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Sell and Buy Quiet - life cycle score estimation using online searches for impact wrenches

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ABSTRACT

Sell and Buy Quiet can be generalized to consider all the factors influencing a purchasing decision. Can Buy Quiet be implemented through web searches? This paper presents an academic-algebraic comparative example of web shopping for the "Best Impact Wrenches of 2022". The word Best is used as a marketing term in this context. This effort aims to advance Sell and Buy Quiet through further developing the Safety Procurement Standard SAE AS6228. The background presents a detailed overview of how e-commerce works for impact wrenches. The best practices are illustrated for internet shopping and how life cycle scores can improve the user experience. An important part of the user experience is product sorting. An ideal sorting option would place relevant products with an excellent overall balance of safety, health, and cost effectiveness over a wide range of diverse common searches at the top of the indexed product list. The ideal sorting option can be implemented by search engines and shopping websites using life cycle scores. Data from manufacturer manuals and manufacturer websites including sound and vibrations were used to calculate life cycle scores. For all choices of conversion parameters and weights, every impact wrench always returns a life cycle score.

1. INTRODUCTION

Hazardous noise exposure causes hearing loss [1]. Reducing noise levels is often accomplished by purchasing quieter equipment but there are numerous obstacles to overcome [2,3]. Sell and Buy Quiet can get beyond these obstacles by considering all the factors influencing a purchasing decision. The factors influencing purchasing decision have been studied for marketing purposes to optimize shopping search engines and shopping websites. This paper presents an academic-algebraic comparative example of web shopping for the "Best Impact Wrenches of 2022". The word "Best" is a marketing word referring to performance expectations based on product specifications and reviews from manufacturers, marketers, consumer protection organizations, and product review organizations which may be biased. The word "Best" is not meant in a scientific significantly better context.

This paper begins with a detailed overview of how impact wrenches are bought and sold through e-commerce. This paper describes the most used search engines, shopping search engines, and shopping websites. The best practices for search engines, queries, faceted searches, and product sorting options are described. The e-commerce user experience is quite sensitive to product sorting. An

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ideal sorting option would place relevant products with an excellent overall balance of safety, health, and cost effectiveness over a wide range of diverse common searches at the top of the indexed product list. All product sorting options can be implemented using a generalization of life cycle scores. Life cycle scores come from the safety procurement standard SAE AS6228 [4]. Higher life cycle scores represent overall safer, healthier, more cost-effective products. Life cycle scores can implement the ideal sorting option. In this context "Best" takes on a new meaning–the product with the highest life cycle score for that particular search. This paper investigates sorting products based on the lifecycle scores. Such product sorting would benefit consumers by directing free market forces to make safer, healthier, and more cost-effective products more visible through online searching and shopping. Successful implementation of lifecycle scores for generalizing "Sell and Buy Quiet" requires education, cooperation, and real competition of all persons involved in the e-commerce chain from the manufacturers to the end users including all the vendors, purchasing agents, administrators and third parties. Implementing ideal product sorting based on life cycle scores can help consumers accomplish this task on a global scale and improve the e-commerce user experience. By having QR codes on store shelves, the e-commerce user experience and brick and mortar retail experience can be blended.

1.1. SAE AS6228 Life Cycle Score Estimation

The life cycle score methodology always calculates a total score for each impact wrench. The data for each measured factor can come from laboratory data or online sources, such as manuals, manufacturers websites, shopping websites, and reviewer websites, and consumer product websites. In this paper, the safety, health, and product specification data is coming from manufacturer manuals and manufacture websites. The measured factors are converted to subscores on a scale from 1 to 10 [5]. Here, 1 is the lowest and 10 the highest. Three scaling formulae (linear, logarithmic, and exponential) can be used [5]. These formulae have various parameters and weights which are adjusted for each application. Each measured factor is weighted based upon relative importance. Unimportant factors are dropped from consideration. A weight of 0.5 indicates a minimally important factor. A weight of 2 indicates an important factor. The sum of the weighed subscores is the life cycle score. For each of the impact wrenches the life cycle scores are compared. A higher total score is better.

