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From Data to Hits: Understanding Mixing and Mastering Techniques that Make a Song Chart-Worthy

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Abstract: *This study presents a technical analysis of 120 songs selected from the Billboard Year-End Hot 100 Singles of 1990, 2000, 2010, and 2020. Each song was analyzed using iZotope Tonal Balance Control 2 for frequency spectrum distribution across four ranges (low, low-mid, high-mid, high), and Youlean Loudness Meter 2 for integrated loudness, average dynamics (PLR), momentary and short-term loudness maxima, and true peak maxima. Song duration, tempo, and bars & beats were measured using Logic Pro X and its BPM Counter plugin. Nine tables were created to summarize both individual song data and aggregated statistics. Tables 1–4 present the metrics for each of the 120 songs analyzed, while Tables 5–9 provide descriptive statistics—including mean, maximum, minimum, mode range, and anti-mode range—which form the basis for the trends and insights discussed in this study. All songs were legally purchased from Apple Music in m4a format to ensure consistency and accuracy. The purpose of this study is to provide music producers, mixing engineers, and mastering engineers with concrete technical benchmarks, enabling them to achieve songs with professional, chart-ready sound. Tonal balance graphs and numeric targets offer guidance for technical decision-making in production, mixing, and mastering. This analysis focuses solely on technical parameters, without evaluating composition or songwriting.*

Key-words: *Chart-Ready Sound, Music Production, Mixing and Mastering, Tonal Balance, Dynamics*

1. Introduction

The technical characteristics of commercially successful songs have evolved significantly over the past few decades, reflecting changes in both musical culture and production technology. Understanding these characteristics is essential for producers, mixing engineers, and mastering engineers who aim to create songs that meet modern commercial standards. In this study, 120 songs from the

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Billboard Year-End Hot 100 Singles of 1990, 2000, 2010, and 2020 were analysed to identify patterns in key technical parameters, including tonal balance, integrated loudness, loudness range, average dynamics, peak levels, track length, tempo, and rhythmic structure (Lech, M. E., et al. 2025).

Several clear trends emerged from the data. Over time, songs have tended to contain more low-end energy, higher integrated loudness, and reduced dynamic range, resulting in increasingly "squashed" mixes. These changes are interconnected: a song with substantial low-end content leaves less headroom, necessitating additional processing, compression, or limiting to maintain loudness without clipping. Simultaneously, track lengths have shortened and tempos have generally increased, reflecting broader cultural shifts toward fast-paced, attention-grabbing music suitable for streaming platforms and social media consumption. This evolution also mirrors a global trend toward darker, more processed, and emotionally intense sounds, which contrasts with the more natural and organic timbres typical of 1990s hits.

While numerous studies have explored trends in Western popular music—examining pitch, timbre, or loudness evolution—or analyzed song features for predicting streaming popularity, few studies translate these findings into actionable guidance for music production. Most existing research focuses on composition, songwriting, or predictive analytics rather than the specific technical aspects of mixing and mastering. This study addresses that gap by providing precise, numerical targets for technical parameters, allowing producers to make informed decisions about which effects to apply and to what extent at each stage of production. By offering concrete benchmarks, the study reduces ambiguity in the production process and helps ensure that songs achieve balanced loudness, tonal clarity, and appropriate dynamic range.

In addition, this study highlights how technical parameters interact with creative choices to achieve professional, chart-ready sound. For example, achieving higher loudness while maintaining clarity often requires careful frequency balancing, compression, and limiting strategies. Tonal balance must be considered in conjunction with dynamic range and peak levels to prevent frequency masking or excessive harshness. By systematically analysing a representative sample of commercially successful songs, this study identifies ranges and averages that can serve as reliable reference points for music engineers. These benchmarks provide a foundation for producing music that sounds competitive in the current industry landscape, while also illustrating how exceptions still achieve commercial success when the technical foundations are strong.

The results of this study are applicable across multiple popular genres, including Pop, Hip Hop, Trap, R&B, and Dance, and are based exclusively on legally purchased m4a files to ensure data consistency and analysis accuracy. While the dataset is limited to 120 songs from the Billboard Year-End Hot 100 Singles, the derived targets provide reliable benchmarks for achieving chart-ready sound from a technical perspective. Notably, the study does not evaluate composition or songwriting; its focus is strictly on the technical aspects of music production, mixing, and mastering.

2. Objectives

The primary aim of this study is to provide data-driven benchmarks for music producers and audio engineers based on the technical characteristics of songs that have achieved mainstream commercial success. By analysing measurable audio parameters of Billboard Year-End Hot 100 Singles across four distinct decades (1990, 2000, 2010, and 2020), this research seeks to define the concrete targets that contribute to a technically competitive and sonically balanced record. The purpose is to eliminate guesswork from the production, mixing, and mastering process, and instead offer practitioners a roadmap grounded in empirical data derived from songs that have already proven their effectiveness in the global music market.

More specifically, the study aims to identify recurring patterns, averages, range limits, and extremes (maximum and minimum values) for a series of quantifiable parameters, namely: time (track length), tempo (BPM), bars and beats, integrated loudness, loudness range, average dynamics (PLR), momentary loudness maximum, short-term loudness maximum, and true peak maximum. Each of these parameters was extracted from the top 30 songs of the selected Billboard periods, resulting in a total dataset of 120 tracks. Although tonal balance could not be numerically measured, visual tonal balance graphs were also compiled to provide valuable qualitative insight into the spectral tendencies of hit songs over time. Together, these elements form a robust reference framework that enables precise calibration of modern productions to meet or exceed the technical standards of chart-topping releases.

