Corrections to the AEC's counting code, and recommended amendments to the Electoral Act, for Senate Counting & Scrutiny

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Abstract

This report summarises our recommendations for technical changes to those parts of the Electoral Act that regulate the Senate Counting and Scrutiny. We show, and explain how to correct, a point on which the AEC's current counting software does not correspond to the requirements of the legislation. As far as we know, this has so far not caused the wrong people to be elected. We also identify ambiguities in the legislation, which might leave the result undefined. These would be better resolved before the election when they are politically neutral.

Although the digitization process is separate from the counting stage, our results bolster the argument for an independent audit of the paper ballots every Senate election, to demonstrate to scrutineers that the ballot-digitization process is accurate, or to allow for any errors to be identified and corrected.

1 Introduction

The Australian Senate count has several distinct phases:

- first preferences are manually counted,
- paper ballots are imaged at a counting centre,
- the images are digitized, using a combined human and automated process,
- the digitized preferences are electronically counted, in order to establish who won a seat.

This report focuses on the last step. We find an example in which the AEC's official counting software deviates from the requirements of the Electoral Act, and two examples of changes of interpretation. We then provide simple examples to demonstrate that these could, in principle, alter election results, though it does not seem to have done so yet. We then detail where either the code needs to be corrected to conform to the Electoral Act, or where the Electoral Act could be amended to match what we know of the code.

The error concerns the resolution of 3-way ties for the candidate with the lowest tally. We find an example from the 2016 WA Senate election, in which the AEC's software applied the wrong tiebreaking rule, resulting in candidates being excluded in the wrong order. This is described in Section 2.

The second issue is that the AEC has not implemented bulk exclusion (Section 13A). Contrary to common belief (and probably contrary to the intentions of the authors of the Electoral Act), bulk exclusion can alter who wins a seat. The Act is hard to interpret on whether bulk elimination is compulsory. This is detailed in Section 3, together with examples to show why bulk exclusion can alter the election outcome. We recommend that bulk exclusion be deleted from the Electoral Act, matching the AEC's current practice.

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As a third issue, the Electoral Act does not clearly define when the count ends, which is relevant because two termination conditions may apply simultaneously. This can leave ambiguity over who wins the last seat (under subsection (17)) and can alter the order in which candidates are considered to have been elected (under subsection 18). Suggested amendments are described in Section 4.

1.1 Prior work

These results are similar to our prior discoveries of errors in the NSW [CBNT17] and ACT [CT] vote counts. The tiebreaking problems are similar to those identified by Wen [Wen10]. Most of our suggestions for simplifications are aligned with Goré and Lebedeva [GL16], whose suggestions for further improvements we also support.

Other open-source STV counting programs include Grahame Bowland's Dividebatur[1] and its successor Dividebatur2[2], Lee Yingtong Li's OpenTally[3], and Milad Ghale's formally verified STV[4]. Dividebatur2 is specifically implemented for the exact Senate rules, and performs tiebreaking correctly, but does not implement bulk exclusion.

We have written extensively in the past about the importance of auditing the digitization process [BCT+19]. Although it is not directly relevant to this report, the importance of double-checking electronic processes is emphasised, so we reiterate that recommendation here:

Recommendation 1. *When the preference data files for Senate votes are published, there should be a rigorous statistical audit to check that they accurately reflect the paper ballots. This should be conducted in a way that allows Scrutineers to check both the algorithms and the data.*

The rest of this report details specific issues in the count.

1.2 Summary and purpose of this report

We have identified one case in which the AEC's software is different from the legislated rules, one in which it could be debated, and one in which the Electoral Act is ambiguous. These all need to be clarified before they make a difference to an election outcome.

The Senate count, like other Single Transferable Vote legislation, is highly complex and dependent on a number of rather arbitrary choices. The ambiguity is the problem—almost any clarification defined in advance would suffice, as long as it was unambiguous and exactly followed by the AEC. For example, if the AEC agreed to publish its source code, the legislation could be amended to reflect it. (Although we would not generally recommend making legislation in this way, it would be harmless for the examples in this report.)

Each section of this report includes specific recommendations for resolving the differences or clarifying the rules.