1.2. Online Shopping Basics

A naïve user may use a general search engine without the specialized capabilities of shopping search engines. A more sophisticated shopper will enter search information into the search query box of a shopping search engine or even a shopping website. The search engine will return results that direct the online shopper to a shopping search engine or directly to an online shopping website. Generally, shopping search engines direct online shoppers to shopping websites. Online shopping websites have features useful for iteratively searching, sorting, and comparing products. Ideally, the shopper will select the "Best" product for their application and make a successful purchase.

1.3. Search Engines

Google has a substantial share of the online search market on all seven continents [6,7,8]. The search engines with at least one percent of the online search market on at least one continent are shown in Table 1 [8]. When searching with the query "impact wrench" some of these search engines did not return information regarding impact wrenches. Some search engines are in languages other than English, so a query for "impact wrench" did not make sense. Some search engines are blocked, which can occur due to security concerns or system and service provider configurations.

1.4. Shopping Search Engines

In general, shopping search engines focus on identifying products but do not enable a direct purchase. Shopping websites enable the consumer to make a purchase. Globally, the most popular shopping search engines are dependent on the product being searched for, country, language, and culture [9]. There are concerns about abuse of trust, self-favoritism, and abuse of market monopoly [6,7]. A search of "Best Shopping Search Engines" was used to make a list of online shopping search engines [10-12]. Many shopping search engines are dedicated to specific product categories that do not include impact wrenches. Table 2 lists the shopping search engines that returned at least one impact wrench given the search query "impact wrench" [10-12].

Some of the shopping search engines only compare prices. Comparison shopping search engines are meant for comparing products based mostly on price. Our research investigates the benefit of including all the safety, health, and cost factors influencing a purchasing decision. By including all these factors in the sorting algorithm, consumers would be able to make more evidence-based decisions. In addition, this would provide a better foundation for understanding overall market trends.

Table 1: Percentage of the search market for several search engines on each continent [8].

Search Engine	Continent						
	Africa	Antarctica	Asia	Australia	Europe	North America	South America
Google	95.86	98.30	91.40	93.20	92.04	88.61	97.29
Bing	2.80	0.39	1.55	4.64	3.71	6.14	1.75
Baidu	0.01	0.00	3.35	0.03	0.00	0.04	0.00
Yahoo!	0.47	0.78	1.34	0.86	0.98	2.78	0.68
DuckDuckGo	0.12	0.46	0.13	0.98	0.61	2.10	0.11
YANDEX	0.04	0.00	1.45	0.04	1.81	0.07	0.02

Table 2: Shopping search engines with a large market share that return at least one impact wrench that are accessible in the United States [10-12].

Count	Shopping Search Engine	Web address
1	Google Shopping	https://shopping.google.com/
2	Bing Shopping	https://www.bing.com/shop/
3	Yahoo Shopping	https://shopping.yahoo.com/
4	Pinterest	https://www.pinterest.com/
5	Shopzilla	https://www.shopzilla.com/
6	PriceGrabber	http://www.pricegrabber.com/

1.5. Shopping Website Design

The best shopping websites have a well-designed user experience which is often rated based on how quickly the product filters return relevant items [10,13]. The initial product search is very important to the success of a shopping website. When a user first comes to a shopping website generally, they navigate to the search query box [14]. Queries are entered into the search box which should correctly return output restricted to the most relevant categories of power tools. Once the correct category of tools is identified the search continues in the faceted search bar. As the controls in the faceted search bar are updated, the products are sorted and displayed in the main window. The default sorting option should return a relevant and diverse set of products [15]. The three control bars that affect the display of indexed items are described in the next three subsections.

The three control bars affecting the display of indexed items.

1) Search box for entering queries
2) Faceted search bar for navigating product filters
3) Product sorting control with multiple options

1.5.1 Search query box

Ideally, the search box queries should correctly return categories of power tools and the most relevant tools within those categories. Restricting the output of the search query to the most relevant categories is often very helpful. The user keeps entering information in the search query box until the correct category of tools is identified, then continues the search in the faceted search bar [15].