The study also explores the practical implications of these benchmarks, discussing the processes and tools that can be used to achieve similar results. By understanding the destination — the numerical and spectral targets that define commercially successful songs — music producers and engineers can more effectively choose the right techniques, such as compression, limiting, or spectral shaping, to reach those objectives. In this sense, the paper does not merely quantify the sound of success but also offers an interpretative guide for how to reproduce it within the context of modern production workflows.

While the analysis focuses exclusively on technical parameters, omitting aspects such as composition, lyricism, or emotional expression, it offers a comprehensive cross-genre perspective on the sonic evolution of popular music. The songs analysed include diverse genres — Pop, Hip-Hop, R&B, Trap, and Dance — thereby ensuring that the findings are representative of mainstream Western music rather than any isolated category. However, the scope is intentionally limited to measurable, engineering-related features rather than creative or stylistic dimensions.

The expected outcome of this research was to confirm the progressive evolution of popular music toward louder, shorter, and more compressed productions, with an increasingly pronounced low end. These assumptions were largely confirmed, yet several findings were particularly striking — notably, the discovery that the vast majority of analysed tracks (103 out of 120) exceeded the nominal 0 dB true peak limit, in some cases reaching values as high as +3.4 dB. Similarly, some songs shown extreme loudness levels as high as –4.2 LUFS integrated, illustrating the industry's ongoing prioritisation of intensity and impact over traditional dynamic integrity. These results challenge long-standing engineering conventions and underscore the need for updated technical benchmarks aligned with current practices.

In essence, this study is designed to bridge the gap between academic research and real-world application, transforming raw data into a practical reference that empowers producers and engineers to achieve chart-ready sound with greater accuracy and efficiency. By providing a clear, evidence-based roadmap to sonic excellence, the research contributes both to the understanding of modern production standards and to the refinement of the technical decision-making process that defines contemporary popular music.

3. Methodology

3.1. Data collection

This study analysed a total of 120 commercially released songs drawn from the Billboard Year-End Hot 100 Singles charts. To ensure consistency and representativeness, the top 30 songs by rank were selected from four distinct chart years—1990, 2000, 2010, and 2020—resulting in four balanced datasets of 30 tracks each. Only full-length versions of the songs were analysed; no excerpts, edits, or shortened versions were used at any stage. All songs were purchased legally through Apple Music and imported in their original m4a format, a high-quality codec chosen for its superior fidelity compared to formats such as MP3

(Matenchuk 2025). No processing, conversion, or normalization was applied before analysis. Each track was imported into Logic Pro X and played from start to finish exactly as bought. The only manual preparation involved aligning the project's start and end markers to match the precise beginning and end of each track, ensuring that all analyses were performed on the complete program material without added silence or truncation.

3.2. Tools and Software used

All analytical procedures were conducted within Logic Pro X, with no standalone applications involved. Several professional audio-analysis tools were employed as Logic plug-ins. iZotope Tonal Balance Control 2 was used to evaluate and visualise the frequency distribution of each track across four spectral regions (low, low-mid, high-mid, and high) (Seah, Daniel. 2020). Youlean Loudness Meter 2 provided detailed loudness and dynamics measurements, including integrated loudness, loudness range, average dynamics (PLR), momentary loudness maximum, short-term loudness maximum, and true peak maximum (Tavaglione, Rob. 2022). All plug-ins were used with default settings, and no presets were engaged to avoid introducing processing variables. Tempo was measured using Logic's stock BPM Counter plug-in, while Logic Pro X's internal metering and project timeline were used to determine track length (time) and the total number of bars and beats. This combination of tools enabled consistent, high-resolution measurement of loudness, spectral balance, dynamics, tempo, and formal structure.

3.3. Measurement Procedures and Analytical Parameters

Nine core parameters were measured for each of the 120 songs. While Tables 1–4 have the raw data for individual songs, only Tables 5–9, which present aggregated statistics such as mean, maxima, minima, mode range, and anti-mode range, are discussed in this article, as they are the most relevant for understanding general trends. Time (track length) was recorded in minutes and seconds, Tempo in beats per minute (BPM), and Bars & Beats via Logic's timeline ruler. Integrated Loudness was measured in LUFS, Loudness Range (LRA) and Average Dynamics (PLR) in LU according to standard loudness-measurement frameworks. Momentary Loudness Max and Short-Term Loudness Max were measured in LUFS, and True Peak Max in dB. Tonal balance was analysed using Tonal Balance Control 2's target-curve system. Individual target curves were generated by uploading each song separately, producing unique spectral fingerprints for all 120 tracks. Group-level tonal profiles were then created by uploading all 30 tracks from each period (2020, 2010, 2000, 1990) to generate averaged target ranges representative of each era. A global tonal profile was also created by uploading all 120 tracks simultaneously; however, the period-specific tonal curves were most relevant for identifying comparative trends. Screenshots of the tonal balance graphs were archived, and representative graphs for the four periods are included in this article to illustrate changes in spectral balance over time.

3.4. Data Processing and Statistical Analysis

All raw data were logged and organised in Apple Numbers, where Tables 1–9 were constructed. For each period, descriptive statistics—including mean, minimum, maximum, mode range, and anti-mode range—were calculated. These calculations were performed using a combination of spreadsheet formulas, manual verification via calculator, and AI-assisted cross-checking to eliminate transcription or computational errors. After completing the per-period analyses (Tables 5–8), an overall statistical summary was compiled (Table 9), aggregating data from all 120 tracks (Figures 1-5). This sequential workflow ensured accuracy at both the period level and the full-dataset level, allowing reliable comparisons across decades.