Our aim in this report is to contribute to improving electoral legislation and process to achieve election results that are unambiguous and publicly verifiable. Everyone makes mistakes, and there is no reason that occasional errors should undermine public trust in the election, if there is a good process for checking and correcting the count. Improving processes to produce clear evidence of an accurate election outcome is of great benefit for public trust in Australian election outcomes.

We encourage everyone to examine and double-check our results. Our code and examples are available at `https://github.com/AndrewConway/ConcreteSTV`

2 Three way ties: error in the WA 2016 Senate count

When the lowest standing candidate is to be excluded, and there is a tie, there is an explicit rule for resolving it:

> Electoral Act, Section 273 31(b)
>
> ...if 2 or more continuing candidates have the same number of votes, those candidates shall stand in the poll in the order of the relative number of votes of each of those candidates at the last count at which *each of them had a different number of votes,* [our emphasis] with the continuing candidate with the greater or greatest number of votes at that count standing higher in the poll and the continuing candidate with the fewer or fewest number of votes at that count standing lower in the poll, but if there

[1] `https://github.com/grahame/dividebatur`
[2] `https://github.com/grahame/dividebatur2`
[3] `https://yingtongli.me/git/OpenTally/`
[4] `https://github.com/MiladKetabGhale/STV-Counting-ProtocolVerification`

Count	HERCOCK, Marion	FARGHER, Sara	HENG, Henry
1	61	54	57
2	64	57	63
3	65	60	63
4	65	61	63
5..9	65	63	65
10,11	65	64	65
12..15	65	65	65
16..41	65	66	66
42..48	66	66	66

Table 1: Tiebreaking in the first 2016 WA Senate special election. Hercock was excluded, though Fargher had the lowest tally when *each* of the three candidates' tallies were different (Count 4).

> has been no such count the Australian Electoral Officer for the State shall determine the order of standing of those candidates in the poll.

There are very similar clauses in subsections (22) and (22b) for order of election and surplus distribution tie resolution.

In the first WA 2016 Senate special count,[5] (conducted on 7 March 2017, after Rod Cullerton was removed), this situation arose at Count 48, where there was a three-way tie for exclusion: M. Hercock, S. Fargher and H Heng all had 66 votes. Their tallies are shown in Table 1. The last count at which *each* of them had a different number of votes was Count 4, with 65, 61 and 63 respectively. Our reading of the legislation is that S. Fargher should therefore be excluded at Count 48.

In the official count, the AEC excluded M. Hercock instead. There is a natural argument for this—at count 41 M. Hercock had a lower tally than either of the others, and there is no reason other than the legislation that this would not be a reasonable basis for tie resolution. Indeed, this approach has the advantage of resolving more situations than the "each of them had a different number" rule. It would be a reasonable thing to legislate, but it is not what the Electoral Act currently requires.

Of course, different methods of resolving who is excluded can easily change the outcome of the election. As a very simple example of how this could affect who is elected, imagine that the number of vacancies was equal to the number of candidates remaining after the candidate in question was excluded. For this reason it is essential that the legislation and the official code be aligned.

Recommendation 2. *Either:*

- *Correct the AEC's official code to follow the legislation for tie resolution, or*
- *Ask the AEC to publish the official code, including its tiebreaking rules, and amend the legislation to match it.*

It is also worth pointing out that sometimes the prior counts do not resolve the tie, and the Australian Electoral Officer is called upon to choose an order. In 2016 and 2019, it appears that all such decisions favoured candidates according to their position on the ballot, with lower candidates better favoured. This seems fair as the donkey vote otherwise favours higher candidates. This seems like an excellent policy which we fully endorse, and would suggest making part of the act.

Recommendation 3. *Formalize as legislation the apparent policy to, in the case of otherwise unresolved ties, favour candidates lower on the ballot.*

3 Bulk Exclusions: omission in the 2016 and 2019 counts

Section 273 subsection (13A) describes a bulk exclusion where multiple candidates are excluded together. It is commonly believed (and probably intended) that this can never alter the election outcome. In this section we show that that assumption is mistaken.

