Scheduling Super Rugby

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Abstract

We develop scheduling models of Super Rugby, the existing Super 14 (2006–2010) and the proposed Super 15 (from 2011), and the revised national provincial ITM Cup competition (from 2011). Developing schedules for these competitions involves a large number of competition design decisions and scheduling compromises between team welfare, travel, television, and revenue management. We show that Super 15 addresses some of the complications that arose in scheduling Super 14. The 2011 ITM cup features a very tight scheduling window due to the Rugby World Cup, with 10 matches per team over a 7 week period. The schedules developed show that it is possible to accommodate most of the (assumed) preferences of teams and organisers.

Key words: Scheduling, rugby.

1   Introduction

Operations Research is playing an increasing role in sport, both in terms of strategy and scheduling (Wright 2009) (Kendall et al. 2010). Scheduling of sports competitions is a difficult combinatorial optimisation problem with a large number of conflicting objectives involving travel, team welfare, television and revenue management. It is very difficult to please everyone involved, or perhaps anyone (Cleaveland Live 2009) (Herald Scotland 2010).

Problem description. In designing a *new* national or international sports competition, there are a number of *design decisions* that can only be addressed by proposing candidate schedules. In this paper we look at two examples of new and relatively small competition formats planned to begin in 2011: the Super 15 and the ITM Cup. The Super 15 is a new competition in 2011, an expansion of previous Super rugby competitions to 15 teams, but with a significantly different structure to previous years. The ITM Cup 2011 edition is a new competition structure featuring a number of significant one-off scheduling difficulties mostly due to the 2011 Rugby World Cup which immediately follows.

Research goals of this paper. Explore various scenarios under which the competitions could take place, and compare the difficulty or resulting complexity of the schedules they imply. Is it possible to quickly develop "good" schedules (with respect to given requirements and preferences) in order to address competition design decisions?

Outline of this paper. Section 2 provides an analysis of the existing Super 14 (2006–2011), Section 3 discusses modelling of the new Super 15, and Section 4 discusses modelling of the new ITM Cup structure. Finally, Section 5 offers some brief conclusions.

2   Super 14 (2006–2010)

Professional rugby in the southern hemisphere began with the Super 12 competition (1996–2005) featuring teams from Australia, New Zealand and South Africa. This was expanded to 14 teams for the Super 14 (2006–2010) (Wikipedia 2010b).

Competition structure.   The Super 14 rugby competition involves 5 teams from New Zealand (Blues, Chiefs, Crusaders, Highlanders and Hurricanes), 4 teams from Australia (Brumbies, Force, Reds and Waratahs) and 5 teams from South Africa (Bulls, Cheetahs, Lions/Cats, Sharks and Stormers). The Cats featured in the Super 14 in 2006 and were replaced by the Lions from 2007. The teams play a single-round-robin tournament (each team plays all other teams exactly once, either at home or away), together with one bye per team, for a total of 14 rounds. Matches between pairs of teams alternate venue each year, e.g., Blues vs Hurricanes was played at the Blues home (2006, 2008 and 2010) and at the Hurricanes home (2007 and 2009). All teams play either six or seven home matches each year, alternating year on year. At most two teams have a bye in any round. The single-round-robin is followed by two semifinals (1 v 4 and 2 v 3) and a final. The competition features some extremely large travel distances.

Actual schedules. The actual 2006 and 2007 schedules played are given in Tables 1 and 2. Negative indicates an away match and upper case highlights away matches in another country. The 2008 schedule was the 2006 schedule played in reverse order of rounds, with the additional change that the matches and byes in rounds 10 and 11 (of the 2006 schedule) involving the Hurricanes, Highlanders, Brumbies and Waratahs were exchanged. The 2010 schedule is *exactly* the 2008 schedule played in reverse order of rounds, and the 2009 schedule is *exactly* the 2007 schedule played in reverse order of rounds. Obviously little account has been made of the availability of venues.