Results	**Time**	**Tempo**	**Bars & Beats**	**Integrated Loudness**	**Loudness Range**	**Average Dynamics (PLR)**	**Momentary Loudness Max**	**Short Term Loudness Max**	**True Peak Max**
Mean	4 Minutes 42 Seconds	109 BPM	130 Bars 3 Beats	-12.5 LUFS	6.6 LU	12.6 LU	-7.8 LUFS	-9.4 LUFS	0.2 dB
Maximum	5 Minutes 41 Seconds (Snap! - The Power (7" Version))	162 BPM (Roxette - It Must Have Been Love)	221 Bars 3 Beats (Jon Bon Jovi - Blaze of Glory)	-4.2 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	16.5 LU (Linda Ronstadt - Don't Know Much (with Aaron Neville))	16.9 LU (Maxi Priest - Close to You)	-1.9 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	-3.0 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	2.2 dB (Heart - All I Wanna Do Is Make Love to You) & (I Wanna Be Rich - Calloway)
Minimum	3 Minutes 28 Seconds (Mariah Carey - Vision of Love)	65 BPM (Linda Ronstadt - Don't Know Much (with Aaron Neville))	59 Bars 1 Beat (Linda Ronstadt - Don't Know Much (with Aaron Neville))	-16.9 LUFS (Snap! - The Power (7" Version))	2.1 LU (Jane Child - Don't Wanna Fall In Love)	4.9 LU (Nelson - (Can't Live Without Your) Love and Affection)	-12.3 LUFS (Maxi Priest - Close to You)	-14.1 LUFS (Maxi Priest - Close to You)	-1.4 dB (En Vogue - Hold On) & (Seduction - Two to Make It Right)
Mode Range	4 Minutes 0 Seconds to 4 Minutes 29 Seconds (8 songs) & 5 Minutes 0 Seconds to 5 Minutes 29 Seconds (8 songs)	110 BPM to 119 BPM (8 songs)	130 Bars 1 Beat to 139 Bars 4 Beats (6 songs)	-14.0 LUFS to -14.9 LUFS (5 songs) & -11.0 LUFS to -11.9 LUFS (5 songs)	3.0 LU to 3.9 LU (8 songs)	10.0 LU to 10.9 LU (6 songs) & 14.0 LU to 14.9 LU (6 songs)	-7.0 LUFS to -7.9 LUFS (5 songs)	-11.0 LUFS to -11.9 LUFS (5 songs)	0.0 dB to 0.4 dB (11 songs)
Anti-Mode Range	3 Minutes 0 Seconds to 3 Minutes 29 Seconds (1 song)	80 BPM to 89 BPM (0 songs) & 130 BPM to 139 BPM (0 songs)	180 Bars 1 Beat to 189 Bars 4 Beats (0 songs) & 200 Bars 1 Beat to 209 Bars 4 Beats (0 songs) & 210 Bars 1 Beat to 219 Bars 4 Beats (0 songs)	-6.0 LUFS to -6.9 LUFS (0 songs) & -5.0 LUFS to -5.9 LUFS (0 songs)	7.0 LU to 7.9 LU (0 songs) & 12.0 LU to 12.9 LU (0 songs) & 14.0 LU to 14.9 LU (0 songs)	5.0 LU to 5.9 LU (0 songs) & 6.0 LU to 6.9 LU (0 songs) & 7.0 LU to 7.9 LU (0 songs) & 8.0 LU to 8.9 LU (0 songs)	-3.0 LUFS to -3.9 LUFS (0 songs) & -2.0 LUFS to -2.9 LUFS (0 songs)	-4.0 LUFS to -4.9 LUFS (0 songs)	1.5 dB to 1.9 dB (0 songs)

Fig. 1. *Descriptive Statistics of Songs from 1990*

Results	Time	Tempo	Bars & Beats	Integrated Loudness	Loudness Range	Average Dynamics (PLR)	Momentary Loudness Max	Short Term Loudness Max	True Peak Max
Mean	4 Minutes 14 Seconds	96 BPM	98 Bars 2 Beats	-9.6 LUFS	5.5 LU	10.6 LU	-5.3 LUFS	-6.8 LUFS	1.0 dB
Maximum	5 Minutes 47 Seconds (Marc Anthony - You Sang to Me)	165 BPM (NSYNC - It's Gonna Be Me)	196 Bars 4 Beats (Nelly - Country Grammar (Hot Shit))	-6.8 LUFS (Toni Braxton - He Wasn't Man Enough)	12.9 LU (Faith Hill - Breathe)	14.1 LU (Lonestar - Amazed)	-2.0 LUFS (Toni Braxton - He Wasn't Man Enough)	-4.1 LUFS (Celine Dion - That's the Way It Is)	3.4 dB (Toni Braxton - He Wasn't Man Enough)
Minimum	3 Minutes 11 Seconds (NSYNC - It's Gonna Be Me)	65 BPM (Brian McKnight - Back At One)	64 Bars 4 Beats (Christina Aguilera - What a Girl Wants)	-12.8 LUFS (Lonestar - Amazed)	1.9 LU (Marc Anthony - You Sang to Me)	7.8 LU (Santana - Smooth (feat. Rob Thomas))	-8.0 LUFS (Savage Garden - I Knew I Loved You)	-8.9 LUFS (Lonestar - Amazed) & (Blaque - Bring It All To Me)	-0.0 dB (Montell Jordan - Get It On Tonite)
Mode Range	4 Minutes 0 Seconds to 4 Minutes 29 Seconds (11 songs)	90 BPM to 99 BPM (8 songs)	70 Bars 1 Beat to 79 Bars 4 Beats (6 songs)	-8.0 LUFS to -8.9 LUFS (11 songs)	2.0 LU to 2.9 LU (5 songs) & 3.0 LU to 3.9 LU (5 songs)	10.0 LU to 10.9 LU (8 songs)	-5.0 LUFS to -5.9 LUFS (9 songs)	-6.0 LUFS to -6.9 LUFS (10 songs)	0.5 dB to 0.9 dB (11 songs)
Anti-Mode Range	5 Minutes 0 Seconds to 5 Minutes 29 Seconds (1 song) & 5 Minutes 30 Seconds to 5 Minutes 59 Seconds (1 song)	100 BPM to 109 BPM (1 song)	150 Bars 1 Beat to 159 Bars 4 Beats (0 songs) & 160 Bars 1 Beat to 169 Bars 4 Beats (0 songs) & 170 Bars 1 Beat to 179 Bars 4 Beats (0 songs) & 180 Bars 1 Beat to 189 Bars 4 Beats (0 songs)	-7.0 LUFS to -7.9 LUFS (1 song) & -6.0 LUFS to -6.9 LUFS (1 song)	9.0 LU to 9.9 LU (0 songs)	7.0 LU to 7.9 LU (1 song) & 14.0 LU to 14.9 LU (1 song)	-8.0 LUFS to -8.9 LUFS (1 song)	-5.0 LUFS to -5.9 LUFS (2 songs)	2.5 dB to 2.9 dB (0 songs)

