrard 2007; Martinez and Martinez 2011). In season 2013–14 the FT% in the Finnish league was .73 (7821/10752) (FBA 2014a).

There was a complication to inserting this FT% into the FGSE equation, however. That was because there is very possibly a tendency for shooters to hit the second FTA of a set more efficiently than the first FTA, and to hit the third FTA even more efficiently than the second FTA (Yaari and Eisenmann 2011). In the NBA season 2005–06 the likelihood of a shooter's making the second attempt was three percentage points higher than his making the first attempt (Arkes 2010). Regarding the present paper, it would have been possible to look into whether such an effect existed in the Finnish league and what the size of the effect was. Had such an effect been found to exist, the value of a set of one FTA would have been lower in the SQAT equation than it now was, and the values of sets of multiple FTA would have been higher. (See Appendix A for the equation.)

However, since it was decided that in the present paper only data gathered from the sample of 22 Honka games would be used (Chapter 5.1), it became impossible to reliably determine the value of an FTA depending on its running numbers in a FT set. That was because the sample size was so small. Also, there were practical issues regarding data gathering since the relevant data were not readily available but they should have been manually gathered from the play-by-play data. Hence in the present paper all FTA were treated the same and their point production in SQAT was calculated by the simple equation of

(FTA x FT%) / FGS.

As mentioned, shooting fouls add to the total number of defensive team's team fouls and thus help the offensive team become eligible to earn bonus FT sets for defensive team's non-shooting fouls (FIBA 2012b). Building the equation for calculating the advantage caused by any shooting foul through the possibility of its leading to later bonus FT sets begins with recognizing that the number of fouls leading to bonus FT sets is four times the number of "bonus quarters" or quarters where the team gets at least one bonus FT set (FIBA 2012b). It should be noted that a quarter is a bonus quarter only if at least one bonus FT set is actually shot – i.e. five fouls committed by defensive team will not alone make the quarter a bonus quarter. That is because regarding SQAT, the goal was not to assess the value of drawing fouls *per se*, but the value of earning FTA. The probability of a foul partly leading to at least one bonus FT set is four times the number of bonus quarters divided by the number of team fouls, i.e.

4 x Bonus quarters / Team fouls.

The number of bonus FT sets caused the four fouls that are involved in causing BS is on the average

Bonus FT sets / Bonus quarters.

The portion of the caused bonus FT sets for each of the four fouls is

Bonus FT sets / (Bonus quarters x 4).

The advantage gained by earning a bonus FT set is the average number of points from a two-FTA set minus the average point production of a play or Point Per Play (PPP):

$$(2 \times FT\%) - (PPP).$$

The PPP equation is simply

$$PPP = PTS / Plays.$$

So the equation for the bonus FT related advantage gained by each shooting foul was

$$(4 \times \text{Bonus quarters} / \text{Team fouls})$$
$$\times (\text{bonus FT sets}) / (\text{Bonus quarters} \times 4)$$
$$\times ((2 \times FT\%) - PPP)$$

Or

$$\text{Bonus FT sets} / \text{Team fouls} \times (2 \times FT\% - PPP).$$

4.4 OFFENSIVE REBOUNDING IN SQAT

Different types of FGS may lead to consistently different ORB% (Witus 2008). Hence ORB% must be considered when measuring FGSE. Also of importance is the fact that on the average, FGS lead to a higher ORB% than FTA do (Maymin et al 2013). According to Maymin et al (2013), in the NBA in seasons from 2006–07 to 2009–10 the percentages were .31 and .13, respectively.

The point production of an offensive rebound is considered to be the same as PPP. The logic is simply that since the offensive team maintains the possession of the ball it may expect to gain the average amount of points produced by a play, in contrast to the defensive team gaining the possession and the opportunity the next points. The equation for points produced by ORB per FGS is:

(ORB / FGS) x PPP

However, there is a complicating factor within the definition of ORB. It obviously includes the actual ORB gathered after missed FG. It should also include the ORB off missed FTA, but the problem is that since the actual outcome of FTA is ignored in the FGSE analysis, it is improper to use the actual ORB that follow those FTA. Instead, the expected number of ORB after FTA is calculated based on FT% and the average ORB% after missed FTA. Hence the equation for the number of ORB is:

(ORB after FGA)

+ (Shooting foul x (1.00 – FT%) x (ORB% after missed FTA)

4.5 THE EQUATION OF SQAT

It is now possible to put together the equation for SQAT, i.e. to see how field goal shooting efficiency (FGSE) is to be calculated based on the assumptions made and conclusions drawn above. This is the SQAT equation:

FGSE =

((2 x 2P + 3 x 3P)

+ (FTA x FT%)

+ Shooting foul x (Bonus FT sets / Team fouls x (2 x FT% – PPP))

+ (ORB after FGA) x PPP

+ Shooting foul x (1.00 – FT%) x (ORB% after missed FTA) x PPP)

/ FGS

Of these numbers, 2P, 3P, FTA, shooting fouls, ORB after FGS and FGS are directly related to the FGS whose efficiency is being calculated. The rest of the numbers – i.e. FT%, bonus FT sets, Team fouls, PPP and ORB% after missed FTA – are league averages. Using them as the standard is a common procedure in performance analysis (Berri and Schmidt 2010; Gerrard 2007; Martinez and Martinez 2011). The number of plays – which is a necessary piece of data for calculating PPP – may be either derived from the play-by-play data or estimated using the equation by Kubatko et al (2007):

Plays = FGA + .44 x FTA + TOV.