Analysis. The number of matches played in each country in each round is highly unbalanced, e.g., 2006 rounds 5 and 11 have only one match played in NZ, 2006 rounds 7–10 all have only one match played in SA, and 2007 round 3 has 5 matches played in SA. All NZ teams play either two SA teams and Force or three SA teams away in consecutive rounds. All SA teams play two AU teams plus either two or three NZ teams away in consecutive rounds. Every team beings and ends the competition on their own side of the Indian Ocean. There are some long sequences of home matches for SA teams, e.g., Stormers 2006 and Cheetahs 2007 have five then a bye. There are some away travel inefficiencies, e.g., Stormers 2007 have an away run of two NZ teams, two AU teams then back to NZ for one NZ team. Disappointingly, a bye seldom follows an away match in another country: in 2006 (once), 2007 (five

Table 1: Super 14 actual 2006 schedule. Negative indicates an away match and upper case highlights away matches in another country. Counts of home matches in each country for each round are appended.

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                                 Round
Team            1   2   3   4   5   6   7   8   9  10  11  12  13  14
(bl)Blues      hu -hi -RD -cr     br -WR  bu  st  fo -SH -CT -LI  cf
(cf)Chiefs    -SH -LI -FO  rd  cr     -BR  hi  bu  st  ct -hu  wr -bl
(cr)Crusade    hi -RD  sh  bl -cf  li     -hu  wr  ct -FO -ST -BU  br
(hi)Highlan   -cr  bl -CT -ST -BU  sh  li -cf  fo  hu      wr -BR -RD
(hu)Hurrica   -bl  fo  li -CT -ST -BU  sh  cr     -hi -BR  cf  rd -WR
(br)Brumbie   -fo -BU -ST  li  sh -BL  cf      ct -wr  hu  rd  hi -CR
(fo)Force      br -HU  cf     -rd  wr  bu  st -HI -BL  cr -LI -CT -SH
(rd)Reds       wr  cr  bl -CF  fo     -CT -SH -LI  bu  st -br -HU  hi
(wr)Waratah   -rd -ST -BU  sh  li -fo  bl  ct -CR  br     -HI -CF  hu
(bu)Bulls     -ct  br  wr      hi  hu -FO -BL -CF -RD  li  sh  cr -st
(ct)Cheetah    bu -sh  hi  hu     -st  rd -WR -BR -CR -CF  bl  fo  li
(li)Cats       st  cf -HU -BR -WR -CR -HI      rd  sh -bu  fo  bl -ct
(sh)Sharks     cf  ct -CR -WR -BR -HI -HU  rd     -li  bl -bu  st  fo
(st)Stormer   -li  wr  br  hi  hu  ct     -FO -BL -CF -RD  cr -sh  bu
NZ home         2   2   2   2   1   3   2   3   4   4   1   2   2   2
AU home         2   1   2   2   3   1   3   2   1   2   3   1   1   2
SA home         3   4   3   2   2   2   1   1   1   1   2   4   4   3
```

times), 2008 (four times), 2009 (once), and 2010 (twice). Also, Chiefs 2006 and Highlanders 2007 have four home matches in a row, and Blues 2007 have three home matches in a row, then a bye, then another home match. Given the recycling of the schedules over the period 2006–2010, these issues have been repeated several times, inconveniencing the same teams each time.

Assumed preferences. Minimise long distance travel, i.e., each team crosses the Indian Ocean exactly twice (to and from SA, crossing 10 time zones) and schedule trips to Perth on the way to/from SA. When not on tour, NZ and AU teams play at most three consecutive matches at home and at most three consecutive matches away (to break long runs of home matches). At least one match in each country in each round (due to television). Attempt to schedule byes following Indian Ocean crossings. No byes in the first three or last three rounds. SA teams cross the Tasman Sea only twice.