Fig. 2. *Descriptive Statistics of Songs from 2000*

Results	Time	Tempo	Bars & Beats	Integrated Loudness	Loudness Range	Average Dynamics (PLR)	Momentary Loudness Max	Short Term Loudness Max	True Peak Max
Mean	3 Minutes 51 Seconds	111 BPM	106 Bars 3 Beats	-8.0 LUFS	5.8 LU	9.3 LU	-4.4 LUFS	-5.5 LUFS	1.3 dB
Maximum	4 Minutes 54 Seconds (Lady Gaga - Bad Romance)	148 BPM (Young Money - BedRock (feat. Lloyd))	178 Bars 3 Beats (Young Money - BedRock (feat. Lloyd))	-5.7 LUFS (JAY-Z - Empire State Of Mind (feat. Alicia Keys))	14.8 LU (Owl City - Fireflies)	11.4 LU (Owl City - Fireflies)	-2.7 LUFS (Eminem - Not Afraid)	-3.9 LUFS (JAY-Z - Empire State Of Mind (feat. Alicia Keys)) & (Eminem - Not Afraid)	2.8 dB (Owl City - Fireflies)
Minimum	3 Minutes 0 Seconds (B.o.B - Airplanes (feat. Hayley Williams))	87 BPM (Eminem - Love the Way You Lie (feat. Rihanna)) & (Rihanna - Rude Boy) & (JAY-Z - Empire State Of Mind (feat. Alicia Keys)) & (Travie McCoy - Billionaire (feat. Bruno Mars))	70 Bars 1 Beat (Iyaz - Replay)	-10.3 LUFS (USHER - Omg (feat. will.i.am))	0.9 LU (David Guetta - Sexy Bitch (feat. Akon))	7.3 LU (JAY-Z - Empire State Of Mind (feat. Alicia Keys))	-6.1 LUFS (Young Money - BedRock (feat. Lloyd))	-7.6 LUFS (Young Money - BedRock (feat. Lloyd))	-0.0 dB (B.o.B - Nothin' On You (feat. Bruno Mars))
Mode Range	3 Minutes 30 Seconds to 3 Minutes 59 Seconds (12 songs)	120 BPM to 129 BPM (10 songs)	100 Bars 1 Beat to 109 Bars 4 Beats (7 songs)	-7.0 LUFS to -7.9 LUFS (11 songs)	4.0 LU to 4.9 LU (7 songs)	8.0 LU to 8.9 LU (10 songs)	-3.0 LUFS to -3.9 LUFS (10 songs)	-5.0 LUFS to -5.9 LUFS (11 songs)	0.5 dB to 0.9 dB (8 songs)
Anti-Mode Range	4 Minutes 30 Seconds to 4 Minutes 59 Seconds (4 songs)	140 BPM to 149 BPM (1 song)	130 Bars 1 Beat to 139 Bars 4 Beats (0 songs)	-5.0 LUFS to -5.9 LUFS (1 song)	1.0 LU to 1.9 LU (0 songs) & 8.0 LU to 8.9 LU (0 songs) & 9.0 LU to 9.9 LU (0 songs)	7.0 LU to 7.9 LU (3 songs) & 11.0 LU to 11.9 LU (3 songs)	-6.0 LUFS to -6.9 LUFS (2 songs) & -2.0 LUFS to -2.9 LUFS (2 songs)	-7.0 LUFS to -7.9 LUFS (2 songs) & -2.0 LUFS to -2.9 LUFS (2 songs)	2.0 dB to 2.4 dB (2 songs)

