Applicants' Analysis Fails to Address the Significantly Different Capabilities of Low-Band and High-Band Spectrum

10. A further correction is also necessary: when comparing the spectral efficiency of two networks, it is also vital to incorporate within the comparison only the characteristics of the network that are under the control of the network operator, while equalizing for factors not under operator control, such as the technical capability of the frequency band it uses. All other factors being equal (network technology, cell site density (cell area), antenna heights, transmitter power, bandwidth, etc.), lower-band spectrum is able to provide a higher spectral efficiency over a given area than higher band spectrum. The reason is that better propagation characteristics of low-band spectrum allow a network using low-band frequencies to deliver a higher received signal level over the cell area, compared to high-band spectrum. A characteristic inherent in all communications systems is that a higher received signal level (power) corresponds to an ability to transmit and successfully receive a higher data rate, as measured in bits-per-second (bps) for a given Hz of bandwidth. Higher bps/Hz over a constant cell area corresponds to higher spectral efficiency, and is a widely used technical metric. Higher bps/Hz/area in turn corresponds to the ability to serve a larger number of subscribers in that area, resulting in higher spectral efficiency as measured by subscribers/MHz/area.

11. A quantitative assessment of the spectral efficiency advantage of lower-band spectrum compared to higher band spectrum can be made based on communication theory, and experience and measurements of real-world systems. For example, application of the well known, empirically-based Okumura-Hata model for wireless propagation results in 10 dB higher propagation loss at 2 GHz compared to 800 MHz. Stated in another way, a system operating in lower band, 800 MHz spectrum would deliver 10 dB more received signal power to locations

within a same-size cell as a system operating in a higher band spectrum such as at 2 GHz. This physical property is documented in many technical references, for example, in M. Hata[3] and A. Goldsmith[4]. This conclusion has also been validated by recent measurements conducted at NIST.[5] Using state-of-the-art wireless transmission technologies such as HSPA or LTE, 10 dB more received power translates to an approximate doubling of the data rate for a network operating in lower- band spectrum compared to a network operating in higher-band spectrum. This is validated in P. Mogensen[6], John Proakis[7], and A. Goldsmith[8]. That the limits on data rate in wireless systems are due to signal strength is described by D.Cox and H. Lee [9]. Since wireless network deployments in a given geographic area reflect both coverage- and capacity-driven considerations, depending on the local geographic subscriber density, this result can be applied to all the metropolitan areas of interest.

12. Applicants' comparison did not take into account the effects that different spectrum bands have on their holders' ability to provide service on a connection/MHz basis. To correct this flaw, our spectral efficiency comparison applies a spectrum weighting factor based on the specific frequency band deployed, so that the different spectral efficiencies of low- and high-band spectrum will be accounted for. Setting a spectrum efficiency reference weighting of

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[3] M. Hata "Empirical formula for propagation loss in land mobile radio service," *IEEE Transactions on Vehicular and Technology*, VT-29, 1980, pages 317-325.

[4] A. Goldsmith *Wireless Communications,* Cambridge University Press, 2005, pp. 42-44.

[5] http://www.nist.gov/itl/antd/emntg/700mhz.cfm

[6] P. Mogensen et al., "LTE Capacity Compared to the Shannon Bound," *IEEE 65th Vehicular Technology Conference, VTC2007-Spring 2007,* pp. 1234-1238.

[7] J. Proakis, *Digital Communications*, Fourth Edition, McGraw Hill 2001.

[8] A. Goldsmith, *Digital Communications*, Fourth Edition, McGraw Hill 2001.

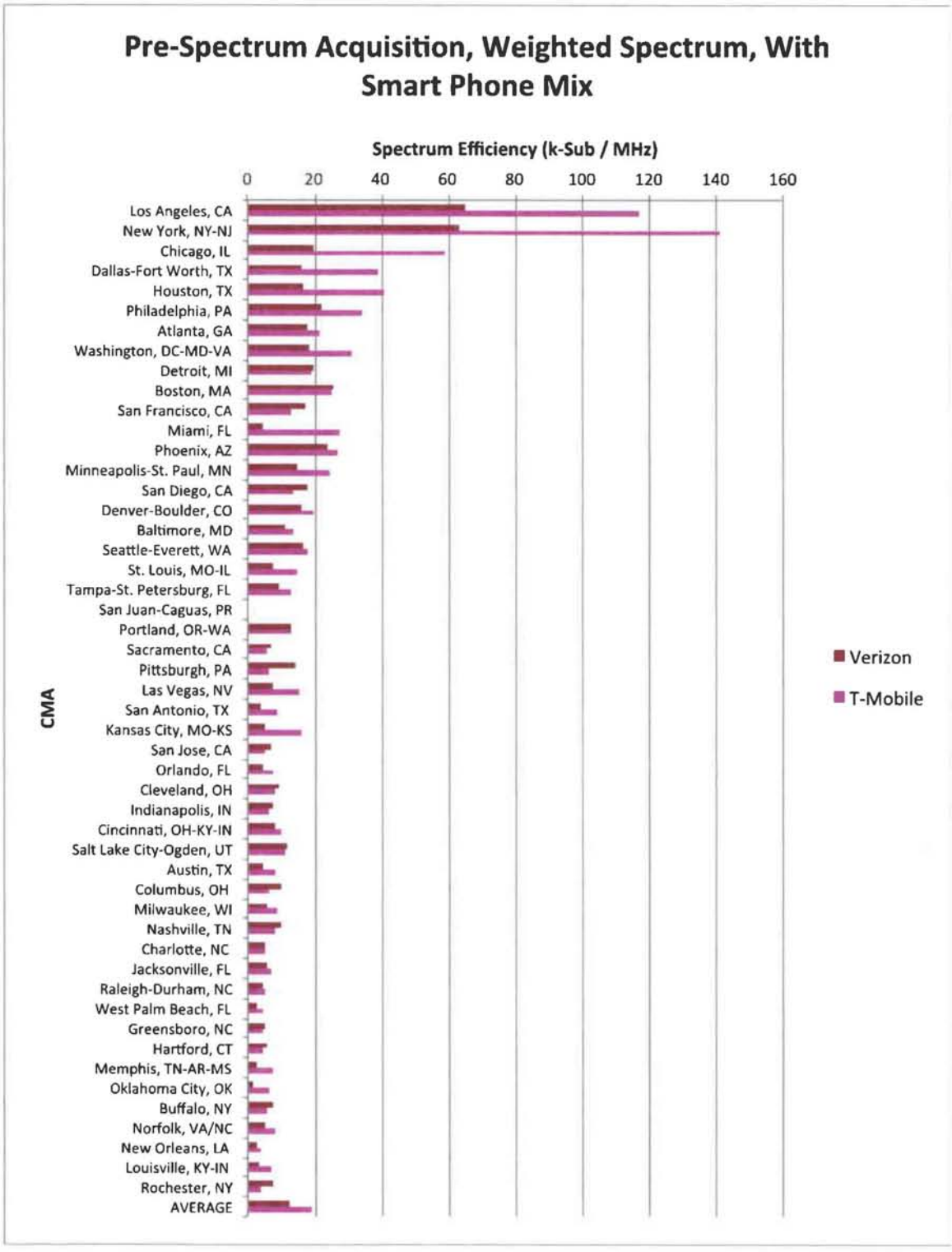
[9] D. Cox and H. Lee"Physical Relationships: Exploring Fundamental Relationships Between Transmission Rate and Range for Wireless Systems," *IEEE Microwave Magazine*, vol. 9, no. 4, Aug. 2008, pp. 89-94.