Suggested schedules. An IP model of the Super 14 has been developed, building on previous work of (Ball 2008). The proposed schedule in Table 3 shows that it is possible to satisfy NZ and AU teams playing at most three consecutive home or away matches, but Lions still have a run of five home matches. Note that (While and Barone 2007) have also previously considered models of the Super 14.

3   Super 15 (2011–2015)

The Melbourne Rebels have been added to the competition (now the Super 15) so there are now five teams each from New Zealand, Australia and South Africa (Wikipedia 2010b). The design specification for the Super 15 was initially rather vague, and hence we set out to develop a number of scenarios to explore the consequences of the design decisions which were (at that time) yet to be revealed. Finally,

Table 2: Super 14 actual 2007 schedule.

Team		1	2	3	4	5	6	7	8	9	10	11	12	13	14
								Round							
(bl)Blues		cr	-BR	-hu	rd	hi	li		wr	-cf	ct	sh	-ST	-BU	-FO
(cf)Chiefs		br	hu	-ST	-BU	-CT		li	-RD	bl	-hi	fo	sh	-WR	-cr
(cr)Crusade		-bl	rd	-LI	-CT	-SH		bu	st	-WR	fo	-hi	hu	-BR	cf
(hi)Highlan		-FO	-LI	-SH	st	-bl	rd		bu	ct	cf	cr	-WR	-hu	br
(hu)Hurrica		-RD	-cf	bl	br	st	-FO	-SH	-LI	bu		ct	-cr	hi	wr
(br)Brumbie		-CF	bl	-rd	-HU	bu	st	-CT	-SH	-LI	wr		fo	cr	-HI
(fo)Force		hi	-ST	-BU	li	-wr	hu	rd		sh	-CR	-CF	-br	ct	bl
(rd)Reds		hu	-CR	br	-BL	li	-HI	-fo	cf		sh	-wr	ct	-ST	-BU
(wr)Waratah		-LI	-SH	-CT		fo	bu	st	-BL	cr	-br	rd	hi	cf	-HU
(bu)Bulls		-sh	ct	fo	cf	-BR	-WR	-CR	-HI	-HU		st	-li	bl	rd
(ct)Cheetah		st	-bu	wr	cr	cf	sh	br		-HI	-BL	-HU	-RD	-FO	-li
(li)Lions		wr	hi	cr	-FO	-RD	-BL	-CF	hu	br	-st		bu	-sh	ct
(sh)Sharks		bu	wr	hi		cr	-ct	hu	br	-FO	-RD	-BL	-CF	li	-st
(st)Stormer		-ct	fo	cf	-HI	-HU	-BR	-WR	-CR		li	-bu	bl	rd	sh
NZ home		2	2	1	3	2	2	2	3	3	3	4	2	1	3
AU home		2	1	1	1	3	3	2	1	2	2	1	3	3	1
SA home		3	4	5	2	2	1	2	2	1	1	1	2	3	3

we will compare our results with the actual published 2011 schedule.

Initial competition structure. Each team plays the other four teams from its country (called a *conference*) in a double-round-robin, i.e., once at home and once away. Each team also plays four of the teams from each of the other conferences once, two teams from each conference at home and two away. Hence, each team plays every other team except for one team from each of the other countries. Each team plays eight intra-conference matches and eight inter-conference matches, for a total of 16 matches in the round-robin phase. The top team from each conference, plus the three highest placed remaining teams, progress to a six team finals series played over three weekends.

Design questions. Clearly, some difficulties from the Super 14 scheduling can be overcome by the design, e.g., each NZ/SA team only plays two matches in SA/NZ and two matches in AU. However, given the initial description of the competition structure, it was still to be determined who each team specifically does not play, and the round-by-round structure of the tournament. Selection of teams not to play could have been resolved from rankings based on previous Super 14 finishing places or win-loss records against particular opponents, but were finally revealed to be based on alphabetical order of teams within each conference (The Australian 2010). Hence the sets of teams who do not play each other in 2011 are as follows: {Blues, Brumbies, Bulls}; {Chiefs, Force, Cheetahs}; {Crusaders, Rebels, Lions}; {Highlanders, Reds, Sharks}; and {Hurricanes, Waratahs, Stormers}.