ORB% after missed FTA may be derived from play-by-play data.

5. METHODS

5.1 SAMPLE AND DATA GATHERING

The sample consisted of 22 games played by Tapiolan Honka in Korisliiga during the 2013-2014 season (For the list of games, see Appendix B). The games were chosen on these grounds:

1) One home game and one road game of Honka against each of the other eleven teams in the league were included.

2) The last such games were included whenever there was an archived video available.
3) If not, the game was replaced by a previous home or road game (whichever the game with the missing video was) against the same team.

The sample came to include 2 games against each opponent, 11 home games and 11 road games, and 10 wins and 12 losses.

For Six Factors, data were gathered mainly from box-score statistics and play-by-play data provided online by the Finnish Basketball Association (FBA 2014c). The only data gathered for calculating Six Factors that were gathered from game videos were the data whether certain free throw sets were due to team fouls or shooting fouls. The game videos were derived from online archives provided by Sstatzz (Sstatzz 2014).

For SQAT, some league averages (i.e. FT%, bonus FT sets, team fouls, PPP and ORB% after missed FTA) are generally to be used (Chapter 4.3). When it came to the present paper, however, it had to be considered that of the five variables mentioned, it was possible to derive league averages only for FT% and Team fouls from the publicly available statistics (FBA 2014b). The league averages of PPP and ORB% could be calculated after deriving data from the play-by-play logs of all 264 regular season games. To be able to calculate bonus FT sets, one had to watch game videos, too, because play-by-play data will not diffenrentiate whether a foul leading to a FTset was a shooting foul or a non-shooting foul.

Hence it had to be questioned whether deriving all of the data mentioned from play-by-play logs and game videos was too time-consuming and hence too impractical a process. This question of practicality concerned not only the process of writing the present paper but also the core purpose of the paper. Because that purpose was to suggest a performance indicator that could be used to help to improve the FGS performance of Honka, the data-gathering process required for using SQAT could not be too work-intensive. If it was, SQAT probably would not be used in the future. According to Tuomas Iisalo – head coach of Honka in 2014–15 – the team does not have the manpower to gather data from all league games as described above (Iisalo 2014).

Because the present paper lies within the context of basketball performance analysis, it was justified to change the definitions of the variables in the SQAT equation to make them meet the constraints of the actual situation where SQAT was to be used (Alamar 2013). Hence the only data used in the present paper were the data gathered from the sample of 22 Honka games. This adjustment diminished the generalizability of the results, but it was nevertheless necessary considering the practical constraints set by the working environment of Honka (Iisalo 2014).

In the SQAT analysis, the shooter's distance from the basket was used as the only independent variable. The shooter's distance from the basket was determined from the game videos, judging where his foot closest to the basket was planted when he shot or, if he shot while airborne, where the closest foot was when he took off (FIBA 2012b). All other data were gathered from the official box score statistics, the official play-by-play archives, or from the data already gathered from the game videos for the Six Factors analysis. Because of this, there were no inconsistencies in the data sets of Six Factors and SQAT.

There were three FGS distance categories used: close range 2PS, mid-range 2PS and 3PS. The practical point of view was used as the rationale when defining the demarcation between close range 2PS and mid-range 2PS. For a shot to be considered close range 2PS it had to be taken:

1) Inside the 3-second area,
2) No closer than 1.10 metres to the free-throw line.

This makes the distance of close range 2PS in the present paper approximately the same as in previous studies and easy to determine based on the markings on the floor (Csataljay et al 2013; FIBA 2012b; Goldsberry and Weiss 2013; 82 Games no date; Maheswaran et al 2012) (See Appendix C).

5.2 DATA ANALYSIS

Six Factors were calculated for Honka and their opponents in the 22 games of the sample. The outcome of a game was defined as the plus/minus point differential from Honka's point of view. Shapiro-Wilk test was used to assess the normality of the independent variables. With Pearson's correlation coefficient, a correlation matrix was put together to see if there was any risk of multicollinearity. T-tests were used to see if there were statistically significant differences in Six Factors between Honka and opponents and between winners and losers. Linear regression analysis was performed to assess the effect size of Six Factors on the outcome of the game.