Fig. 3. *Descriptive Statistics of Songs from 2010*

Results	Time	Tempo	Bars & Beats	Integrated Loudness	Loudness Range	Average Dynamics (PLR)	Momentary Loudness Max	Short Term Loudness Max	True Peak Max
Mean	3 Minutes 14 Seconds	123 BPM	100 Bars 2 Beats	-8.8 LUFS	6.0 LU	9.3 LU	-5.1 LUFS	-6.5 LUFS	0.5 dB
Maximum	4 Minutes 5 Seconds (Billie Eilish - Everything I Wanted)	180 BPM (DaBaby - ROCKSTAR (feat. Roddy Ricch))	150 Bars 3 Beats (Future - Life Is Good (feat. Drake))	-6.1 LUFS (Post Malone - Circles)	11.5 LU (Billie Eilish - everything i wanted)	10.8 LU (WHATS POPPIN (Remix) (feat. DaBaby, Tory Lanez & Lil Wayne)) & (Cardi B - WAP (feat. Megan Thee Stallion))	-3.4 LUFS (Post Malone - Circles) & (Harry Styles - Watermelon Sugar)	-4.0 LUFS (Post Malone - Circles)	1.4 dB (Jack Harlow - WHATS POPPIN (Remix) (feat. DaBaby, Tory Lanez & Lil Wayne))
Minimum	2 Minutes 35 Seconds (Megan Thee Stallion - Savage)	75 BPM (Gabby Barrett - I Hope (feat. Charlie Puth))	63 Bars 4 Beats (Dan + Shay & Justin Bieber - 10000 Hours)	-10.5 LUFS (Trevor Daniel - Falling)	2.3 LU (The Weeknd - Blinding Lights)	6.2 LU (Post Malone - Circles)	-7.4 LUFS (Lil Mosey - Blueberry Faygo)	-8.9 LUFS (Lil Mosey - Blueberry Faygo)	-0.8 dB (Lewis Capaldi - Someone You Loved)
Mode Range	3 Minutes 0 Seconds to 3 Minutes 29 Seconds (14 songs)	90 BPM to 99 BPM (7 songs)	80 Bars 1 Beat to 89 Bars 4 Beats (6 songs)	-9.0 LUFS to -9.9 LUFS (9 songs)	5.0 LU to 5.9 LU (7 songs)	9.0 LU to 9.9 LU (12 songs)	-5.0 LUFS to -5.9 LUFS (11 songs)	-6.0 LUFS to -6.9 LUFS (10 songs)	0 dB to 0.4 dB (11 songs)
Anti-Mode Range	4 Minutes 0 Seconds to 4 Minutes 30 Seconds (1 song)	80 BPM to 89 BPM (0 songs) & 150 BPM to 159 BPM (0 songs)	150 Bars 1 Beat to 159 Bars 4 Beats (1 song)	-6.0 LUFS to -6.9 LUFS (1 song)	8.0 LU to 8.9 LU (0 songs)	6.0 LU to 6.9 LU (1 song)	-7.0 LUFS to -7.9 LUFS (1 song)	-4.0 LUFS to -4.9 LUFS (3 songs) & -8.0 LUFS to -8.9 LUFS (3 songs)	-1.0 dB to -0.6 dB (1 song)

Fig. 4. *Descriptive Statistics of Songs from 2020*

Results	Time	Tempo	Bars & Beats	Integrated Loudness	Loudness Range	Average Dynamics (PLR)	Momentary Loudness Max	Short Term Loudness Max	True Peak Max
Mean	4 Minutes 0 Seconds	110 BPM	109 Bars 1 Beat	-9.7 LUFS	6.0 LU	10.5 LU	-5.7 LUFS	-7.1 LUFS	0.8 dB
Maximum	5 Minutes 47 Seconds (Marc Anthony - You Sang to Me)	180 BPM (DaBaby - ROCKSTAR (feat. Roddy Ricch))	221 Bars 3 Beats (Jon Bon Jovi - Blaze of Glory)	-4.2 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	16.5 LU (Linda Ronstadt - Don't Know Much (with Aaron Neville))	16.9 LU (Maxi Priest - Close to You)	-1.9 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	-3.0 LUFS (Nelson - (Can't Live Without Your) Love and Affection)	3.4 dB (Toni Braxton - He Wasn't Man Enough)
Minimum	2 Minutes 35 Seconds (Megan Thee Stallion - Savage)	65 BPM (Brian McKnight - (Back At One) & (Linda Ronstadt - Don't Know Much (with Aaron Neville))	59 Bars 1 Beat (Linda Ronstadt - Don't Know Much (with Aaron Neville))	-16.9 LUFS (Snap! - The Power (7" Version))	0.9 LU (David Guetta - Sexy Bitch (feat. Akon))	4.9 LU (Nelson - (Can't Live Without Your) Love and Affection)	-12.3 LUFS (Maxi Priest - Close to You)	-14.1 LUFS (Maxi Priest - Close to You)	-1.4 dB (En Vogue - Hold On) & (Seduction - Two to Make It Right)
Mode Range	3 Minutes 30 Seconds to 3 Minutes 59 Seconds (29 songs)	90 BPM to 99 BPM (26 songs)	100 Bars 1 Beat to 109 Bars 4 Beats (2 songs)	-8.0 LUFS to -8.9 LUFS (26 songs)	3.0 LU to 3.9 LU (21 songs)	10.0 LU to 10.9 LU (29 songs)	-5.0 LUFS to -5.9 LUFS (32 songs)	-6.0 LUFS to -6.9 LUFS (32 songs)	0.0 dB to 0.4 dB (33 songs)
Anti-Mode Range	5 Minutes 30 Seconds to 5 Minutes 59 (4 songs)	150 BPM to 159 BPM (1 song) & 180 BPM to 189 BPM (1 song)	110 Bars 1 Beat to 119 Bars 4 Beats (0 songs) & 120 Bars 1 Beat to 129 Bars 9 Beats (0 songs)	-5.0 LUFS to -5.9 LUFS (1 song) & -4.0 LUFS to -4.9 LUFS (1 song)	14.0 LU to 14.9 LU (0 songs)	5.0 LU to 5.9 LU (0 songs)	-12.0 LUFS to -12.9 LUFS (1 song) & -1.0 LUFS to -1.9 LUFS (1 song)	-14.0 LUFS to -14.9 LUFS (1 song)	3.0 dB to 3.4 dB (1 song)