1.5.2 Product filter (faceted search) bar

On a typical shopping website, there is a faceted search bar for navigating product filters on the left column. This bar helps to filter through the products based on various specifications, attributes, and requirements. Each time a facet is selected the products are sorted according to the updated

criteria. The number of products remains the same, but the products are sorted differently. For each iteration of the facets, different products will be viewable at the top of the list. Having a greater variety of products being viewable is helpful to the shopper [16]. The faceted search connects purchasers to the products given a set of applications and routinely used technical specifications with quickly updated results [17-19].

From the view point of life cycle score estimation, product filtering (also known as faceted search) allows shoppers to refine product searches based on multiple attributes like price, color, size, and reviews. All product attributes are measured factors in the life cycle scores. Attributes such as color, size, and reviews are characterized as user acceptance in the life cycle score methodology. The products at the top of the list should have the highest life cycle scores. To increase views of their products, noise control engineers need to design products that have high life cycles scores for as many combinations of the faceted filter bar as possible. Noise control engineers should be a part of the marketing team and understand how the products are going to be marketed so the design is properly optimized.

The best practices for the faceted search filter bar are summarized by the list below [13,14].

1) Use category-specific filters e.g. impact wrench, framing nailer, reciprocating saw
2) Promote important filters
3) Headline particularly important filters using clone controls
4) Use multi-selection filters e.g. select multiple price ranges (0-50), (50-100), …, (500+)
5) Have thematic filters e.g. “Best stubby impact wrench”, [20-25], see Table 4.
6) Display applied filters both in their original position and in an overview
7) Truncate long lists of product filtering values e.g. show the first value and a “more” button
8) Make filter changes separate events in the browser history
9) Show compatibility filters e.g. manufacturer and model of battery power supply

1.5.3 Product sorting control

The products are sorted based on the selected product search option, search query, and the current status of the product filters. Product sorting helps to find the best power tool more efficiently for the purchaser’s needs. A list of product sorting options was composed from evidence developed to maximize sales from online shopping [26,27]. The default sorting option should be Relevance (Diversity-Based). Diversity in this context means the top of the list are the results from multiple thematic-common searches given the query and faceted search selections (see Section 2 Table 4). Alphabetical sorting can be helpful to users searching for a specific manufacturer and model. Other options depend on the interests of the particular shopper.

Options for product sorting

1) Relevance (Diversity-Based)
2) Alphabetical
3) Featured
4) Price
5) Popularity
6) Best selling
7) Average Customer Reviews
8) Newest Arrivals

To increase views of their products, noise control engineers need to design products that score well with each of the product sorting options especially relevance. To convey a category’s true breadth, a product list should represent all its major product types within the first 20 or so products on desktop and within the first 10 or so on mobile, due to fewer products being visible at once [26,27]. Diversity-based relevance is an excellent default sorting option. Search relevance optimization is no longer a luxury; it is essential. If the sorted product list in the main window includes too many irrelevant items, then a user will likely abandon the website. The sorted items should be based on the

search query and product filters and the sorting list can include clearance items, best thematic items, and promotions.

On standard e-commerce and mass merchant sites like Amazon, Walmart, and Home Depot, reviews are one of the most heavily utilized parts of the site, so the ability to sort by reviews is helpful to those consumers. For direct to customer sales, e.g. directly from a manufacturer website to a customer, reviews on the direct to customer website are not important [28].

1.6. Web Search Strategies

Often online and physical hardware stores will have impact wrenches available. Other retail stores often will have one or more impact wrenches. However, these stores are not likely to have a large selection and their websites may have only simple faceted search capabilities for power tools. Some stores will not carry impact wrenches at all. This puts the burden for knowing the specifications on the purchaser.

Searches often start with product specifications and the need to understand the full breadth of available technologies that satisfy those specifications. Engineering technical information search engines satisfy the need to understand technical specifications, detail the breadth of technologies currently available, and explain how to use those technologies.