The AEC does not appear to have implemented bulk exclusions since 2013, presumably in the mistaken belief that it cannot not alter the count. It is unclear whether bulk exclusion is at the AEC's discretion or not. The Electoral Act Section 273 (13) states:

[5]The official Distribution of Preferences is at https://www.aec.gov.au/Elections/federal_elections/2016/files/wa-senate-dist-prefs-2016fe-special-count-07032017.pdf

(13) Where, after the counting of first preference votes or the transfer of surplus votes (if any) of elected candidates, no candidate has, or fewer than the number of candidates required to be elected have, received a number of votes equal to the quota:

(a) the candidate who stands lowest in the poll must be excluded; or

(b) if a bulk exclusion of candidates may be effected under subsection (13A), those candidates must be excluded;

The logic seems unclear here—we are not lawyers and cannot say with confidence whether "those candidates must be excluded" would apply whenever (13A) permits it, but that would be one plausible interpretation.

In this section we provide two simple examples to show that, in two different ways, bulk exclusion can alter the outcome. The first concerns the order of eliminations, the second is due to rounding. In each case, different people are elected depending on whether the bulk exclusion rule is applied.

3.1 Bulk Exclusions and order of elimination

Subsection 13A (d) (i) does not have a clause requiring candidate C to satisfy a similar condition to 13A (b) (ii). This means that bulk exclusions can change the order of elimination. This can readily change the outcome of an election. A simple example is shown here with 6 vacancies, and votes as described in the table below:

Preference List	**Occurrences**
L1, L2, W1, W3	2
L2	3
L3, L2, W1, W3	4
L4, W1, W2	6
L5, W4	1
L5, W5	2
L5, W6	3
L5, W7	4
L5	10
W7	400
W6	400
W5	400
W4	400
W3	400
W2	388
W2, W4	6
W2, W5	4
W2, W6	2
W1	400

Using the rules as applied by the AEC in 2013, as best we can reverse engineer, would result in the distribution of preferences shown in table 2, with bulk exclusion occurring on count 1:

However, using the rules that seem to have been applied by the AEC in 2016, ignoring bulk exclusions, the order of elimination changes, and candidate W3 is elected instead of W2. Furthermore the order of election of candidates W4, W5, W6 and W7 is reversed, as shown in table 3

Curiously enough, using the rules apparently applied by the AEC in 2019, the same candidates are elected, but in a different order; see section 4.2.

3.2 Bulk Exclusions and rounding

It is more obvious that Bulk Exclusions can change rounding, and this can change the result of the election. Rounding may seem like a small effect, but in 2016 Tasmania, there were 285 votes lost due to rounding, and the margin between the last two candidates was 143 votes.

Here is a very simple demonstration of how the presence or absence of bulk exclusion can change rounding and thus who is elected in a 2 vacancy election.

Count	W1	W2	W3	W4	W5	W6	W7	L1	L2	L3	L4	L5	Exh.	TV
1	400	400	400	400	400	400	400	~~2~~	~~3~~	4	6	20		
2	+2							−2	−3				+3	1
Exclude L1, L2	402	400	400	400	400	400	400	0	0	~~4~~	6	20	3	
3	+4									−4				1
Exclude L3	406	400	400	400	400	400	400			0	~~6~~	20	3	
4		+6									−6			1
Exclude L4	406	406	400	400	400	400	400				0	~~20~~	3	
5				+1	+2	+3	+4					−20	+10	1
Exclude L5	406	406	~~400~~	401	402	403	404					0	13	
6			−400										+400	1
Exclude W3	406	406	0	401	402	403	404						413	

Table 2: Elected : W1, W2, W7, W6, W5, W4. Rules used : AEC2013. Elected candidates are colored purple once they have a quota.

Count	W1	W2	W3	W4	W5	W6	W7	L1	L2	L3	L4	L5	Exh.	TV
1	400	400	400	400	400	400	400	~~2~~	3	4	6	20		
2								−2	+2					1
Exclude L1	400	400	400	400	400	400	400	0	5	~~4~~	6	20		
3									+4	−4				1
Exclude L3	400	400	400	400	400	400	400		9	0	~~6~~	20		
4	+6										−6			1
Exclude L4	406	400	400	400	400	400	400		~~9~~		0	20		
5			+6						−9				+3	1
Exclude L2	406	400	406	400	400	400	400		0			~~20~~	3	
6				+1	+2	+3	+4					−20	+10	1
Exclude L5	406	~~400~~	406	401	402	403	404					0	13	
7		−400		+6	+4	+2							+388	1
Exclude W2	406	0	406	407	406	405	404						401	
8				-1^{407}									$+1^{407}$	1/407
Surplus W4	406		406	406	406	405	404						402	

Table 3: Elected : W1, W3, W4, W5, W6, W7. Rules used : AEC2016. Elected candidates are colored purple once they have a quota. Superscripts are the number of papers corresponding to the given number of votes.