Fig. 5. *Aggregate Descriptive Statistics Across the Four Studied Periods (1990, 2000, 2010, and 2020)*

4. Results and Discussion

4.1. Overview of Tonal Balance trends

The tonal balance analysis revealed pronounced shifts in the spectral distribution of commercially successful music over the four decades studied. Tonal balance refers to the relative distribution of energy across low, low-mid, high-mid, and high frequency regions, providing insight into how engineers and producers shape a song's overall spectral identity. Analysis of average tonal balance curves showed that the 2020 period showed the highest levels of low-frequency content and low-mid energy, whereas the 1990 period displayed the lowest low-frequency levels and the highest high-mid presence. Conversely, high-frequency content peaked in the 2000 period and reached its lowest value in 2020. These patterns set up a clear long-term movement toward increasingly dark, low-weight mixes.

The contrast between 1990 and 2020 was particularly striking. The 1990 period presented mixes with minimal low-frequency energy and elevated high-mid level aesthetic characteristics of earlier pop, R&B, and soft-rock productions. In direct opposition, 2020 productions embraced dense low-end and subdued high-mids, reflecting contemporary preferences for bass-driven, highly processed sonics associated with hip-hop, trap, and modern pop. The 2000 and 2010 periods occupied intermediate positions, with 2000 showing the highest overall high-frequency levels and 2010 showing more balanced but still progressively darkening trends. This trajectory toward darker, more low-focused productions aligns with the increasing prevalence of sub-bass-oriented genres, advances in digital processing, and the cultural shift toward streaming-optimized playback systems that reproduce low frequencies more effectively than early consumer devices (Figure 6).

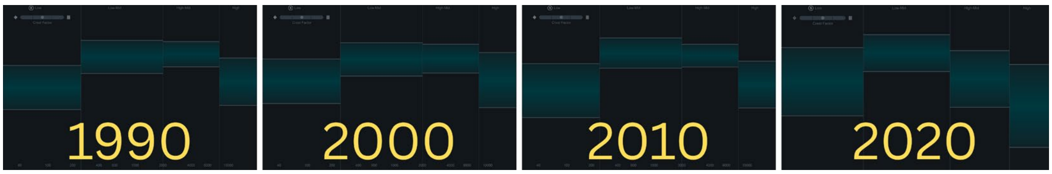

Fig. 6. *Average tonal balance curves for 1990, 2000, 2010, and 2020*

4.2. Integrated loudness across decades

Integrated loudness provides a measure of the perceived overall loudness of a track over its full duration, expressed in LUFS (Loudness Units compared to Full Scale). It corresponds to how loud a listener perceives a song to be on average, incorporating both intensity and the temporal distribution of energy. Higher (less negative) LUFS values show louder productions (Shepherd 2023).

The dataset proved clear confirmation of the expected trajectory: loudness increased dramatically from the 1990s onward, reached its apex during the 2010 decade, and partially moderated by 2020. The 2010 period, widely recognized as the height of the loudness war, exhibited an average integrated loudness of –8.0

LUFS, with the loudest track of that decade—JAY-Z's "Empire State of Mind"—reaching –5.7 LUFS. Surprisingly, however, the single loudest track across all 120 songs did not originate from the loudness-war decade but from the 1990 period: Nelson's "(Can't Live Without Your) Love and Affection" at –4.2 LUFS. Despite this extreme outlier, the 1990 decade had the lowest overall mean at –12.5 LUFS, confirming that such loudness values were exceptional and not indicative of broader production norms.

By 2020, integrated loudness values remained high but showed modest restraint compared to 2010, reflecting an industry-wide recalibration following streaming platform loudness normalization standards. The mean integrated loudness for 2020 was –8.8 LUFS, still significantly louder than historical norms but representing a subtle shift away from the hyper-compressed extremes of the early 2010s. When considering all four decades combined, the global average of –9.7 LUFS aligned closely with expectations and reflects the overall intensity level of contemporary popular music.

4.3. Average Dynamics (PLR) and Compression Practices

To contextualize loudness levels, average dynamics were examined using Peak-to-Loudness Ratio (PLR), a metric being the difference between a track's true peak level and its integrated loudness. PLR quantifies the dynamic density of a song: lower values indicate heavier compression and reduced transient impact, while higher values signify more dynamic openness (Know-how. 2022).

The findings revealed a clear and progressive decline in dynamic range over the decades. The 1990 period exhibited the highest average PLR at 12.6 LU, indicating relatively open, less processed productions typical of the era's pop and ballad-oriented repertoire. The decade 2000 showed a moderate decrease to 10.6 LU, and by 2010 and 2020, PLR values converged at 9.3 LU for both decades. This flattening of dynamic variation confirms the expectation that contemporary productions are increasingly compressed, clipped, and limited for competitive loudness.

These results support a broader interconnected pattern: as mixes became more low-end-heavy, the available headroom decreased, pushing producers to rely on compressors, clippers, and brick wall limiters to keep competitive playback levels. Low-frequency energy naturally consumes disproportionate amounts of headroom, and this constraint encourages aggressive dynamic processing to minimize transients and raise RMS levels. The consistent decline in PLR therefore reflects fundamental technical necessities in achieving loud targets within the tonal climates of each decade.