The point values for different types of FGS and their outcomes were calculated using the SQAT equation and the statistics derived from the sample games while doing the Six Factors analysis. The point values turned out to be (See Appendix D for detailed calculations):

2PS + DRB = .00

3PS + DRB = .00

2PS + ORB = .98

3PS + ORB = .98

2PS + shooting foul = 1.60

2P = 2.00

3PS + shooting foul = 2.35

2P + shooting foul = 2.85

3P = 3.00

3P + shooting foul = 3.85

In the SQAT analysis, frequency data and thus nonparametric tests were used. The Chi square test was used to assess if the distribution of close range 2PS, MD2 and 3PS was different between Honka and opponents and between winning and losing teams. The Mann Whitney U test was used to see if there were differences in the point production. The comparisons were made between close range 2PS, mid-range 2PS and 3PS of Honka, opponents, winning teams, and losing teams. Also, the close range 2PS, mid-range 2PS and 3PS performances of different teams were compared. These comparisons were made on one hand between Honka and opponents and on the other hand between winning teams and losing teams. Because statistically significant differences were found between close range 2PS and 3PS performances of winning and losing teams, Z tests were used to find out if some variable(s) could be shown to explain those differences.

The data were processed using Excel and StatPlus software and on-line statistical tools provided by Social Science Statistics (no date).

6. RESULTS

6.1 SIX FACTORS

According to the Shapiro-Wilks test, all independent variables excluding Honka TOV% were normally distributed. Honka TOV% was deemed not to be normally distributed ($p<.05$). The outlier was that in one game Honka turned the ball over 25 times for a TOV% of .28. While that was a high percentage, it was not an anomaly: in one game the opponents' TOV% reached .26. Re-test using the Kolmogorov-Smirnov test determined Honka TOV% to be normally distributed, too. On these two grounds, parametric tests were used when testing for Six Factors. No correlation between Honka's offensive and defensive Six Factors reaches .500 and thus demands further attention. (See Appendix E for the correlation matrix.)

No statistically significant difference was exposed between Honka's offensive and defensive Six Factors, i.e. between the offensive Six Factors of Honka and the opponents (See Appendices F through I). The only offensive Six Factors where there was a statistically significant difference between the winning team and the losing team was clean eFG% ($p<0.001$) (Table 6).

Table 6: Z test comparing Six Factors of winning and losing teams

	Clean eFG%	Foul eFG%	ORB%	TOV%	FT frequency	FT%
Winning teams	.58% 793/1378	.35% 59.5/168	.26% 194/744	.14% 266/1868	.12% 224/1868	.76% 298/391
Losing teams	.48% 673/1397	.34% 52/154	.29% 234/809	.16% 307/1898	.10% 194/1898	.73% 247/340
Z score	4.9451	0.1885	-1.2554	-1.6531	1.729	1.1047
P value	0*	0.8493	0.20766	0.09894	0.08364	0.27134

**=Statistically significant (p<0.0001).*

Clean=No shooting foul, foul=shooting foul, eFG%=Effective field goal percentage, ORB%=Offensive rebounding percentage, TOV%=Turnover percentage, FT=Free throw. Abbreviations: Basketball Reference 2014.

Six Factors explained over .90% of the variance in game outcomes (R Square=.97, Adjusted R Square=.93. There were four statistically significant predictors of game outcomes: they were clean eFG% and TOV% for both teams (Table 7).

Table 7: Multiple linear regression analysis of Six Factors and game outcomes

Variable	Coefficient (standard error)	p-level
Honka clean eFG%	1.115 (0.157)	0.00006**
Honka Foul eFG%	0.046 (0.080)	0.19494
Honka ORB%	-.013 (0.180)	0.36951
Honka TOV%	-.854 (0.295)	0.03247*
Honka FT frequency	.0776 (.307)	0.98919
Honka FT%	-0.097 (0.169)	0.51931
Opp clean eFG%	-1.220 (0.193)	0.00014**
Opp Foul eFG%	-0.090 0.065	0.19494
Opp ORB%	-0.197 (0.207)	0.35591
Opp TOV%	0.912 (0.347)	0.02726*
Opp FT frequency	-0.874 (0.394)	0.05397
Opp FT%	-0.117 0.109	0.31009

N=22, R=.986, R Square=.972, Adjusted R Square=.934, Standard error=4.208, F=25.719, p-level=.00002.
***Statistically significant (p<0.001), *Statistically significant (p<0.05).*

Clean=No shooting foul, foul=shooting foul, eFG%=Effective field goal percentage, ORB%=Offensive rebounding percentage, TOV%=Turnover percentage, FT=Free throw. Abbreviations: Basketball Reference 2014.

6.2 SQAT

There were no statistically significant differences between Honka and opponents or between winning teams and losing teams when it came to the distribution of close range 2PS, mid-range 2PS and 3PS. For all teams combined, there was a statistically significant (p<0.0001) difference in their point production between their close range 2PS and mid-range 2PS and between their 3PS and mid-range 2PS (Table 8). For both Honka and opponents as well as for winning teams and losing teams, there was a statistically significant (p<0.01) difference in their point production between their close range 2PS and mid-range 2PS. For Honka, opponents and winning teams, there was also a statistically significant difference between mid-range 2PS and 3PS but no statistically significant difference between close range 2PS and 3PS. For losing teams, it was the other way around: there was a statistically significant difference between close range 2PS and 3PS but no statistically significant difference between mid-range 2PS and 3PS. (See Appendices F through I.)