Count	Q	W1	W2	L3	L2	L1	Exh.	Rounding	TV
1	400	245	246	3	2	1			
2	-100^{400}			$+0^{3}$	$+0^{3}$	$+0^{3}$	$+97^{391}$	$+3$	1/4
Surplus Q	300	245	246	~~3~~	~~2~~	~~1~~	97	3	
3				-3	-2	-1	$+6$		1
Exclude L1, L2, L3	300	245	246	0	0	0	103	3	
4		$+2^{9}$		-0^{3}	-0^{3}	-0^{3}		-2	1/4
Exclude L1, L2, L3	300	247	246				103	1	

Table 4: Elected : Q, W1. Rules used : AEC2013. Elected candidates are colored purple once they have a quota. Superscripts are the number of papers corresponding to the given number of votes.

Count	Q	W1	W2	L3	L2	L1	Exh.	Rounding	TV
1	400	245	246	3	2	1			
2	-100^{400}			$+0^{3}$	$+0^{3}$	$+0^{3}$	$+97^{391}$	$+3$	1/4
Surplus Q	300	245	246	3	2	~~1~~	97	3	
3						-1	$+1$		1
Exclude L1	300	245	246	3	2	0	98	3	
4		$+0^{3}$				-0^{3}			1/4
Exclude L1	300	245	246	3	~~2~~		98	3	
5					-2		$+2$		1
Exclude L2	300	245	246	3	0		100	3	
6		$+0^{3}$			-0^{3}				1/4
Exclude L2	300	245	246	~~3~~			100	3	
7				-3			$+3$		1
Exclude L3	300	245	246	0			103	3	
8		$+0^{3}$		-0^{3}					1/4
Exclude L3	300	245	246				103	3	

Table 5: Elected : Q, W2. Rules used : AEC2016. Elected candidates are colored purple once they have a quota. Superscripts are the number of papers corresponding to the given number of votes.

Preference List	**Occurrences**
L3	3
L2	2
L1	1
W1	245
W2	246
Q, L3, W1	3
Q, L2, W1	3
Q, L1, W1	3
Q	391

Using bulk exclusion as in 2013 produces winners Q and W1 as shown in table 4. Not using bulk exclusion as in 2016 produces winners Q and W2 as shown in table 5.

3.3 Bulk Exclusion summary and conclusion

These examples show that, as currently legislated, bulk exclusion can alter election outcomes, though it has not done so in practice so far.

Bulk exclusion is an unnecessary complication for an electronic count. The ambiguity over whether or not to use it could result in a contested election outcome that is difficult or impossible to resolve. The best way to avoid this is to remove bulk exclusion from the Act.

Recommendation 4. *Remove Bulk Exclusion from the Act. This includes subsections (13A), (13B), (13C), portions of (13AA), and several definitions in (29).*

4 Ambiguity in the Act: termination of the count

There are three different ways a candidate can be elected:

- by attaining a quota,
- by being the higher of the two continuing candidates when there is exactly one unfilled seat (Subsection (17)).
- by being a continuing candidate when the number of unfilled seats equals the number of continuing candidates, (subsection (18))

The Act does not explicitly define when the distribution of preferences ends—in particular, it is unclear when subsections (17) or (18) apply. Subsection (18) affects only order, not who gets elected. However, subsection (17) can affect who wins.

Commonwealth Electoral Act 1918, Section 273, (17)

> In respect of the last vacancy for which two continuing candidates remain, the continuing candidate who has the larger number of votes shall be elected notwithstanding that that number is below the quota, and if those candidates have an equal number of votes the Australian Electoral Officer for the State shall have a casting vote but shall not otherwise vote at the election.

Unlike a computer program, which (usually) has an implicit but well-defined sequence of execution steps, the Electoral Act simply lists a number of things that could happen (in subsections (9) through (18)) but does not specify which should be chosen when the conditions for two or more have been met.