1.0 for the 700 MHz and cellular bands results in a 0.5 weighting for AWS/PCS spectrum, corresponding to the 2 to 1 spectrum efficiency advantage of low versus high band spectrum.[10]

13. Table 2 below shows the result of weighting the spectrum in this manner. As can be seen, when the differing spectrum bands are appropriately weighted, T-Mobile is shown to be as or more spectrally efficient than Verizon Wireless in 8 of the top 10 markets, and 31 of the Top 49 markets. Averaged over these markets, T-Mobile's efficiency exceeds that of Verizon Wireless by more than 50% percent.

[10] Our weighting factors are slightly different from those developed by Peter Cramton in his Declaration attached to T-Mobile's Petition to Deny in this proceeding, and which T-Mobile proposes be used by the Commission in adjusting its screen. This difference reflects the different purposes of our and his respective weightings. Our analysis focuses specifically on technical considerations that directly impact – and should have been factored into – the Applicant's spectrum efficiency analysis. Mr. Cramton's price-based analysis, as I understand it, also effectively includes all the other factors that go into making the spectrum more or less valuable. While this difference must be borne in mind, it is instructive that the actual ratios of numeric weights assigned by our different methods are not far removed from each other.

TABLE 2[11]



[11] In this table, a larger metric value indicates better performance.

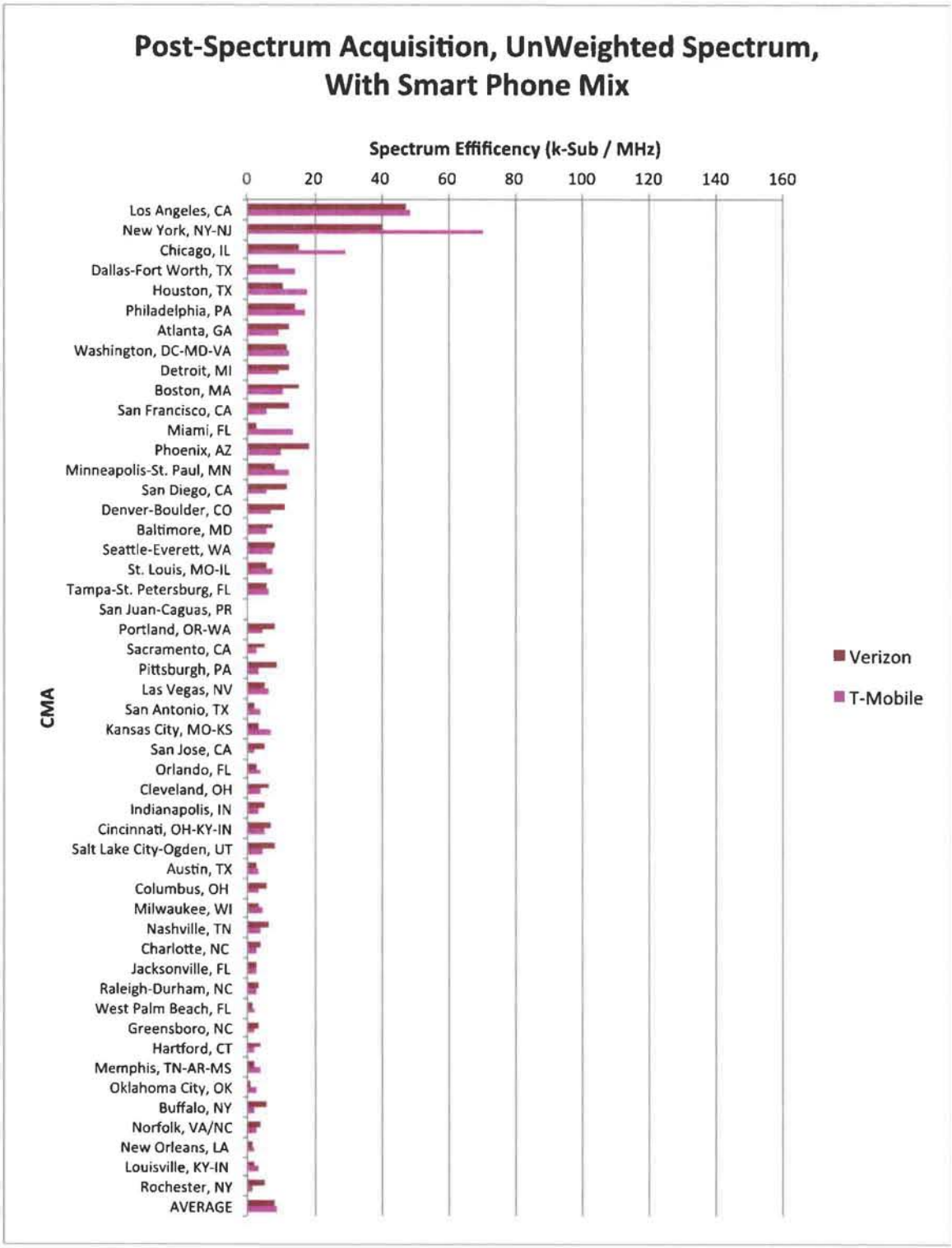
Adding In Both Carriers' Proposed Spectrum Acaquisitions Leads to the Same Conclusion