Table 8: FGS point production for all teams combined

PTS produced / Shot type	0	0.98	1.60	2.00	2.35	2.85	3.00	3.85	Total (PTS)	PTS / FGS
Close range 2PS (PTS)	354	160 (156.8)	193 (308.08)	687 (1374)		100 (285)			1494 (2123.88)	1.42
Mid-range 2PS (PTS)	276	93 (91.14)	14 (22.4)	217 (434)		6 (17.1)			606 (564.64)	0.93
3PS (PTS)	458	159 (155.82)			5 (11.75)		374 (1122)	3 (11.55)	999 (1301.12)	1.30
Total	1088	412 (403.76)	207 (330.48)	904 (1808)	5 (11.75)	106 (302.1)	374 (1122)	3 (11.55)	3099 (3989.64)	1.29

PTS=Points, 2PS=Two-point shots, 3PS=Three-point shots. Abbreviations: Basketball Reference 2014.

For all teams combined, .20% of close range 2PS (n=1494) led to a FT set. For mid-range 2PS, FT frequency was .03% (n=606) and for 3PS it was 0.01 (n=999). In that regard, there was a statistically significant difference between close range 2PS and mid-range 2PS (p<0.0001) and between close range 2PS and 3PS ($p<0.0001$). There was also a statistically significant difference in FT frequency between mid-range 2PS and 3PS ($p<0.001$).

Close range 2PS led to a better ORB% (.31%, n=514) than either mid-range 2PS (.25%, n= 369) or 3PS (.26%, n=617). However, the difference was statistically significant only between close range 2PS and 3PS ($p<0.05$).

Between Honka and opponents, there was no statistically significant difference in the point production in any of the three FGS categories. In other words, the point production of Honka's close range 2PS was not statistically different from the point production of the opponents' close range 2PS et cetera. Between winning and losing teams, however, there was a significant difference regarding close range 2PS ($p<.01$) and 3PS ($p<.05$), but not regarding mid-range 2PS. Of the Six Factors variables that are relevant to close range 2PS and 3PS specific and that affect SQAT, there was a statistically significant difference only in clean eFG% ($p<.01$). This was true for both close range 2PS and 3PS (Tables 9 and 10).

Table 9: Z test comparing close range 2PS performance of winning and losing teams

	Clean eFG%	Foul eFG%	ORB%	FT frequency
Total	.57% (687/1201)	.34% (100/293)	.31 (160/514)	.20 (293/1494)
Winning teams	.62% (374/608)	.35% (55/156)	.28% (65/234)	.20% (156/764)
Losing teams	.53% (313/593)	.33% (45/137)	.34% (95/280)	.19% (137/730)
Z score	3.0573	0.4341	-1.4998	0.8037
P value	0.0022*	0.6672	0.13362	0.42372

**=Statistically significant (p<.01).*

Table 10: Z test to compare 3PS performance of winning and losing teams

	Clean eFG%	Foul eFG%	ORB%	Foul frequency
Total	.57% (374/981)	.56% (3/8)	.26% (159/617)	.01% (8/999)
Winning teams	.64% (210/494)	.50% (1/3)	.26% (73/284)	.01% (3/497)
Losing teams	.51% (164/487)	.60% (2/5)	.26% (86/333)	.01% (5/502)
Z score	2.8485	-0.1886	-0.0344	-0.6958
P value	0.00438*	0.8493	0.97606	0.48392

**=Statistically significant (p<.01).*

Clean=No shooting foul, Foul=shooting foul, eFG%=Effective field goal percentage, ORB%=Offensive rebounding percentage. Abbreviations: Basketball Reference 2014.

7. DISCUSSION AND CONCLUSIONS

The core purpose of the present paper was to suggest a performance indicator that measures field goal shooting efficiency (FGSE) and provides information applicable to enhancement of a team's performance. This purpose placed the paper within the realm of practical basketball performance analysis. The performance indicator developed was Shot Quality Assessment Tool or SQAT. A prerequisite to SQAT was a statistical framework that covers a team's offensive and defensive performance and within which SQAT could be applied. This framework was Six Factors, or a variation of Four Factors first presented by Oliver (2004).

Theoretically, it was argued that when it came to basketball performance analysis, Six Factors was an improvement over Four Factors. The Six Factors analysis of 22 Honka games supported this claim. It was shown that winning teams had a higher effective field goal percentage than losing teams when the shooter did not get fouled (clean eFG%). In contrast there was no statistically significant difference in the FGSE in FGS where the shooter did get fouled (foul eFG%). This distinction could not have been made using Four Factors, yet the distinction was practically important because it implied that when trying to improve FGSE of Honka, practicing FGS when fouled was not of great importance.