It was initially unknown whether there would be fixed rounds of only intra-conference matches, how the venues would be decided for the inter-conference matches (would they be related to 2010 Super 14 venues), whether the whole competition is contiguous, and how many byes each team has. There are $4+4+4+4 = 16$ matches for each team for a total of $15 \times 16/2 = 120$ matches. Since there are at most seven matches per round we require at least 18 rounds to complete all the matches, hence each team must have at least two byes.

Table 3: Super 14 proposed alternative 2009 schedule.

Team	Round

Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(bl)Blues	-BR	wr	-FO	hi	-cf	-hu	rd		li	sh	ct	-ST	-BU	cr
(cf)Chiefs	hu	-ST	-BU	-CT	bl	-RD		br	-WR	li	sh	-cr	-hi	fo
(cr)Crusade	fo	-LI	-CT	-SH	st		hu	-hi	bu	rd	-WR	cf	-BR	-bl
(hi)Highlan	-WR	-FO	st	-bl	-LI	-SH	bu	cr	ct		rd	br	cf	-hu
(hu)Hurrica	-cf	-SH	-LI	st	wr	bl	-cr	bu	br	ct		-FO	-RD	hi
(br)Brumbie	bl	-CT	-SH	-LI	bu	st		-CF	-HU	wr	fo	-HI	cr	-rd
(fo)Force	-CR	hi	bl	-wr	rd		li	sh	-ST	-BU	-br	hu	ct	-CF
(rd)Reds	-ST	-BU	-wr		-fo	cf	-BL	li	sh	-CR	-HI	ct	hu	br
(wr)Waratah	hi	-BL	rd	fo	-HU	bu	st		cf	-br	cr	-LI	-SH	-CT
(bu)Bulls	ct	rd	cf		-BR	-WR	-HI	-HU	-CR	fo	st	-sh	bl	-li
(ct)Cheetah	-bu	br	cr	cf		-li	sh	st	-HI	-HU	-BL	-RD	-FO	wr
(li)Lions	-sh	cr	hu	br	hi	ct	-FO	-RD	-BL	-CF		wr	-st	bu
(sh)Sharks	li	hu	br	cr		hi	-ct	-FO	-RD	-BL	-CF	bu	wr	-st
(st)Stormer	rd	cf	-HI	-HU	-CR	-BR	-WR	-ct	fo		-bu	bl	li	sh
NZ home	2	1	1	2	3	1	3	3	4	4	3	2	1	3
AU home	2	1	2	1	2	3	2	2	2	1	2	2	3	1
SA home	3	5	4	3	1	2	1	1	1	1	1	3	3	3

Assumptions and scenarios. We assume that the venues for inter-conference matches are decision variables. All teams begin and end the competition on their own side of the Indian Ocean and cross it exactly twice. We propose three basic scenarios for the structure of the competition: *phased*, *semi-phased* and *unphased*. These scenarios are illustrated and analysed as follows. In each case, we have used subcost-guided simulated annealing (Wright 2001), with move structures based on Kempe chains (Wright 1994), to find good solutions.

3.1   Phased Competition

Suppose that the first five rounds consist of a single-round-robin for each conference and the last five rounds consist of another single-round-robin for each conference (with venues reversed). The middle rounds hold all $15 \times 8/2 = 60$ inter-conference matches. Since there are at most seven matches per round we require at least nine rounds to complete all the inter-conference matches. Table 4 gives an example of a phased competition with $5 + 5 + 9 = 19$ rounds. Here each team has three byes. Notice that this creates the situation where many teams have (ignoring the bye) a run of four home matches and a run of four away matches in the inter-conference rounds. Also, the Rugby World Cup 2011 puts pressure on the desirable number of weeks for the 2011 competition, so 19 rounds is undesirable if 18 are possible. Note that there are two rounds with no SA home matches and two rounds with five SA home matches.

3.2   Semi-Phased Competition

Suppose that the first five and last five rounds are as in the phased competition, but that at most one inter-conference match can also be played in each of these rounds. Hence all intra-conference matches must occur within the first five and last five rounds. Table 5 gives an example of a semi-phased competition with 18 rounds

Table 4: Super 15 proposed *phased* 2011 schedule.