14. A further analysis and comparison of the spectrum efficiency of the T-Mobile and Verizon networks in the Top-50 cellular market areas was performed, this time reflecting on a pro forma basis the effect of adding to each operator's spectrum allocation the licenses that would be acquired as a result of pending and proposed transactions. For T-Mobile, the spectrum added is that resulting from spectrum assigned to it by AT&T pursuant to the break-up of their proposed merger; for Verizon Wireless, the spectrum added is that resulting from the proposed acquisition of spectrum from SpectrumCo and Cox as well as LEAP. Pending spectrum transactions data was provided by T-Mobile, based on FCC records.

15. Table 3 below shows this pro forma post-acquisition, market by market comparison of the spectrum efficiency of the Verizon and T-Mobile networks, correcting (as in Table 1 above) for the effect of the different mix of smartphone and featurephones on the Verizon Wireless' and T-Mobile networks. As before, the relative mix of smartphones on Verizon Wireless' network is taken as 40%, while the relative mix of smartphones on the T-Mobile network is taken at 50%, and smartphones are assumed to consume 35 times as much bandwidth as featurephones.[12] Table 3 shows that when the correction for differing smartphone mix *alone* is made, in the forward-looking analysis, T-Mobile is still shown to be as or more spectrally efficient than Verizon Wireless in 5 of the 5 top markets, and many more of the Top 49 markets. Averaged across 49 markets, T-Mobile's efficiency is essentially the same as that of Verizon Wireless.

[12] Applicants provided this estimated ratio on page 7 of the Opposition, though they failed to reflect it in their spectrum efficiency analysis.

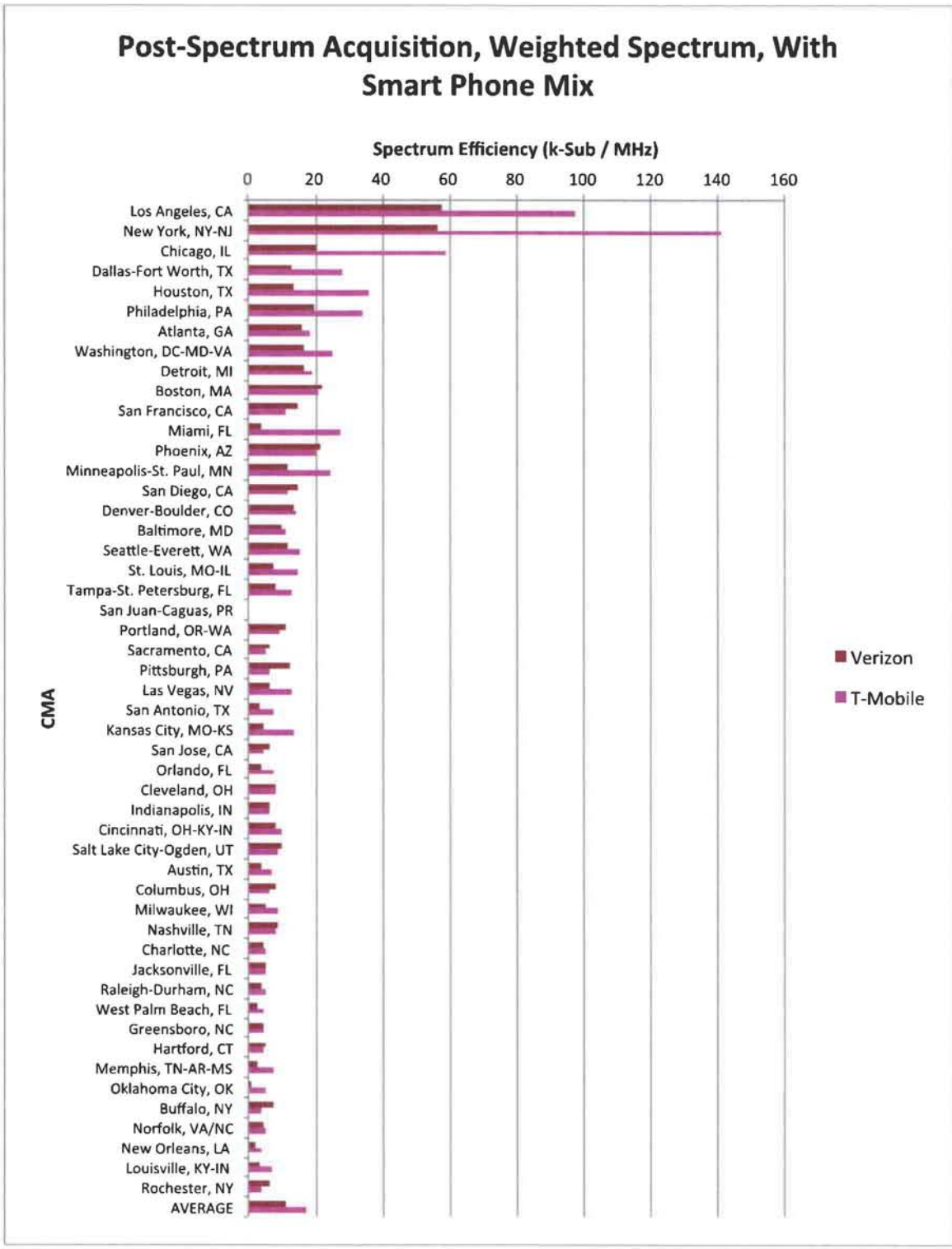
TABLE 3[13]