4.4. Short-Term and momentary loudness maxima

Short-term loudness captures perceived intensity averaged over approximately three seconds, and momentary loudness measures the same over roughly 400 milliseconds. These two metrics reveal how tracks manage loudness fluctuations on different timescales and how peaks behave in highly compressed masters (Désard 2022).

As expected, the two measures were relatively close across all periods. When aggregated, the mean short-term maximum across all decades was –7.1 LUFS, while the mean momentary maximum was –5.7 LUFS. The maxima observed across the entire dataset further illustrated the extreme intensities achieved in certain productions, with momentary maxima reaching –1.9 LUFS and short-term maxima reaching –3.0 LUFS. The minimum values, –14.1 LUFS for short-term and –12.3 LUFS for momentary, reinforced the breadth of variability met across the dataset.

The proximity of these values corroborated the expectation that heavily compressed contemporary masters show relatively stable loudness envelopes with limited transient fluctuation. The ranges also emphasize the continuity of loudness-war practices across decades—despite the noted moderation post-2010—while simultaneously highlighting the significant stylistic differences between decades in terms of loudness strategy.

4.5. True peak level extremes and the prevalence of clipping

True peak level measures the highest amplitude a digital audio signal reaches when reconstructed in the analog domain, thereby revealing inter-sample peaks that may exceed 0 dBFS (Swisher 2021). In audio engineering pedagogy, surpassing 0 dBTP is traditionally discouraged because it implies clipping; however, contemporary production practices often embrace such clipping for aesthetic or competitive reasons (Miraglia, Dustin. 2024).

The true peak analysis produced the most surprising finding of the entire study: 103 out of 120 tracks exceeded the 0 dB true peak threshold. This indicates that most commercially successful songs on the Billboard Year-End Hot 100 Singles lists embraced levels that would typically be considered technically improper. More unexpectedly still, several recordings exceeded the threshold by extreme margins, with Toni Braxton's "He Wasn't Man Enough" reaching 3.4 dBTP. Equally surprising were the lowest observed values, such as –1.4 dBTP in En Vogue's "Hold On" and Seduction's "Two to Make It Right", which contradicted the expectation that all charting songs would cluster closely around 0 dBTP.

This evidence challenges the notion that strict adherence to anti-clipping standards is necessary for commercial success. Instead, the data suggests that controlled clipping may be widely tolerated—or even aesthetically embraced—within mainstream audio production, particularly when used to achieve added perceived loudness and density.

4.6. Track length and temporal evolution

Analysis of track length confirmed a decisive trend toward concision. The average duration decreased from 4 minutes 42 seconds in 1990 to 4 minutes 14 seconds in 2000, then to 3 minutes 51 seconds in 2010, and finally to 3 minutes 14 seconds in 2020. The extremes were especially striking Marc Anthony's "You Sang to Me" reached 5 minutes 47 seconds in 2000, whereas Megan Thee Stallion's "Savage" lasted only 2 minutes 35 seconds in 2020.

These shifts reflect broader cultural transformations: the rise of hook-centric writing, the migration toward streaming platforms that reward repeat plays, and the influence of modern genre conventions that emphasize immediacy and impact. The contrast between earlier ballads and contemporary trap-driven structures underscores the acceleration of musical pacing over time.

4.7. Tempo trends and range variability

Tempo analyses also confirmed expectations about stylistic evolution (Cant 2024). The highest average BPM occurred in the 2020 period at 123 BPM, consistent with the rise of high-energy pop, EDM-influenced production, and rhythmically driven trap. Simultaneously, the wide tempo range across all decades was remarkable: values spanned from 65 BPM, as in Brian McKnight's "Back at One" and Linda Ronstadt's "Don't Know Much", to 180 BPM in DaBaby's "ROCKSTAR". This diversity suggests that despite overarching trends toward energy and immediacy, chart success still accommodates a wide stylistic spectrum.

4.8. Loudness Range (LRA) consistency across decades

Loudness range quantifies the variation in loudness over the course of a track and reflects how dynamically expressive a production is (Frampton, Tom. 2017). In contrast to integrated loudness and PLR—which showed broad variation, the loudness range exhibited remarkably consistent averages across decades: 6.6 LU (1990), 5.5 LU (2000), 5.8 LU (2010), and 6.0 LU (2020). The narrow spread of just over one loudness unit was unexpected and suggests that, regardless of increasing compression intensity, producers kept relatively consistent degrees of large-scale dynamic contrast. Even the most extreme outlier, David Guetta's "Sexy Bitch", which showed an LRA of only 0.9 LU, indicates the degree to which localized exceptions exist within broader stability.

4.9. Tonal balance outliers and notable exceptions

The general movement toward darker, bass-oriented production did not prevent notable exceptions. Billie Eilish's "everything i wanted", one of the most tonally atypical entries of the 2020 dataset, showed extremely elevated low and low-mid energy with comparably minimal high-mid and high-frequency content (Fig 7). Despite being contrary to the overall spectral trends and having an unusually long duration for the decade (4 minutes 5 seconds), the track achieved high commercial success. This reinforces the idea that songwriting, vocal performance, and artistic identity may supersede technical conventions when a track resonates culturally or emotionally.