It was also shown that turnover percentage (TOV%) was a statistically significant factor when it came to the game outcomes, i.e. losing teams turned the ball over more frequently than winning teams did. This was an expected result and possibly due to two properties of a TOV: by definition, the offensive team does not score in a possession where it commits a TOV, and for the defensive team, a steal starts a possession that will probably produce more points than an average possession (Lehto et al 2010).

In contrast, the analysis of offensive rebounding percentage (ORB%) produced an unexpected result since losing teams had a higher ORB% than winning teams did. Even though this difference was not statistically significant it still needs to be discussed since it is illogical and hence untrue that gaining a possession should hurt a team's chances of success. In order to correctly interpret the result, the ORB% result should viewed from a practical standpoint. That way it may be claimed that even though gaining ORB and a possession is advantageous, an attempt to gain ORB may have a negative impact on the offensive team. That is because the more players go after ORB, the more ORB the team will get (Ribas et al 2011) but also the more opportunities for productive fast breaks the other team will get (Wiens et 2013). This underlined the interconnectedness of a team's offensive and defensive performances: the net value of going after ORB may be negative.

SQAT analysis showed that the advantage winning teams had in clean eFG% was due to their being more accurate than losing teams in close range two-point shots (2PS) and three-point shots (3PS) but not in mid-range 2PS. Overall, close range 2PS were shown to produce more points per FGS than mid-range 2PS or 3PS. For winning teams, 3PS were shown to be more productive than their mid-range 2PS. In contrast, the losing teams' 3PS were not more productive than their mid-range 2PS. This may have implied that shooting 3PS effectively is a key factor regarding winning games.

Overall, close range 2PS had the same clean eFG% as 3PS did (.57%). The reason why close range 2PS produced more points per FGS than 3PS did (1.42 and 1.30, respectively) was because close range 2PS led to a higher free throw (FT) frequency and ORB%. Mid-range 2PS was the least productive FGS category (0.93 points per FGS) because of a low clean eFG% (.38%) and because only seldom did they lead to FTA or ORB. The possibility to draw these conclusions is an example of advantages available when SQAT is used not alone but within a more broad-ranging statistical framework, Six Factors in this case.

Another example of these advantages is the possibility to analyse why a team has a certain ORB% or FT frequency. That is because the type of FGS affects ORB% and FT frequency. If the team shoots close range 2PS exceptionally infrequently, their ORB% will very probably be low. In this case, the most obvious way to enhance ORB% will probably be to enhance the frequency of close range 2PS. But if the FGS distribution is not different from that of other teams and the ORB% is still low, practical implications are quite different. Then, instead of changing the FGS distribution, the team probably should consider their personnel, offensive spacing, or rebounding technique. In the present paper this type of analysis could not be done since there was no statistically significant difference between Honka and opponents in ORB%, FT frequency, or FGS distribution.

Based on the above, it seems plausible Six Factors and SQAT did provide a more profound basis for coaches' decision-making than Four Factors and eFG%. So in that sense, they were an improvement in the field of practical performance analysis. However, it should be noted that data gathering is always a part of the analysis process. From that standpoint, Four Factors and and eFG% may often be the more practical option because all of the data they require may be derived from the traditional box score statistics. On the contrary, this is not the case regarding Six Factors and SQAT but for them extra data must be gathered from play-by-play data and game videos (Chapter 5.1). Hence, it can not stated that this or that method is better for practical performance analysis that the other one. Rather the availability of the data and other practical issues should be considered when deciding which method to use.

7.1 LIMITATIONS

The limitations of the present study were numerous. Perhaps the most severe one was the smallness of the sample size. Because of that, the results were not generalizable beyond the Honka games in the Finnish league in 2013-14. Also because of the sample size, the analysis was limited to the team level – i.e. players were not assessed individually. Larger samples are needed in order to show if all independent variables of Six Factors predict game outcomes in a statistically significant way and to make it possible analyse individual players.

In performance analysis concerning invasion team sports, league averages are often used as baseline values (Berri and Schmidt 2010; Gerrard 2007; Martinez and Martinez 2011). Because the Finnish league averages of FT%, bonus FT sets, team fouls, points per play and ORB% were not available for the purposes of the present study, their values for the Six Factors and SQAT equations had to be gathered from the sample only. This may led have to biased results. E.g. FT% in the sample was .75% and in all league games .73% (FBA 2014a). Had the league averages been considered, each FTA would have been worthy of 0.02 points less than it now was in the SQAT equation.