[13] In this table, a larger metric value indicates better performance.

16. As with Table 2 above, Table 4 below shows the forward-looking, market by market comparison of the spectrum efficiency of the Verizon and T-Mobile networks, correcting for the different mix of smartphones and featurephones, using a spectrum efficiency weighting of 1.0 for the 700 MHz and cellular bands, and a spectrum efficiency weighting of 0.5 for the PCS and AWS bands. When different spectrum bands are appropriately weighted in this pro forma post-acquisition analysis, T-Mobile is shown to be as or more spectrally efficient than Verizon Wireless in 5 of the 5 top markets, 9 of the 10 top markets, and 33 of the Top 49 markets. Averaged over these markets, T-Mobile's spectrum efficiency exceeds that of Verizon Wireless by 70%.

TABLE 4[14]



[14] In this table, a larger metric value indicates better performance.

17. In short, when a meaningful spectrum efficiency analysis is carried out instead of the flawed one presented by Applicants, it becomes clear that T-Mobile is significantly more efficient than Verizon Wireless based on the subscriber-per-MHz metric.

Applicants' Alternative Spectrum Share to Customer Connection Share Metric, When Corrected for the Same Flaws, Leads Again to the Conclusion That T-Mobile Is Significantly More Spectrally Efficient than Verizon Wireless

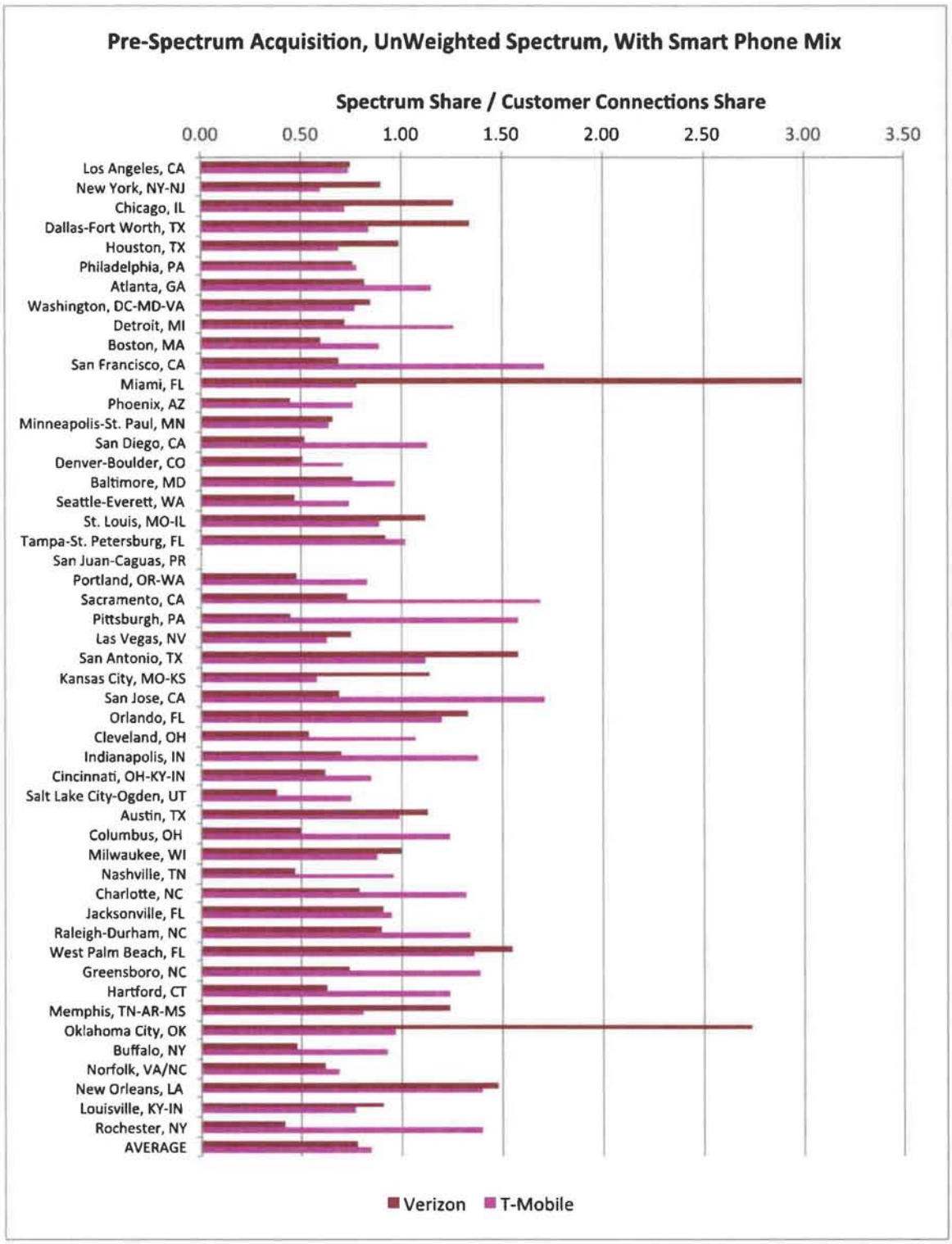
18. Under my supervision and direction, Roberson and Associates next conducted an analysis and comparison using Applicants' proposed alternative metric, the ratio of spectrum share to customer connections share of the T-Mobile and Verizon networks in the Top-50 cellular market areas, but again removing from each operator's allocation spectrum it does not yet have, accounting for the different network demands imposed by smartphone user connections compared to featurephone user connections, and adjusting for the relative spectrum efficiency differences between high- and low-band spectrum. For this analysis we have used the available customer market share data from **[***BEGIN CONFIDENTIAL***]**[redacted]**END CONFIDENTIAL***]**, which is equivalent to the customer connections share measure used in the Verizon analysis. Here, our analysis shows that the ratio of spectrum share to customer connections share for T-Mobile pre-acquisitions exceeds Verizon Wireless' ratio in 9 of the top 10 markets, and 31 of the 49 top markets.