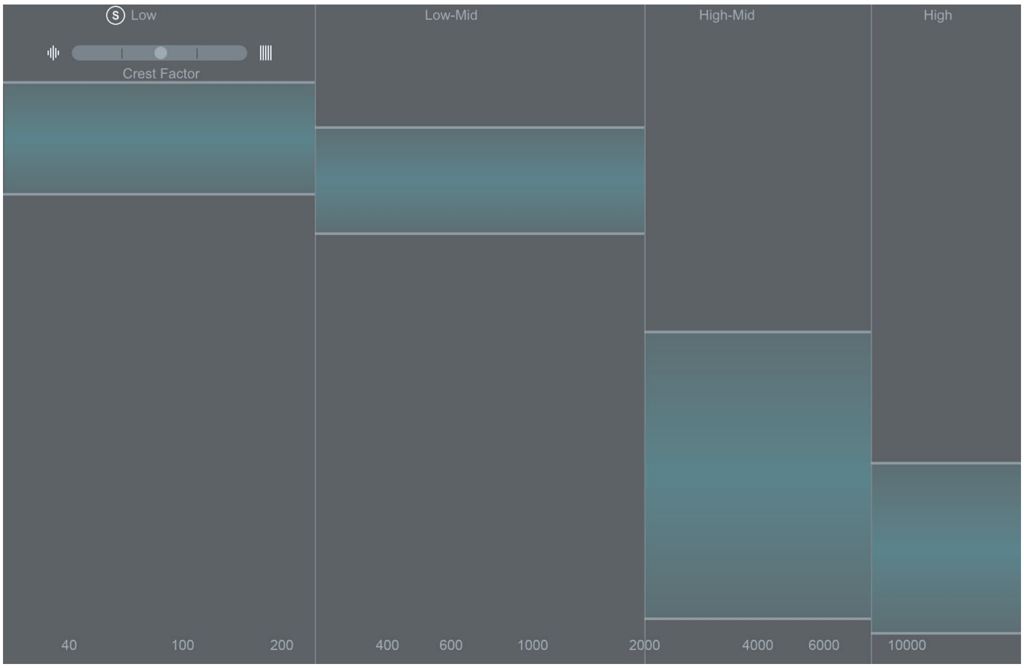

Fig. 7. *Tonal balance of Billie Eilish's "everything i wanted"*

4.10. Variability across all parameters

A striking overarching observation was the sheer breadth of variation across maxima and minima for nearly every parameter examined. Track lengths ranged from 2:35 to 5:47, BPM from 65 to 180, integrated loudness from –4.2 to –16.9 LUFS, and true peak values from –1.4 dBTP to +3.4 dBTP. Although some variability was expected, the size of these ranges was surprisingly large given that all recordings were drawn from Billboard Year-End Hot 100 Singles lists—arguably the most mainstream, commercially curated musical dataset.

4.11. Practical Implications for Audio Engineering and Production

Collectively, these findings provide a precise set of benchmarks that can guide contemporary producers and audio engineers. Using the 2020 dataset as reference enables practitioners to align their work with what demonstrably succeeds in the modern marketplace. Knowing the mean and range limits for parameters such as integrated loudness, dynamic density, tempo, and spectral distribution allows engineers to avoid unintended extremes and ensures a technically competitive sonic result. The tonal balance graphs, when paired with the numerical benchmarks, offer particularly actionable insight into how EQ, saturation, compression, clipping, and limiting should be employed to achieve contemporary results (Gonzaler 2023). Although technical ability remains essential—especially in advanced processes such as serial and parallel compression or EQ maneuvers like the Pultec trick for low-end amplification—the removal of guesswork afforded by this study substantially accelerates the pathway to professional-grade outcomes (Dupont 2020).

4.12. Limitations: The Absence of Stereo imaging analysis

The primary limitation of this study lies in its exclusion of stereo imaging analysis. While tone and dynamics form two critical axes of a song's "3D" sonic identity, stereo width forms the third. The software tools available for this study provided only momentary stereo imaging information rather than full-length imaging graphs, preventing systematic comparative analysis. Inclusion of stereo width data would have expanded the interpretative framework to encompass spatial processing strategies such as reverb, delay, doubling, chorus effects, and polarity-based widening techniques. Future research incorporating such data would offer a more comprehensive understanding of the spatial characteristics that contribute to commercial success.

5. Conclusions

This study provides a comprehensive analysis of tonal balance, loudness, dynamics, track length, and tempo across four decades of commercially successful music. The findings confirm several expected trends: music has progressively become darker, more low-end-heavy, shorter in duration, faster in tempo, and more compressed. Integrated loudness has generally increased, peaking during the 2010 loudness war, while dynamic range has simultaneously decreased to allow competitive playback levels despite denser low-frequency content. These results highlight a clear evolution in audio production practices, reflecting both technological advances and shifting aesthetic preferences within the music industry.

At the same time, the analysis revealed several unexpected and insightful patterns. Most notably, most tracks exceeded 0 dB true peak, challenging conventional audio engineering norms and demonstrating that commercial success does not strictly require adherence to traditional peak limitations. Additionally, extremes in track length, tempo, and loudness underscore the significant variability present even among top-charting songs, suggesting that compositional quality, performance, and audience engagement can outweigh purely technical considerations. The tonal balance and dynamic patterns also show that exceptions exist, as exemplified by tracks such as Billie Eilish's "everything i wanted," which diverge from general trends yet achieve commercial success.

Overall, these findings offer practical guidance for producers and audio engineers looking to align their work with contemporary standards while keeping creative flexibility. By using the identified benchmarks for tonal balance, loudness, and dynamics, practitioners can achieve technically competitive results while still allowing space for artistic innovation. Furthermore, this study sets up a foundation for future research, including stereo imaging analysis, to offer an even more complete understanding of the technical and aesthetic factors contributing to chart success over time.

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