As a specific example, suppose one candidate (A) attains a quota (and hence a seat), leaving two other candidates, B and C, competing for a single last seat. Should subsection (17) apply immediately, electing whichever of B and C has a larger total, or should A's surplus be distributed first? The legislation is not clear.

Subsection (14) states

> (14) Any continuing candidate who has received a number of votes equal to or greater than the quota on the completion of a transfer under subsection (13) or (15) of ballot papers of an excluded candidate or candidates, as the case may be, shall be elected, and, unless all the vacancies have been filled, the surplus votes (if any) of the candidate so elected shall be transferred...

The question is whether, "all the vacancies have been filled," because (17) applies immediately, or instead (17) should not be applied until after this transfer has been completed. A similar ambiguity arises over exclusions (subsection (15)): when a candidate is excluded, should subsection (17) apply immediately, or should the excluded candidate's preferences be distributed first?

These decisions could affect who wins, because preference distribution could alter the relative rankings of the two continuing candidates.

4.1 Practical examples of when subsection (17) can alter the election outcome

In practice, for all the examples we could find, the AEC seems to apply (17) only after all transfers have been completed. This seems like the right thing to do, and we believe the legislation should be amended to reflect (what seems to be) the AEC's practice. Indeed, subsection (17) could simply be removed—it is unnecessary because the exclusion of the lower candidate immediately causes subsection (18) to apply (one candidate and one seat remaining).

Resolving the ambiguity is important because this case arises frequently in practice. For example, consider the special count of the 2016 South Australian Senate votes, conducted in 2017 after the removal of Bob Day.[6] The last steps are summarised in Table 6. At the end of Count 453, there are three remaining candidates: McEwen (ALP), Gichuhi (FFP), and Burgess (ON). Burgess has the least votes and is excluded, leaving only two candidates. If subsection (17) were applied immediately, McEwen would win (with the higher tally). But after all the preferences are distributed, Gichuhi wins. Similar examples arose in 2013 in NSW, Vic, WA and Tasmania.

[6] https://www.aec.gov.au/Elections/Federal_Elections/2016/files/sa-senate-dist-prefs-2016fe-special-count-13042017.pdf

Count	McEWEN	GICHUHI	BURGESS
453			
Surplus KAKOSCHKE-MOORE	54099	52482	~~16684~~
454–465			
Exclude BURGESS	65841	69442	0

Table 6: The last steps of the 2016 South Australian Senate special election count, conducted in 2017. If paragraph (17) was applied at count 453, as soon as Burgess was excluded, McEwen would win instead of Gichuhi.

Count	W1	W2	W3	W4	W5	W6	W7	L1	L2	L3	L4	L5	Exh.	TV
1	400	400	400	400	400	400	400	~~2~~	3	4	6	20		
2								−2	+2					1
Exclude L1	400	400	400	400	400	400	400	0	5	~~4~~	6	20		
3									+4	−4				1
Exclude L3	400	400	400	400	400	400	400		9	0	~~6~~	20		
4	+6										−6			1
Exclude L4	406	400	400	400	400	400	400		~~9~~		0	20		
5			+6						−9				+3	1
Exclude L2	406	400	406	400	400	400	400		0			~~20~~	3	
6				+1	+2	+3	+4					−20	+10	1
Exclude L5	406	~~400~~	406	401	402	403	404					0	13	
7														
Exclude W2	406	400	406	401	402	403	404						13	

Table 7: Elected : W1, W3, W7, W6, W5, W4. Rules used : AEC2019. Elected candidates are colored purple once they have a quota.

Recommendation 5. *Remove subsection (17), or clarify that it applies only after all papers from surplus distributions and exclusions are transferred (which seems to be the AEC's current practice).*

4.2 Subsection 18

Subsection (18) does not affect who wins, but may affect their order—we do not know whether this matters in any politically-relevant way.