19. Similar to the previous analysis of spectrum efficiency as measured by subscribers per MHz of bandwidth, we have removed from this alternative metric the spectrum assigned to T-Mobile by AT&T pursuant to the break-up of the proposed merger, and have performed a market-by-market comparison to compare the relative spectrum shares and customer connections shares between network operators.

20. As above, our analysis and comparison of the relative spectrum share versus market share corrects Applicants' analysis by taking into account the difference in smartphone market share between operators. The relative mix of smartphones on Verizon Wireless' network is again taken as 40%, while the relative mix of smartphones on the T-Mobile network is taken at 50%. As above, as well, smartphones are assumed to consume 35 times as much bandwidth as featurephones.

21. Table 5 below shows the effects of correcting the analysis of the ratio of spectrum share to customer connections share to reflect the differing smartphone connection mix between operators. It shows that when this correction *alone* is made, T-Mobile is demonstrated to be more efficient (has a lower ratio of spectrum share to customer connections share) than Verizon Wireless in 5 of the top 5 markets, and many more of the Top 49 markets. Averaged across 49 markets, T-Mobile's ratio of 0.84 differs only marginally from that of Verizon Wireless' 0.78.

TABLE 5[15]

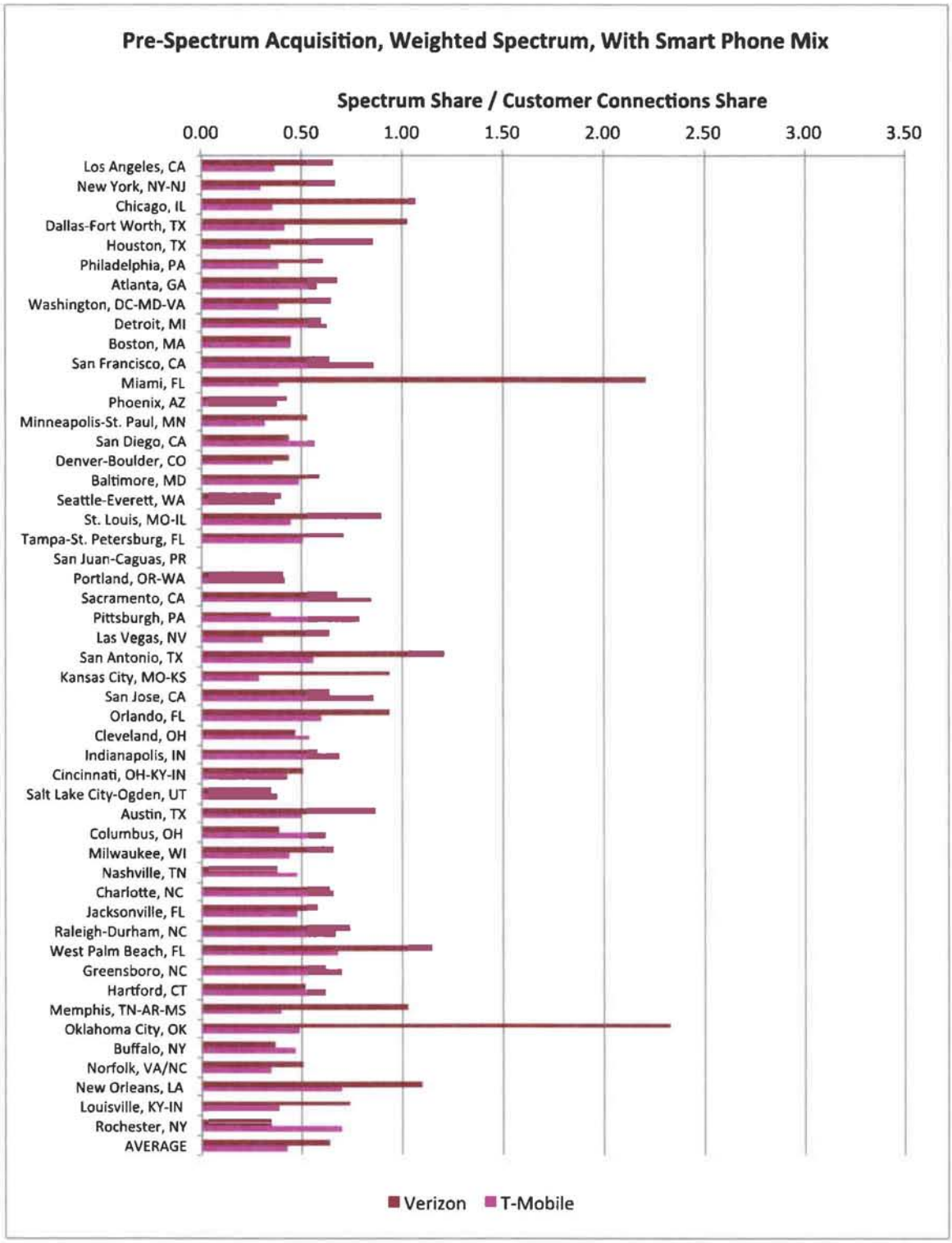


[15] In this table, a smaller metric value indicates better performance.