```
                  [                ]              Round              [                ]
Team           1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19
(bl)Blues     cf -cr    hi -hu    fo -RB -WR -ST -LI  ct  sh     rd  hu  cr -hi     -cf
(cf)Chiefs   -bl -hu  hi  cr     -BU -ST -FO  br      sh  rd -WR  li -cr      hu -hi  bl
(cr)Crusade   bl -hu -cf -hi -RB     br  wr  bu  st -FO -CT -SH  cf -bl      hu  hi
(hi)Highlan   hu    -cf -bl  cr     fo -CT -BU -RD -BR  st  li  rb     -hu  bl  cf -cr
(hu)Hurrica  -hi  cf  cr     bl -SH -LI -RD      wr  bu  ct  rb -BR -bl  hi -cf -cr
(br)Brumbie   fo -rd     rb  wr -LI -SH -CR -CF  ct  hi      st  hu -rb -fo -wr  rd
(rb)Rebels    wr  fo  rd -br     cr  bl -ST -LI  sh      bu -HU -HI  br -rd -fo     -wr
(rd)Reds      br -rb -wr  fo -ST -CT  hu  sh  hi     -CF  bu -BL  wr  rb     -br -fo
(wr)Waratah  -rb     fo  rd -br -CT -BU  bl -CR -HU      li  cf  st -rd      br -fo  rb
(fo)Force    -br -rb -wr    -rd -BL -HI  cf  ct      li  cr -SH -BU      br  rb  wr  rd
(bu)Bulls    -li  st     ct -sh  cf  wr      hi -CR -HU -RB -RD  fo      li -ct -st  sh
(ct)Cheetah   st -sh  li -bu     wr  rd  hi -FO -BR -BL -HU  cr     -li -st  bu  sh
(li)Lions     bu    -ct  sh -st  br  hu      rb  bl -FO -WR -HI -CF  ct -bu -sh     st
(sh)Sharks    ct  st -li  bu  hu  br     -RD -RB -CF -BL  fo  cr -st      li -ct -bu
(st)Stormer  -ct -bu -sh     li  rd  cf  rb  bl     -CR -HI -BR -WR  sh  ct      bu -li
NZ home        2  2  2  2  2  1  1  1  2  2  4  4  2  3  2  2  2  2  2
AU home        2  2  2  2  2  1  1  3  2  3  2  3  3  2  2  2  2  2  2
SA home        2  2  2  2  2  5  5  2  3  1  0  0  2  2  2  2  2  2  2
```

(each team with two byes). There is now a better spread of tours and slightly more balanced number of home matches in each country.

3.3 Unphased Competition

Suppose that there are no restrictions of when intra-conference and inter-conference matches are played. Table 6 gives an example of an unphased competition with 18 rounds (each team with two byes). The spread of number of home matches in each country in each round is slightly improved over semi-phased (only round 12 has four home matches in one country) but this is still far from the goal of at least two matches in each country in each round. However, there are some particularly bad features: Stormers and Bulls play each other twice within the first three rounds; three byes in round 3 (very early) and in round 17 (very late); Chiefs play Crusaders twice before playing Blues (many instances of this); several runs of five matches without an away matches (Hurricanes, Brumbies, Lions, and six for Sharks); and Brumbies and Force each have a run of four away matches.

3.4 Actual Competition

Table 7 gives the actual published schedule for the 2011 competition (Wikipedia 2010b). This is clearly an unphased competition design. A Canadian company Optimal Planning were involved in producing the competition schedule (Optimal Planning 2010). They list a large number of well known national sports leagues in their client list, including NFL and AFL (USA), and NRL and A-league (Australia). In general this is a remarkably good schedule and a considerable improvement upon the schedule in Table 6: at least two home matches in each country in every round; good separation between return fixtures; no NZ or AU team has a run of four away matches; and all except Stormers have a maximum two consecutive home matches. Some minor criticisms: many instances of byes between home matches;