Another limitation follows from the fact that Six Factors and SQAT are scoring indicators. Because in invasion team sports scoring is always a result of a complicated process (Garganta 2009), scoring indicators such as Six Factors and SQAT alone will not tell how a team should try to enhance its performance. This was a limitation because the present paper was written in the context of practical performance analysis and because it is the primary goal of practical performance analysis to help to enhance the performance of a team or an individual. Six Factors and SQAT do show where there may be room for improvement, but other data are needed in order to make justified decisions about how to best enhance a particular phase of their game. SQAT may show that a team has a lower clean eFG% in their close range 2PS than their opponents. This is helpful, but before acting upon this information, further analysis is needed to determine whether the biggest room for improvement lies e.g. in the shooting skill, in the amount of defensive pressure, or in some other factor.

7.2 FUTURE RESEARCH

Future research should gather larger samples to see if the methods of Six Factors and SQAT can be validated. At the moment Four Factors is a statistical framework commonly used to assess the overall efficiency of a team. Future research could compare Four Factors and Six Factors to see it there are differences in their applicability. This could be done by applying Six Factors and Four Factors to the same large data set and then comparing the results. Analogously, the results of SQAT and eFG% could be compared, since at the moment eFG% is the most commonly used way of assessing FGSE.

In addition to the team level analysis, individual players could be analysed. The applicability of SQAT could be improved by adding other independent variables other than the shooting distance. These additional independent variables could include defensive pressure (Weil 2011), the usage of dribbles (Chang et 2014), and the shooter's movement prior to the shot (Bartlett 2008).

Since the present paper was written in the context of basketball performance analysis, the most interesting type of future research would be applying Six Factors and SQAT to a real-life situation and assessing the results achieved – i.e. seeing if the methods actually helped the team enhance their performance.

7.3 CONCLUSIONS

When measuring field goal shooting efficiency, all field goal shots should be included in the analysis. Currently in basketball performance analysis this usually does not happen, but the field goal shots where the shooter is fouled and does not make the shot are excluded from the efficiency analysis. This is the case regarding both Four Factors and effective field goal percentage, which are to widely accepted and utilized methods.

Six Factors is a statistical framework presented in the present paper and designed to measure a team's overall offensive and defensive efficiency. Six Factors offered an improvement over the widely used Four Factors because Six Factors considered all field goal shots and differentiated between a team's ability to earn free throws and their ability to hit free throws.

Shot Quality Assessment Tool or SQAT is a performance indicator presented in the present paper and designed to measure the field goal shooting efficiency. SQAT was an improvement over effective field goal percentage because SQAT considered not only all field goal shots but also the probability of an offensive rebound and the probability of a shooting foul.

This paper was limited mainly by the smallness of the sample. Bigger samples and further research are needed in order to test the reliability, validity and practical applicability of both Six Factors and SQAT.

APPENDICES

Appendix A: Calculating SQAT while considering the correlation between FT% and the running number of FTA

There may be a correlation between the FT percentage and the running number of FTA. Because of this, when calculating the point production of free throws in SQAT, this equation used in the present paper, or

$$(FTA \times FT\%) / FGS$$

may be replaced with this equation:

$$(FTA1^{st}\% \times FTA1^{st} + FTA2^{nd}\% \times FTA2^{nd} + FTA3^{rd}\% \times FTA3^{rd}).$$

There $FTA1^{st}\%$ is the FT% of the first FTA in a set, $FTA1^{st}$ is the number of first FTA in a set, and so on.

It must be noted that these three FT% cannot be derived a data set where all FTA are included. That is because a player's FT% may correlate with the average length of his FT sets (Yaari and Eisenmann 2011). One possible reason for this phenomenon is that players who take a lot of 3PS, and thus earn a lot of sets of three FTA, may be better-than-average FT shooters (Yaari and Eisenmann 2011). A second possible reason is that players, who shoot sets of one FTA sets exceptionally frequently, may be worse-than-average FT shooters. That might be because most fouls occur in the vicinity of the basket (82 Games no date) and because power forwards and centres receive passes near the basket exceptionally frequently (Mavridis et al 2009). Thus power forwards and centres may get to shoot more than their fair share of sets of one FTA, and they tend to have lower FT% than other players (Jacas 2011). Hence, when one wants to assess how much the efficiency changes during a FT set, the assessment must be based on the relevant sets only. I.e. only sets of two or three FTA may be used to assess the difference in efficiency between the first FTA and the second FTA, and only sets of three FTA may be used to assess the difference between the second FTA and the third one.