In 2016, the AEC seemed to apply section 18 after finishing started exclusions and any surplus distributions that may thereby arise. For example, in the Queensland 2016 election, at count 830, candidate R. McGarvie was excluded, leaving 2 candidates and 2 seats. The exclusion was carried out in full (11 counts), and C Ketter was discovered to have a quota, leaving 1 candidate (M Roberts) and 1 vacancy. This candidate was not elected until count 841, when C Ketter's surplus was distributed. Similar events happened in Victoria (count 814), and NSW (count 1054). A different thing occurred in WA 2016 (with R. Cullerton excluded) where on count 535 K. Muir was excluded, leaving 2 candidates and 2 seats. The first step of the exclusion was performed, at the end of which the remaining 2 candidates were both declared elected. Regardless, the transfer of votes for the first step of exclusion was always performed.

In 2019 the rules seemed to change and the AEC applied subsection (18) immediately after identification of a candidate to be excluded, before transferring any votes. In 2019 NSW, count 429, K. McCulloch is excluded. This leaves 2 candidates, 2 vacancies. The preference distribution was aborted and no ballots were transferred in this count.

Recommendation 6. *Clarify when subsection (18) applies.*

The example used in Section 3.1 can be applied using the rules the AEC appeared to have used in 2019, aborting an exclusion after identification of the candidate to be excluded. This produces yet another different outcome from the same votes shown in table 7. This time only the order of election changes, with the order of election of candidates W4, W5, W6 and W7 being reversed.

5 Conclusion

Everyone makes mistakes, and all software has bugs and security vulnerabilities.[7] For election software, the crucial thing is not to make the software perfect (which is impossible) but to ensure an open and transparent process that allows the software, and its results, to be scrutinised and double-checked. It is a good thing when errors and vulnerabilities are found and fixed.

We have found one error (in the implementation of tiebreaking) in the AEC's official Senate counting software. This needs to be corrected before the next election, and we would be happy to help patch it if the source code is made openly available. Alternatively, the Electoral Act could be amended to match the AEC's current algorithm—it does not really matter how ties are broken, as long as the algorithm is specified in advance. Modifying the Electoral Act to match the current algorithm would also be aided by opening the source code.

The same applies to the other two ambiguities we identified in the Electoral Act: bulk exclusion and the order of application of subsection (17). The legislation is unclear, and needs to be clarified, either to match the AEC's current code (if it is made available) or independently. A system that allows discretion over ambiguous rules, or runs a count different from the specified rules, may result in disputes at election time that are difficult or impossible to resolve.

The purpose of this report is to avoid this outcome, by providing specific directions on correcting the AEC's code (Section 2), realigning the AEC's code with the unclear legislation (Section 3), and resolving ambiguitites in the legislation (Section 4). This should give very high confidence that the counting software is accurate and produces the unique outcome defined by legislation.

It is easy to double-check the Senate counting software, because the software's inputs (votes) and outputs (distributions of preferences) are both publicly available. This allows for the open public double-checking that is critical to democracy. (Of course it does not guarantee that all such problems will be found before they affect a count.) It is very helpful that the AEC makes this information publicly available.

By contrast, it is not possible to double-check—so as to find and fix errors in—the software that converts paper ballots to digitized preferences. This leaves the AEC without a way of providing evidence of an accurate election outcome. A statistical audit of randomly-chosen paper ballots, in the presence of scrutineers, would allow the digitized preferences to be double-checked against their paper originals. This would give onlookers a chance to find and fix problems, or to see that there was good evidence that the number of discrepancies was small.

6 Summary of Recommendations

Recommendation 1. *When the preference data files for Senate votes are published, there should be a rigorous statistical audit to check that they accurately reflect the paper ballots. This should be conducted in a way that allows Scrutineers to check both the algorithms and the data.*

Recommendation 2. *Either:*

- *Correct the AEC's official code to follow the legislation for tie resolution, or*
- *Ask the AEC to publish the official code, including its tiebreaking rules, and amend the legislation to match it.*

Recommendation 3. *Formalize as legislation the apparent policy to, in the case of otherwise unresolved ties, favour candidates lower on the ballot.*

Recommendation 4. *Remove Bulk Exclusion from the Act. This includes subsections (13A), (13B), (13C), portions of (13AA), and several definitions in (29).*

Recommendation 5. *Remove subsection (17), or clarify that it applies only after all papers from surplus distributions and exclusions are transferred (which seems to be the AEC's current practice).*

Recommendation 6. *Clarify when subsection (18) applies.*

[7] Even our software. We found the AEC tiebreaking error when we were re-implementing our version of the Senate count and noticed we had made the same mistake.

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