If the purchase is less urgent then a much more sophisticated web search for the best power tool can be used. These different search strategies yield very different results. Long-term strategy online searches may start with education then to a search engine, shopping search engine, shopping website, or an industrial supplier. Online retailers have shipping options, so locality is less critical, but still relevant.

Web Search types

1) Engineering technical information searches
2) Map-based searches
3) Big box retail hardware stores
4) Search engines
5) Shopping search engines
6) Shopping websites
7) E-commerce industrial suppliers

1.6.1 Technical information searches

Technical information search engines are a major destination for people searching for technical content including current research findings, lists of products, design considerations, and product purchasing [29]. Technical information search engines are an excellent place to broadly learn the breadth of applications for developing solutions. These websites connect technical experts, buyers, and sellers to the engineering information and product specifications. They provide details about equipment operations and design. Technical information search engines have a tremendous breadth of knowledge, amount of detail on the latest technologies, and understanding of how these technologies work. Commencing a search on impact wrenches with a technical information search engine provides an understanding of most applications of impact wrenches. It is helpful to understand the full capabilities of impact wrenches including all the important factors and niche applications from a global perspective before making a purchase.

1.6.2 Shopping websites

A search for the “Best shopping websites” yielded a list of websites [30-32]. Shopping websites often have a revenue stream causing a conflict of interest. Clearly identify the seller. Read shopping website and seller disclaimers and conflict of interest statements. There are many shopping websites which focus on selling products with a limited range of categories. Table 3 shows websites that returned an impact wrench and did not require a login. The shopping websites Amazon and Google shopping have a complete filtering experience. The shopping websites Walmart, Alibaba, and Yahoo shopping had limited faceted search options. Consumers in need of an impact wrench with certain

specifications may abandon a website if it does not have a well-developed faceted search. Shopping websites with a good user experience can be built using an e-commerce builder [33-35].

Table 3: Shopping websites with a large market share that returned at least one impact wrench and are available in the United States [30-32].

Count	Shopping Website	Web Address
1	Amazon	https://www.amazon.com/
2	eBay	https://www.ebay.com/
3	Walmart	https://www.walmart.com/
4	Etsy	https://www.etsy.com/
5	Google Shopping	https://shopping.google.com/
6	Overstock.com	https://www.overstock.com/
7	Target	https://www.target.com/
8	Aliexpress	https://www.aliexpress.com/
9	Home Depot	https://www.homedepot.com/
10	Kohls	https://www.kohls.com/

1.6.3 Big box retail hardware stores

A search using the phrase "Best Home Improvement and Retail Hardware Stores" returned websites with suggested retailers [36,37]. The search yielded big box retail hardware stores with online shopping such as Home Depot, Lowes, Menards, and Ace Hardware. There were several other websites but the search capabilities were not as well developed including Do It Best Online, Build with BMC, Harbor Freight, and True Value.

1.6.4 E-commerce industrial suppliers

A search using the phrase "e-commerce Industrial Supply" yielded several results. There are e-commerce Industrial Suppliers such as McMaster-Carr, MSCdirect, Grainger which have well developed search capabilities and technical information for a specific target audience of purchasers. Other industrial suppliers did not have well developed web content for impact wrenches, e.g. GT Industrial Supply and Industrial Supply Company.

1.7. Incentivizing Safety

Consumers benefit from market conditions that promote safer products. Safer products can be promoted by extending life cycle scores to have a measured factor for the ability to clearly identify the seller and another measured factor for product certifications. The measured factor for identifying the seller incentivizes the same safety and health responsibilities in e-commerce as brick-and-mortar retail stores [38]. The measured factor for product certifications would promote product certifications from Nationally Recognized Testing Laboratories (NRTL) products [39-41].

2. METHODS

The factors that are important when making a purchasing decision have been studied by web designers. A search was made for online shopping websites that have well developed product filters for impact wrenches. Several online shopping websites have well developed product filters for impact wrenches. A list of online shopping websites for impact wrenches was made. Those websites were visited and a list of faceted search items for each site was made. The faceted search items were aggregated and simplified into a single list of faceted search items for impact wrenches.