22. As in our first analysis, we performed the further correction to reflect the different spectral efficiency capabilities of low- and high-band spectrum. Again, a weighting factor of 1.0 is applied to 700 MHz and 800 MHz spectrum, and a weighting factor of 0.5 is applied to PCS and AWS spectrum.

23. Table 6 below shows the results of weighting spectrum in this manner in the comparison of the ratio of operator spectrum share to customer connections share. As can be seen, when the different spectrum bands are appropriately weighted, T-Mobile is demonstrated under this metric to be more efficient in 8 of the top 10 markets, and 31 of the top 49 markets. (In Table 6, a lower ratio indicates higher efficiency.) Averaged over these 49 markets, T-Mobile's ratio of 0.42 is significantly lower – and therefore better – than Verizon's 0.63.

TABLE 6[16]

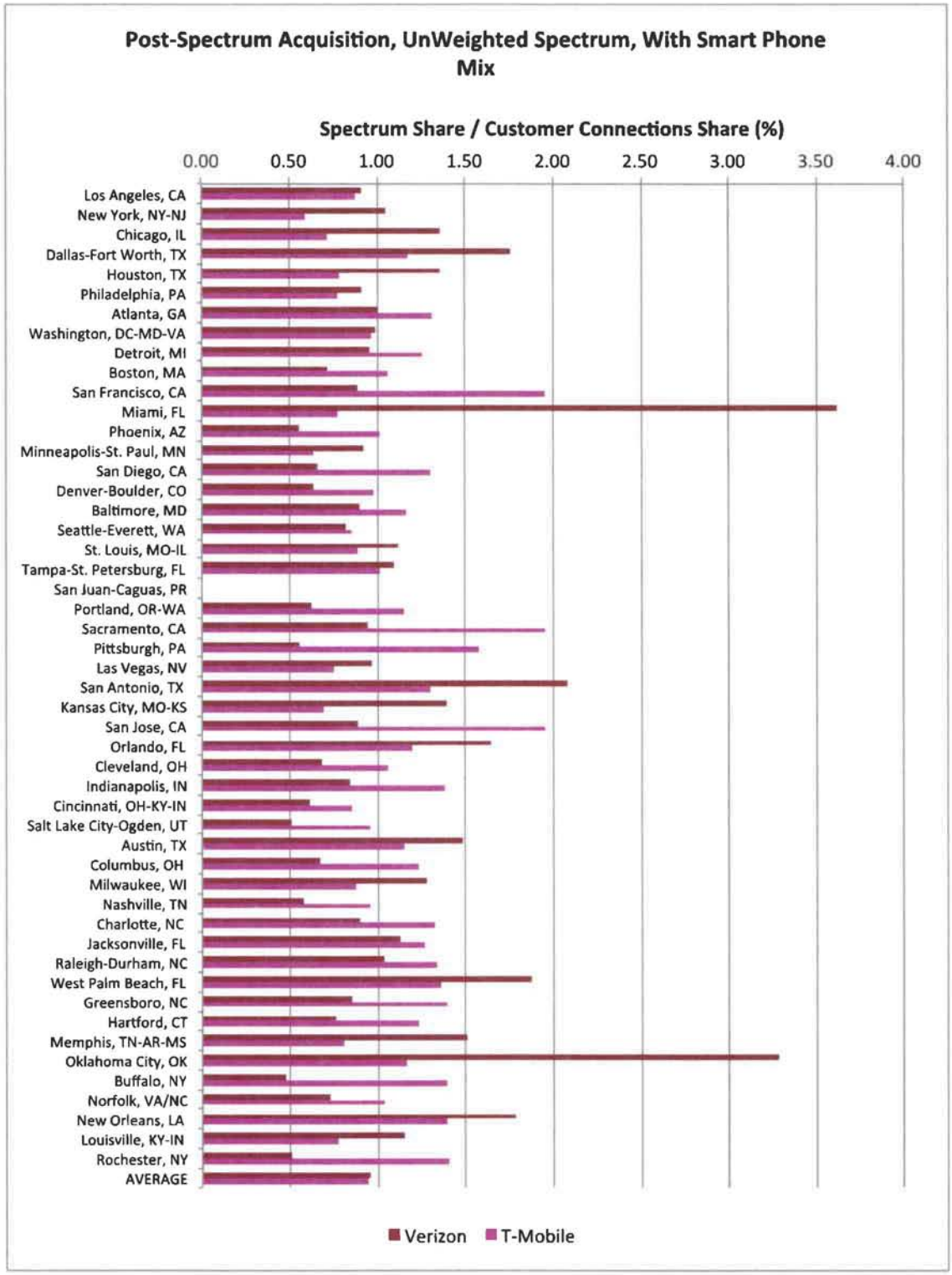


[16] In this table, a smaller metric value indicates better performance.

24. As above, a further, post-acquisition analysis and comparison of the ratio of operator spectrum share to customer connections share of the T-Mobile and Verizon networks in the Top-50 cellular market areas was performed, by adding to each operator's spectrum allocation the licenses that would be acquired as a result of pending and proposed transactions.