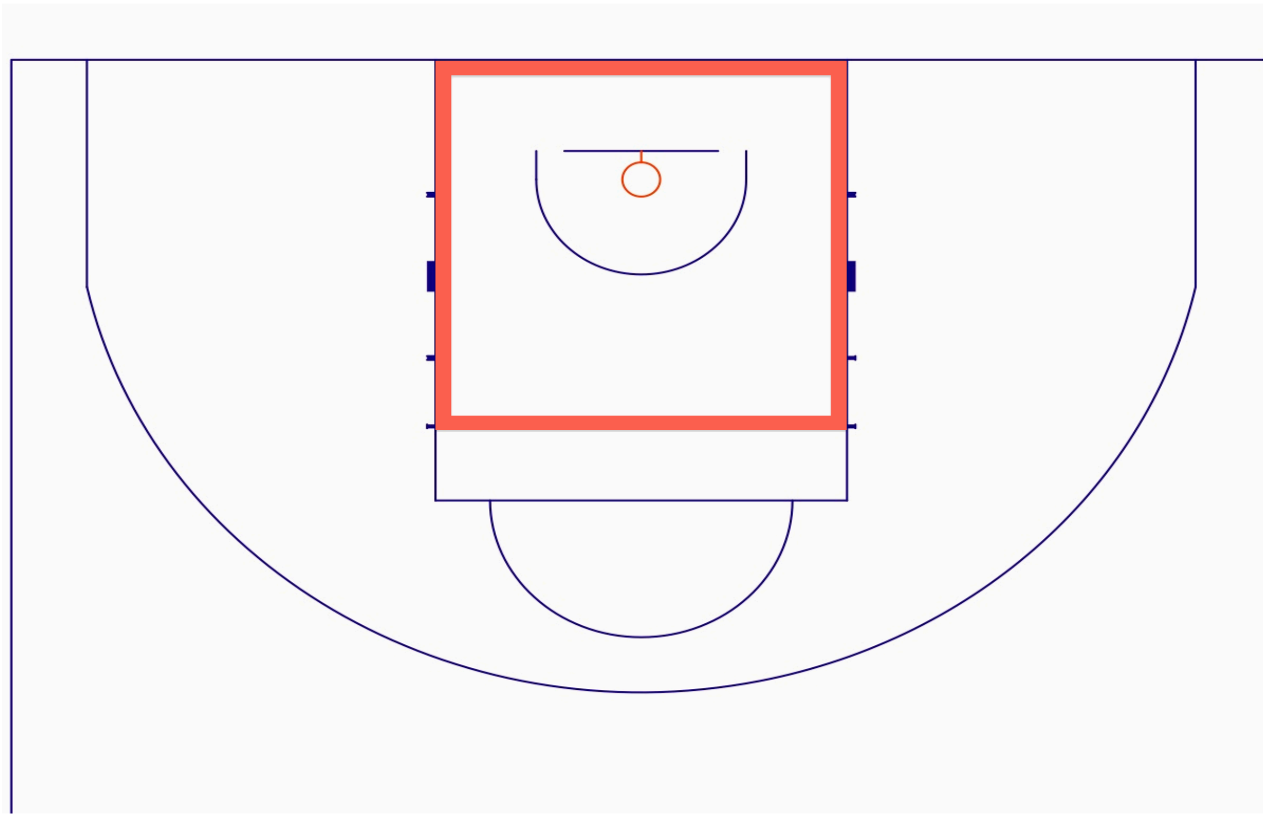
Appendix B: Honka games in the sample

Date	**Opponent**	**Home/away**
October 5	Korikobrat	H
December 6	Kataja	A
February 1	Vilpas	H
February 5	Kouvot	A
February 7	Korihait	A
February 15	Pyrinto	H
February 19	Karhu	A
February 21	Bisons	H
March 1	Namika Lahti	H

March 3	KTP	A
March 5	LrNMKY	A
March 8	Korikobrat	A
March 14	Kataja	H
March 19	Vilpas	A
March 22	Kouvot	H
March 26	Korihait	H
March 28	Pyrinto	A
April 2	Karhu	H
April 5	Bisons	A
April 9	KTP	H
April 12	Namika Lahti	A
April 16	LrNMKY	H

Appendix C: The area of close range 2 point field goal shots

The area of close range 2 point field goals is marked by the red lines in the picture.



Appendix D: The SQAT equation

When using SQAT, the point production of each FGS is calculated using this equation:

((2 x 2P + 3 x 3P)

+ (FTA x FT%)

+ Shooting foul x (Bonus FT sets / Team fouls x (2 x FT% – PPP))

+ (ORB after FGA) x PPP

+ Shooting foul x (1.00 – FT%) x (ORB% after missed FTA) x PPP

Based on the sample of games used in the present paper, the values are:

FT% = .75

Bonus FT sets / Team fouls = 0.12

PPP = 0.98

ORB% after missed FTA = .17

Given these values, the SQAT equation for the purposes of the present paper becomes:

((2 x 2P + 3 x 3P)

+ (FTA x 0.75)

+ Shooting foul x 0.12 x (2 x 0.75 – 0.98)

+ (ORB after FGA) x 0.98

+ Shooting foul x (1.00 – 0.75) x 0.17 x 0.98

Or

((2 x 2P + 3 x 3P)

+ (FTA x 0.75)

+ Shooting foul x 0.06

+ (ORB after FGA) x 0.99

+ Shooting foul x 0.04

Or

((2 x 2P + 3 x 3P)

+ (FTA x 0.75)