Table 5: Super 15 proposed *semi-phased* 2011 schedule.

Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	[			]						Round		[						]
(bl)Blues	-cf	hi	-cr		-hu	rd	-WR	li	-SH	-CT	st		rb	-BR	cr	-hi	hu	cf
(cf)Chiefs	bl	-cr	hu	hi		-ST	-BU	ct	rb		-FO	sh	-BR	cr	-hu	wr	-hi	-bl
(cr)Crusade	-hi	cf	bl	-hu	hi	-RB		-RD	bu	st	br		fo	-cf	-bl	hu	-LI	-CT
(hi)Highlan	cr	-bl	fo	-cf	-cr		li	wr	-RD	-RB	sh	-BU	-ST	hu		bl	cf	-hu
(hu)Hurrica	-LI	-SH	-cf	cr	bl	-WR	rd		ct	br	bu	-FO		-hi	cf	-cr	-bl	hi
(br)Brumbie	fo	wr	rd		-rb	ct	-ST	-SH	li	-HU	-CR		cf	bl	-fo	-rd	rb	-wr
(rb)Rebels		fo	-wr	-rd	br	cr	ct	bu	-CF	hi	-LI	-ST	-BL	rd	wr	-fo	-br	
(rd)Reds	wr		-br	rb	fo	-BL	-HU	cr	hi	bu	-CT	-LI	sh	-rb		br	-wr	-fo
(wr)Waratah	-rd	-br	rb	-fo		hu	bl	-HI	st	sh		-CT	-BU	fo	-rb	-CF	rd	br
(fo)Force	-br	-rb	-HI	wr	-rd	-BU	-SH	st		li	cf	hu	-CR	-wr	br	rb		rd
(bu)Bulls	-ct	li		-st	sh	fo	cf	-RB	-CR	-RD	-HU	hi	wr	-sh		ct	st	-li
(ct)Cheetah	bu	-st	sh		li	-BR	-RB	-CF	-HU	bl	rd	wr		-li	st	-bu	-sh	cr
(li)Lions	hu	-bu	st	sh	-ct		-HI	-BL	-BR	-FO	rb	rd		ct	-sh	-st	cr	bu
(sh)Sharks	-st	hu	-ct	-li	-bu		fo	br	bl	-WR	-HI	-CF	-RD	bu	li		ct	st
(st)Stormer	sh	ct	-li	bu		cf	br	-FO	-WR	-CR	-BL	rb	hi		-ct	li	-bu	-sh
NZ home	2	2	3	2	2	1	2	3	3	2	4	1	2	2	2	3	2	2
AU home	2	2	2	2	2	3	2	3	3	4	1	1	2	3	2	2	2	2
SA home	3	3	2	2	2	2	3	1	1	1	2	4	2	2	2	2	3	3

Lions play ten matches before first bye (after Stormers second bye); Highlanders play Crusaders twice before Blues (also for Bulls, Lions and Sharks); Crusaders play all NZ conference teams away before playing any at home; and Blues and Chiefs have simultaneous byes twice.

4 ITM Cup

The ITM Cup (since 2010) is the highest level domestic rugby competition in New Zealand (Wikipedia 2010a), featuring semi-professional teams from 14 provincial unions (see Table 8). It was previously known as the Air New Zealand Cup (2006–2009). In 2009 and 2010, a single-round-robin competition was played, with the home/away status of individual matches alternating between years. It has been proposed that the 2011 competition follow a new competition design.

> "The new competition format from 2011 will see 14 teams split into two divisions of seven teams based on their on-field finishing positions in 2010. The top seven teams will form the Premiership and the bottom seven the Championship. Teams will play all other teams in their division plus four other teams from the other division (there will be an innovative new process for teams to select their cross-division opponents with the detail to be finalised in the first quarter next year). All matches will carry full competition points. The winner of the Championship will receive automatic promotion to the Premiership replacing the 7th placed team in the Premiership which will be relegated to the Championship. In 2011, due to New Zealand hosting RWC 2011, the competition window will be restricted to eight weeks. As a result, in 2011 only, there will be three mid-week matches and no semi-finals."
>
> (Manawatu Rugby Union 2010)

Table 6: Super 15 proposed *unphased* 2011 schedule.

									Round									
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
(bl)Blues	cr	rb		hi	-hu	ct	rd	-LI	-ST	-FO	sh	-cf		-WR	hu	-hi	-cr	cf