25. Table 7 below shows this forward-looking, market by market comparison of the ratio of spectrum share and customer connections share of the Verizon and T-Mobile networks, correcting for the effect of the different mix of smartphone and featurephones on the Verizon Wireless' and T-Mobile networks, using the same factors as above. Table 7 shows that when the correction for differing smartphone mix *alone* is made in the forward-looking analysis, the ratio of spectrum share to customer connections share of T-Mobile is shown to be equal or lower than Verizon Wireless in 5 of 5 top markets, and many of the Top 49 markets. (In Table 7, a lower ratio indicates higher efficiency.) Averaged across 49 markets, T-Mobile's ratio of spectrum share to customer connections share is nearly identical to that of Verizon Wireless.

TABLE 7[17]

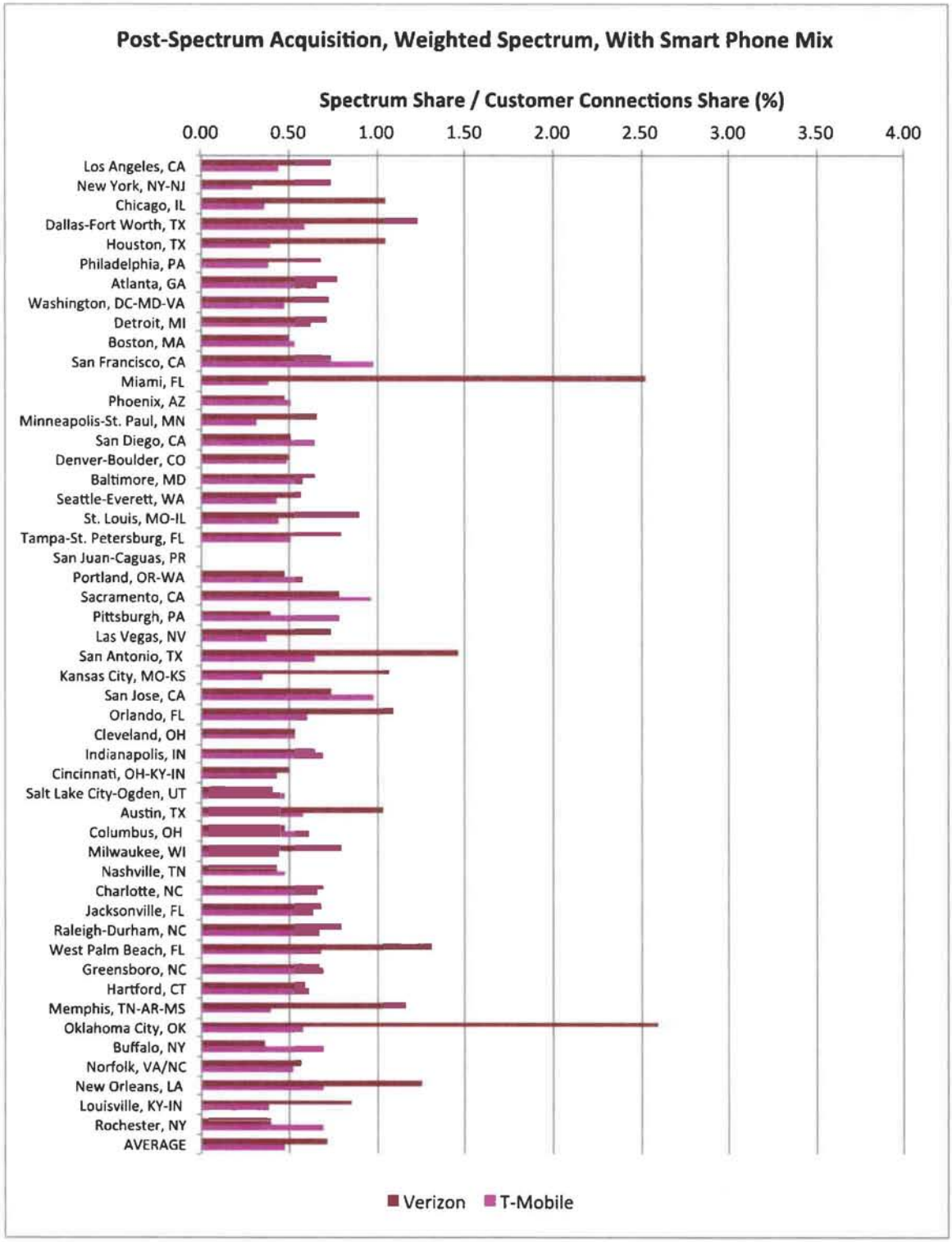


[17] In this table, a smaller metric value indicates better performance.

26. Table 8 below shows the post-acquisition, market by market comparison of the ratio of spectrum share to customer connections share of the Verizon and T-Mobile networks, correcting for the different mix of smartphones and featurephones, and taking into account the relative ability of low- and high-band spectrum to support customer connections, again using the same factors as above. When different spectrum bands are appropriately weighted in the forward-looking analysis, the ratio of spectrum share to customer connections share for T-Mobile is shown to be lower or equal to Verizon Wireless in 9 of the 10 top markets, and 33 of the Top 49 markets. Averaged over these markets, the ratio of spectrum share to customer connections share for T-Mobile is less than Verizon Wireless by more than 30% percent. (In Table 8, a lower ratio indicates higher efficiency.)

27. Thus, as with the first metric, when a meaningful comparison of network operator efficiency as measured by the ratio of spectrum share to customer connections share is carried out, and the flaws in Applicants' analysis are corrected, it is clear that T-Mobile is significantly more efficient that Verizon Wireless, particularly in the major metropolitan areas where the subscriber demand on spectrum is greatest.