+ Shooting foul x 0.10

+ (ORB after FGA) x 0.99

Appendix E: Six Factors and Honka-Opponents correlation matrix

	Honka clean eFG%	Honka foul eFG%	Honka ORB%	Honka TOV%	Honka FT freq.	Honka FT%	Opp. clean eFG%	Opp. foul eFG%	Opp. ORB%	Opp. TOV%	Opp. FT freq.	Opp. FT%
Honka clean eFG%	1											
Honka foul eFG%	-.006	1										
Honka ORB%	-.153	.223	1									
Honka TOV%	-.387	-.084	.091	1								
Honka FT freq.	.020	.054	-.129	-.126	1							
Honka FT%	.018	-.237	-.344	.345	-.182	1						
Opp. clean eFG%	.052	-.041	.061	-.436	-.400	-.343	1					
Opp. foul eFG%	-.038	-.193	.026	-.171	-.107	-.074	.052	1				
Opp. ORB%	.273	-.168	-.103	-.235	-.307	.261	.109	-.397	1			

Opp TOV%	.482	.353	.314	-.023	-.207	-.209	-.011	-.043	-.010	1		
Opp FT freq.	-.025	-.267	-.155	.035	-.445	-.173	.137	.114	-.003	.120	1	
Opp FT%	.017	.093	.417	.009	-.069	-.105	.393	-.239	.021	.021	-.95	1

eFG%=Effective field goal percentage, ORB%=Offensive rebounding percentage, Opp=Opponents, TOV%=Turnover percentage, FT=Free throw, FT%=Free throw percentage, Freq.=Frequency. Abbreviations: Basketball Reference 2014.

Appendix F: FGS point production for Honka

PTS produced / Shot type	0	0.98	1.60	2.00	2.35	2.85	3.00	3.85	Total (pts)	PTS / FGS
Close range 2PS (PTS)	168	73 (71.54)	91 (145.6)	343 (686)		58 (165.3)			733 (1068.44)	1.46
Mid-range 2PS (PTS)	130	49 (48.02)	7 (11.2)	106 (212)		2 (5.7)			294 (276.92)	0.94
3PS (PTS)	250	79 (77.42)			4 (9.4)		192 (576)	1 (3.85)	526 (667.67)	1.27
Total (PTS)	548	201 (196.98)	98 (156.8)	449 (898)	4 (9.4)	60 (171)	192 (576)	1 (3.85)	1553 (2013.03)	1.30

Abbreviations: See below.

Appendix G: FGS point production for Opponents

PTS produced / Shot type	0	0.98	1.60	2.00	2.35	2.85	3.00	3.85	Total (pts)	PTS / FGS
Close range 2PS (PTS)	186	87 (85.26)	102 (163.2)	344 (688)		42 (119.7)			761 (1056.16)	1.39
Mid-range 2PS (PTS)	146	44 (43.12)	7 (12.2)	111 (222)		4 (11.4)			312 (288.72)	0.93
3PS (PTS)	208	80 (78.4)			1 (2.35)		182 (546)	2 (7.7)	473 (634.45)	1.34
Total (PTS)	540	211 (206.78)	109 (174.4)	455 (910)	1 (2.35)	46 (131.1)	182 (546)	2 (7.7)	1546 (1978.33)	1.28

Abbreviations: See below.

Appendix H: FGS point production for winning teams

PTS produced / Shot type	0	0.98	1.60	2.00	2.35	2.85	3.00	3.85	Total (pts)	PTS / FGS
Close range 2PS (PTS)	169	65 (63.7)	101 (161.6)	374 (748)		55 (156.75)			764 (1130.05)	1.48
Mid-range 2PS (PTS)	133	40 (39.2)	7 (11.2)	103 (206)		2 (5.7)			285 (262.1)	0.92
3PS (PTS)	211	73 (71.54)			2 (4.7)		210 (630)	1 (3.85)	497 (710.05)	1.43
Total (PTS)	513	178 (174.44)	108 (172.6)	477 (954)	2 (4.7)	57 (162.45)	210 (630)	1 (3.85)	1546 (2102.2)	1.36

Abbreviations: See below.

Appendix I: FGS point production for losing teams

PTS produced / Shot type	0	0.98	1.60	2.00	2.35	2.85	3.00	3.85	Total	PTS / FGS
Close range 2PS (PTS)	185 (0)	95 (93.1)	92 (147.2)	313 (626)		45 (128.25)			730 (994.55)	1.36
Mid-range 2PS (PTS)	143 (0)	53 (51.94)	7 (11.2)	114 (228)		4 (11.4)			321 (302.54)	0.94
3PS (PTS)	247 (0)	86 (84.28)			3 (7.05)		164 (492)	2 (7.7)	502 (591.03)	1.18
Total (PTS)	575 (0)	234 (229.32)	99 (158.4)	427 (854)	3 (7.05)	49 (139.65)	164 (492)	2 (7.7)	1553 (1888.12)	1.22

Abbreviations for Appendices F–I: PTS=Points, 2PS=Two-point shots, 3PS=Three-point shots, FGS=Field goal shots. Abbreviations: Basketball Reference 2014.

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