(cf)Chiefs	hi	wr	-cr	rb	-BR	-RD	-hu	cr	-hi	sh		bl	-ST	-LI	bu	hu		-bl
(cr)Crusade	-bl	-hi	cf	-SH	-BU	st	ct	-cf	hu		wr	-RD	-BR	hi	fo		bl	-hu
(hi)Highlan	-cf	cr	li	-bl	st	-RB		fo	cf	-BU	-CT	-WR	hu	-cr		bl	-hu	br
(hu)Hurrica	-FO	-CT	-SH	li	bl		cf	br	-cr	rd	-RB		-hi	bu	-bl	-cf	hi	cr
(br)Brumbie	-wr	rd	-rb	ct	cf		rb	-HU	-LI	-ST	-fo	sh	cr		wr	fo	-rd	-HI
(fo)Force	hu	li		-BU	-SH	wr	st	-HI	-rd	bl	br		rb	rd	-CR	-br	-wr	-rb
(rb)Rebels	-rd	-BL	br	-CF	ct	hi	-br	rd		-wr	hu	bu	-fo	-ST	-SH	wr		fo
(rd)Reds	rb	-br	wr	st		cf	-BL	-rb	fo	-HU		cr	bu	-fo	-LI	-CT	br	-wr
(wr)Waratah	br	-CF	-rd		li	-fo	-BU	-CT	sh	rb	-CR	hi		bl	-br	-rb	fo	rd
(bu)Bulls	st		-st	fo	cr	-li	wr	-sh	ct	hi		-RB	-RD	-HU	-CF	sh	li	-ct
(ct)Cheetah	sh	hu		-BR	-RB	-BL	-CR	wr	-bu	li	hi	-st	-li	-sh	st	rd		bu
(li)Lions		-FO	-HI	-HU	-WR	bu	-sh	bl	br	-ct	st		ct	cf	rd	-st	-bu	sh
(sh)Sharks	-ct	-st	hu	cr	fo		li	bu	-WR	-CF	-BL	-BR		ct	rb	-bu	st	-li
(st)Stormer	-bu	sh	bu	-RD	-HI	-CR	-FO		bl	br	-li	ct	cf	rb	-ct	li	-sh	
NZ home	2	3	2	3	2	2	3	3	2	2	2	1	1	2	3	2	2	3
AU home	3	2	2	2	3	3	2	1	2	2	2	4	3	2	1	2	2	2
SA home	2	2	2	2	2	1	2	3	3	3	2	1	2	3	3	3	2	2

Design challenges. What are the design decisions as a result of compressing the competition into seven weekend and six midweek rounds? Assume that all teams play all seven weekend rounds (maximum TV coverage) and that the number of midweek matches each week is minimised (assume either three or four midweek matches each week). Then each team will play exactly three midweek matches. An important design question is then whether it is possible to ensure that each team plays at most three matches in a row without a bye. *This is extremely important in terms of player welfare and the size of squad that must be employed.* This implies that six teams play midweek rounds $\{2, 6, 10\}$, six teams play midweek rounds $\{4, 8, 12\}$ and the remaining two teams either both play one of these, $\{4, 6, 10\}$ or $\{4, 8, 12\}$. The schedule proposed in Table 8 shows that this is indeed possible. But what is the effect upon the schedule of enforcing this requirement?

Assumed preferences. Home-away-home runs should be avoided. Travel distance should be minimised. If long-distance travel is necessary, e.g., Northland to Southland, then this is within a mini-tour of two or more away matches. At least two teams from each division are involved in each round, ensuring that there is some mixing of the premiership and championship matches in the midweek rounds.

Proposed schedule. Table 8 gives a proposed schedule (but using team seedings from the 2009 competition finishing order). Two rounds, marked [7] and [9], are interdivision-only rounds. The << and >> symbols indicate a *flexible* match in which the two teams both have a bye immediately before/after, and hence it would be possible to shift that "weekend" match earlier/later. The resulting schedule shows that: there a some problems for Southland (away to North Harbour, home, then away to Wellington) and Counties (mini-tour away to Southland, Northland and Tasman); the final round has no flexible matches; but there are a lot of very nice little sequences of away matches. Note that no actual schedule for the 2011 ITM Cup has yet been published (the 2010 final was played on 5th November 2010).

Table 7: Super 15 *actual* published 2011 schedule.