2.1. Thematic-Common Searches

A thematic web search on the query "Best Impact Wrenches of 2022" yielded many websites. In general, narrowly defined timely topics are found in marketing blogs and there are no refereed journal articles. Online articles are often embedded with advertisements and may be biased, and the authors may not be authorities on the subject. Carefully read the authors biography and conflict of interest

statements and disclaimers. Often the articles describe the authors as either a Do-It-Yourselfer or and so many years of experience with home and project repairs. Six of the websites had particularly good discussions of the features which influence whether the impact wrench is the "Best" in a marketing sense. Themes were similar to the "Best cordless 3/8 inch compact/stubby versatile *manufacturer* impact wrench under 5 pounds". Thematic-common search results were found from online tool reviewers. A list of the "Best" impact wrenches was made based on the thematic searches, and the faceted search data was collected for these models of impact wrenches [20-25]. Table 4 shows some of the typical words and phrases that appear in thematic searches for impact wrenches. Thematic searches are formed by combining the words and phrases in Table 4.

The faceted search data was collected for 64 unique models of impact wrenches. The power sources were pneumatic, battery powered, and corded. Data was not collected for any hydraulic impact wrenches. The parameters and weights for the life cycle score estimation were adjusted for consistency with the interpretation of the thematic searches. The thematic-search tool review and thematic-life cycle score search results were compared by manufacturer and model numbers.

Table 4: List of "Best" thematic-common search criteria that can be combined to form compound searches. The italic font indicates that the expression is substituted with a specific search value.

General Condition	Open-ended Condition	Faceted Conditions
overall	heavy-duty	*manufacturer*
compact/stubby	angular grip	*drive size*
affordable/budget	for lug nuts	*energy system*
if money is no object	kit with sockets	*grip configurations*
hybrid/quick change	versatile	*weight threshold*

A search for the best impact wrenches of 2022 was made. A list of the manufacturer and model numbers for the best impact wrenches of 2022 was made. For comparison purposes, an additional search for low-noise impact wrenches was made. The impact wrench data was aggregated into a spreadsheet. Pricing information came from Google Shopping. All other data such as weight, dimensions, and performance specifications, including sound power level, sound pressure level, and hand-arm vibrations data came from the manufacturers through manuals and manufacturer websites.

2.2. Product Sorting by Life Cycle Scores

All the sorting options from Section 1.5.3 can be implemented through extensions of the life cycle score methodology to support search engines, shopping search engines, and shopping websites. Additional measured factors can be added to the life cycle score to handle additional factors such as Alphabetical, Featured, Popularity, Best selling, Average Customer Reviews, and Newest Arrivals, product liability, thematic-common searches, etc. [5].

The measured factor-subscore relationship is linear decreasing for alphabetical name, energy consumption, sound power and pressure levels. The measured factor-subscore relationship is linear decreasing for energy capacity, forward and reverse torque. The measured factor-subscore relationship is exponential decreasing for weight, length, and geometric volume. The measured factor-subscore relationship is logarithmic decreasing for cost and hand-arm vibrations. The other measured values were converted using Boolean algebra. The conversion parameters were based on commonly used permissible exposure levels, threshold values, histograms, and other criteria. The data for calculating life cycle scores comes from tool manufacturer websites and manuals. Missing measured factor data is handled by converting the missing factor to the lowest subscore. When calculating life cycle scores, the lack of a manufacturer user manual and manufacture website caused all measured factors to be converted to the lowest subscore. This is commensurate with the safety problems that could occur.

For categorical factors such as "3/8 inch drive" satisfying the criteria yields a subscore of 50 otherwise the subscore is 0. When a "3/8 inch drive" if specified a 1/2-inch drive may have a higher life cycle score than a 3/8-inch drive. This should be interpreted as a 1/2-inch drive may be a better

choice given the faceted search criteria and available data. The purchaser may want to consider the possibility of purchasing the 1/2-inch drive impact wrench and a 1/2-to-3/8-inch adapter.