TABLE 8[18]



[18] In this table, a smaller metric value indicates better performance.

Conclusion

28. In summary, when accurate and complete comparisons of network operator efficiency as measured by either spectrum efficiency or the ratio of operator spectrum share to customer connections share are made, instead of the incomplete and therefore misleading ones presented by Applicants, it becomes clear that T-Mobile is significantly more efficient in its use of spectrum than Verizon Wireless.

[SIGNATURE ON NEXT PAGE]

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct to the best of my knowledge, information, and belief.

Executed this 26th day of March, 2012.

Dennis A Roberson

Dennis Roberson

EXHIBIT B

EXHIBIT B

SUPPLEMENTAL DECLARATION

OF

PROFESSOR JUDITH CHEVALIER

March 26, 2012

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I. INTRODUCTION

1. I, Judith Chevalier, submit this supplemental declaration on behalf of T-Mobile USA, Inc. ("T-Mobile") in Docket WT 12-4. I have been retained to provide expert analysis and testimony, if necessary, regarding two related transactions involving transfers of spectrum between SpectrumCo, LLC ("SpectrumCo"), Cox TMI Wireless, LLC ("Cox") and Cellco Partnership d/b/a Verizon Wireless ("Verizon"). Specifically, I have been asked to respond to certain arguments in the March 1, 2012 Declaration of Michael L. Katz ("Katz Declaration") as well as comment on certain aspects of the Joint Marketing Agreements ("JMAs"). This Declaration is true and correct to the best of my knowledge information and belief.
2. My professional qualifications and experience were described in my declaration, filed as Exhibit A to the Petition to Deny of T-Mobile on February 21, 2012, and my CV was attached as Appendix A to that declaration.

II. SUMMARY OF CONCLUSIONS

3. The summary of my conclusions is as follows:
    - Professor Katz mischaracterizes my concerns with the proposed transaction, and having established this straw man, attacks it rather than addressing the arguments in my declaration.
    - Arguments made about Verizon's spectral efficiency are both irrelevant to the question of potential hoarding by Verizon and misleading. The metric that Verizon uses in support of its efficiency argument is not necessarily indicative of

spectral efficiency. Moreover, Verizon's investments in capacity do not rule out withholding in the past or the future.

- Professor Katz proposes a counter-model that fails to capture key features of the industry and the issue at hand. Professor Katz's counter-model does not support his argument that the Commission should not be concerned about the incentives Verizon faces to withhold spectrum.
- Finally, the JMAs present both horizontal and vertical competition concerns. Firstly, the JMAs represent coordinated action among a group of horizontal competitors. Secondly, the JMAs potentially restrict access to key inputs and distribution channels for wireless service providers other than Verizon. This concern is exacerbated by the fact that one of the cable companies, Comcast, is substantially vertically integrated and is a supplier of content. Finally, these agreements may diminish the role of Verizon's parent company, Verizon Communications Inc ("Verizon Communications"), which is a provider of wireline broadband services, including video, voice and data (FiOS), as an additional horizontal competitor to the cable companies.

III. CONCERNS ABOUT THE PROPOSED TRANSACTION

4. Professor Katz's declaration mischaracterizes my concerns with the proposed transaction between Verizon and the cable companies making much of his declaration irrelevant to the issue at hand. The spectrum transfer under consideration in this case poses concerns because of Verizon's substantial existing holdings of high-quality spectrum and the incentives it would face to hoard the spectrum newly acquired from SpectrumCo and

Cox. Moreover, smaller competitors would have an economic incentive to put this spectrum to use serving consumers as quickly and efficiently as possible, whereas Verizon may have an incentive to use the spectrum less quickly and less intensively, in order to limit overall output in the market and drive up prices. Professor Katz mischaracterizes my concern as a proposal to "second-guess the secondary market" that would have the effect of "...distorting or limiting secondary market sales to favor certain potential buyers..."[1] In fact, it is this very goal of assigning spectrum to its highest-value users that motivates my concerns about the proposed transaction.[2] Even if Verizon demonstrated the highest private value for the spectrum at issue at the time of the transaction with SpectrumCo, this does not imply that Verizon would create the highest social value from its usage of the spectrum and is not inconsistent with the incentive a dominant firm faces to hoard a scarce input.

5. Moreover, Professor Katz's declaration mischaracterizes the theory of resource hoarding. Contrary to what he claims, I do not believe that having additional spectrum automatically creates dominance.[3] Rather, as I explain in my original declaration, "different firms have different incentives to utilize new potential capacity depending on their relative dominance in the market."[4] Spectrum is an essential and scarce input for the wireless industry. Any firm that holds large amounts of spectrum potentially has

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[1] Declaration of Michael L. Katz, "An Economic Assessment of Arguments Made by Opponents to SpectrumCo's And Cox's Proposed License Assignments to Verizon Wireless," submitted in support of Joint Opposition to Petitions to Deny and Comments ("*Joint Opposition*"), Docket 12-4, dated March 1, 2012, ("*Katz Declaration*"), p. 2, ¶4.

[2] Similarly, Professor Katz also states that "[E]conomic analysis strongly indicates that a policy of reserving secondary-market purchases for certain providers or classes of providers would be misguided and harmful to consumers." (See Katz Declaration, p. 11, ¶22.)

[3] Professor Katz states that "Opponents of the license assignments appear to believe that having additional spectrum automatically creates dominance." (See Katz Declaration, p. 6, ¶12).

[4] Declaration of Professor Judith Chevalier, submitted in support of Petition to Deny of T-Mobile, USA, Inc., Docket 12-4, dated February 21, 2012, ("*Chevalier Declaration*"), pp. 10-11, ¶27.