```
                                          Round
Team           1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18
(bl)Blues      cr  -SH  -LI  -FO   hu  -cf   ct        wr   rb  -hi  -hu  -RD   st        cf  -cr   hi
(cf)Chiefs    -BR  -hi   rb  -hu   sh   bl  -WR        cr  -LI  -BU   hi   st  -cr       -bl   hu   rd
(cr)Crusade   -bl  -hu   wr   br  -hi   sh        bu  -cf   hi  -FO  -ST  -CT   cf  -RD        bl   hu
(hi)Highlan   -hu   cf  -BU  -ST   cr        br   ct  -RB  -cr   bl  -cf   hu        li   fo  -WR  -bl
(hu)Hurrica    hi   cr        cf  -bl  -RB   bu  -BR  -CT  -SH   rd   bl  -hi        fo   li  -cf  -cr
(br)Brumbie    cf  -rb   rd  -CR        wr  -HI   hu   fo       -CT  -SH   li  -fo   st  -rd   rb  -wr
(fo)Force     -rd        sh   bl  -LI  -ST   rb   wr  -br   bu   cr  -wr        br  -HU  -HI   rd  -rb
(rb)Rebels     wr   br  -CF   sh  -rd   hu  -fo        hi  -BL  -wr   rd  -BU  -CT        st  -br   fo
(rd)Reds       fo  -wr  -br        rb   ct  -LI  -ST   bu   wr  -HU  -rb   bl        cr   br  -fo  -CF
(wr)Waratah   -rb   rd  -CR        ct  -br   cf  -fo  -BL  -rd   rb   fo        li  -SH  -BU   hi   br
(bu)Bulls     -li  -ct   hi        st   li  -HU  -CR  -RD  -FO   cf        rb  -sh   ct   wr  -st   sh
(ct)Cheetah   -sh   bu  -st   li  -WR  -RD  -BL  -HI   hu        br  -li   cr   rb  -bu   sh        st
(li)Lions      bu  -st   bl  -ct   fo  -bu   rd  -sh   st   cf        ct  -BR  -WR  -HI  -HU   sh
(sh)Sharks     ct   bl  -FO  -RB  -CF  -CR   st   li        hu  -st   br        bu   wr  -ct  -li  -bu
(st)Stormer         li   ct   hi  -bu   fo  -sh   rd  -li        sh   cr  -CF  -BL  -BR  -RB   bu  -ct
NZ home        2    2    2    2    3    2    3    2    2    2    2    2    2    2    2    3    2    3
AU home        3    2    2    2    2    3    2    2    3    2    2    2    2    2    2    2    3    2
SA home        2    3    3    2    2    2    2    2    2    2    3    3    2    2    2    2    2    2
```

5 Conclusions

Super 14. It is very difficult to ensure that SA teams don't have long sequences of home matches, schedule byes usefully, and balance number of matches in each country in each round.

Super 15. The phased and semi-phased competition designs produce noticeable difficulties in fairly scheduling the middle of the competition, whereas the flexibility of an unphased competition gives scope for consideration of other preferences. There remains some modelling issues in terms of separation of byes, separation of return fixtures, spreading of home matches through the season, whether it matters if one side has played two more matches than another at any stage, and whether it is preferred not to repeat last year's venue for matches between teams from different countries.

ITM Cup. The schedule design looks achievable with careful attention to timing of individual matches.

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Table 8: ITM Cup proposed 2011 schedule. Negative indicates away match, upper case for premiership teams, lower case for championship teams, dedicated interdivision only rounds 7 and 9, odd rounds are weekends, and even rounds are midweek.

Team							Round						
	1	2	3	4	5	6	[7]	8	[9]	10	11	12	13
(CN)Canterbury	ts		<<-SL	HB	WK>>		-nl	-cm	ot		WL	-BP	-AK
(WL)Wellington	-WK	-nl	BP		-HB	mn	-nh>>		tn	AK	-CN		SL
(SL)Southland	HB>>		<<CN	-BP	-AK		-ot	WK	cm>>		-nh	tn	-WL
(HB)Hawke's Bay	-SL>>		AK	-CN	WL		<<-tn	BP	ts>>		-mn	-WK	nl
(AK)Auckland	-BP	WK	-HB		SL	nh	-cm		<<nl	-WL	-ot>>		CN
(WK)Waikato	WL	-AK	cm		-CN>>		-mn	-SL	nh		<<-ts	HB	BP
(BP)Bay of Plenty	AK		-WL	SL	ot		<<-ts	-HB	mn		<<-tn	CN	-WK
(tn)Taranaki	mn		nl	-cm	-nh		<<HB	ts	-WL		<<BP	-SL	-ot
(ts)Tasman	-CN	ot	nh>>	<<-nl			<<BP	-tn	-HB>>		<<WK	cm	-mn
(ot)Otago	-cm	-ts	mn>>		-BP	nl	SL		-CN	-nh	AK>>		tn
(mn)Manawatu	-tn	nh	-ot>>		cm	-WL	WK		-BP	-nl	HB		ts
(nh)North Harbour	nl	-mn	-ts>>		tn	-AK	WL>>		-WK	ot	SL		-cm
(nl)Northland	-nh	WL	-tn		<<ts	-ot	CN		<<-AK	mn	cm		-HB
(cm)Counties Man	ot		-WK	tn	-mn		AK	CN	-SL>>		-nl	-ts	nh
Flexible:	0/1		1/2		1/1		2/1		1/2		2/1		0/0

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