Relevance (Diversity-Based) sorting requires calculating the life cycle scores for multiple searches based on many search options including thematic searches then populating the indexed sorting list with a unique listing of the top results from each search. When sorting based on "Price", the weightings of all factors other than "Price" would be set to zero so that "Price" is the only remining factor. Alphabetical sorting requires adding the manufacturer and model names as measured factors. Those factors are then sorted alphabetically the sorting indices are converted to subscores on a scale from 1 to 10. Typically, the total life cycle scores are sorted in descending order.

3. RESULTS

A signal faceted search bar was aggregated from several popular shopping websites. Based on a search of the "Best impact wrench of 2022", a list of 64 models of impact wrenches was made. Two spreadsheets were made one with data from both manufacturers and shopping websites and another with only manufacturer data. The combined manufacturer and shopping website spreadsheet was used for comparing internet searches of manufacturer and shopping websites for consistency and bias. The only manufacturer spreadsheet was used for reporting sound and vibrations data and calculating life cycle scores. For consistency, only the pricing data from Google Shopping was used to calculate the life cycle scores.

3.1. Faceted Search Attributes (Measured Factors)

Faceted search bars from Global Spec, Google Shopping, Amazon, and McMasterCarr were combined and simplified into a list of 17 categories of faceted search items.

Summary Combined Faceted Search Bar (Measured Factors)

1) Manufacturer (28 unique manufacturers; Alphanumeric)
2) Model Number (64 unique model numbers, Alphanumeric)
3) Tool Category (Impact Wrench, Impulse Driver)
4) Grip Configurations (Pistol Grip, Straight (Inline) Grip, Angular Grip)
5) Socket Mount (Friction Ring, Pin Detent, 1/4-inch hex, Quick-Loc)
6) Energy Systems (Pneumatic, Hydraulic, Electric Corded, Battery)
7) Energy System Rating (Air Watts, Electric Watts, Fluid Watts, Battery Energy Capacity)
8) Weight (tool including battery 5 Amp Hours preferred kg)
9) Drive size (6.35, 9.5, 11, 12.7, 19, 25.4, 63.5 mm)
10) Product dimensions (Length-bit holder to back plate, Height-bottom of handle to top, Width-side to side mm)
11) Forward Torque (Continuous Nm)
12) Reverse Torque (Continuous Nm)
13) Number of Speed Setting (1, 2, 3, 4, …, Variable)
14) Maximum Impacts per second (Continuous IPM)
15) Maximum Free Speed (Continuous RPM)
16) Cost (including tool, battery, and charger USD)
17) Product Certifications (NRTL, ETL, UL, …)

3.2. Data Collection from Websites for Impact Wrenches

There are many websites operated by the manufactures, online shopping stores, and online and retail hardware stores that have detailed consistent information on impact wrenches. Most of the power tool manufacturers have dedicated websites with detailed information on their power tools and links to download the user manual and other documents. In this paper, the three most used shopping websites were Amazon, Home Depot, and Lowes which were good sources of data.

For the energy system rating the effort and flow information were collected as much as possible; however, the detailed information is often not readily available. Battery voltage and capacity are generally available. Air pressure was often reported as 90 psi. Standardized volume flow rate often

had two reported values average and maximum at load. The pricing data for battery powered tools included the tool, at least one battery (preferably 5 amp hours or more), and a battery charger.

In general, the power tool data on the shopping websites agreed with the manufacturer's websites and manuals. The data disagreements between manufacturers and shopping websites often were simply typos or the result of aggregating multiple items into a kit. The manufacturer data had a general lack of information on product dimensions, sound power, sound pressure, and vibrations.

3.3. Sound and Vibrations data for Impact Wrenches

Table 5 shows a summary of the impact wrench data sorted in a multicolumn fashion first by the sound power, then by sound pressure, hand arm vibrations, and cost. The data in Table 5 comes from tool manufacturer websites and tool manuals. For comparison purposes, a web search with the query "Quietest Impact Wrenches" included many of the tools listed in Table 5 [42-44]. Not all manufacturers of impact wrenches were included in this comparative example. Of 64 tools only 13 had complete sound power, sound pressure, and hand-arm vibrations data. Four manufacturers had sound power level, sound pressure level, and hand-arm vibration data for all their impact wrenches. Four other manufacturers had partial sound and vibrations data.

Table 5: Summary of the performance, safety, health, and cost data. L_W is the sound power level (dBA re. 20 pW). L_p is the sound power level (dBA re. 20 μPa). a_{rms} is the hand arm vibrations.

Impact	Energy	Reverse	L_W	L_p	a_{rms}	Cost
1	Battery	1491	100	89	12.2	433
2	Pneumatic	1760	103	92	7.7	405
3	Pneumatic	1760	103	92	9.0	340
4	Pneumatic	1302	105	94	12.0	214
5	Pneumatic	610	106	95	12.1	187
6	Battery	2040	106	95	17.0	476
7	Battery	2040	106	95	17.0	568
8	Pneumatic	1356	107	96	8.7	525
9	Pneumatic	1100	108	97	9.6	243
10	Pneumatic	678	109	98	16.0	79
11	Pneumatic	2000	112	101	9.0	696
12	Pneumatic	2000	115	103	9.0	558
13	Pneumatic	1830	115	104	9.0	349
14	Pneumatic	563	-	85	-	142
15	Pneumatic	1756	-	86	-	239
16	Pneumatic	1756	-	86	-	278
17	Battery	201	-	86	-	435
18	Pneumatic	678	-	98	7.5	142
19	Battery	1650	-	98	-	509

3.4. Best Battery and Pneumatic Powered Impact Wrenches

In this section the word "Best" means the highest life cycle score as adjusted for the thematic search given the available data from the manufacturer's website and user manuals. Table 6 shows the masked impact wrenches selected using the life cycle scores given the thematic-common searches and available data. The left two columns show the results for the battery powered impact wrenches. Columns three and four indicate the results for the pneumatic impact wrenches.

Tables 5-6 include several of the same impact wrenches because Table 5 includes impact wrenches where more data is available from the manufacturer's website and user manuals which only increases their life cycle scores. In Table 6, Impact Wrench 1 dominates the thematic searches for battery powered tools since it has the lowest overall sound, vibrations, and cost data, competitive

specifications data, also it is relatively short, small and low weight. For pneumatic impact wrenches, Impact Wrench 9 dominates the thematic searches since it is quieter than impact wrenches 10-64, and is shorter, smaller, and lower weight than many other impact wrenches. Impact wrenches 24, 27, and 28 did not have sound or vibrations data available from the manufacturer; never the less, they have higher life cycle scores than all the other impact wrenches by being better optimized for their respective thematic searches. A thematic search for "low noise" would yield a list similar to Table 5.

Table 6: Battery and pneumatic powered tools selected using life cycle scores.

Battery Powered		Pneumatic Powered	
Thematic-Common Search	Impact Wrench	Thematic-Common Search	Impact Wrench
overall	1	overall	9
overall runner-up	6	overall runner-up	5
3/8-inch	19	entry-level on a budget	18
for torque	6	cheapest-of-the-cheap	28
for the money	1	compact	5
compact	1	affordable compact	18
stubby	24	angular grip	14
if money is no object	1	heavy-duty	9
affordable	1		
versatile	27		

4. SUMMARY, DISCUSSISON, and CONCLUSIONS

This paper presented a brief example of searching the web for the "Best Impact Wrenches of 2022". An overview of e-commerce was presented. The user experience and best practices for technical information searches, general use search engines, shopping search engines, and shopping websites were discussed. An important part of the user experience is the sorted product list. Life cycle scores can be embedded in the sorting process. In this methodology for all thematic-common searches, all the impact wrenches are always returned in the indexed product list. This sorting feature gives all impact wrenches an opportunity to appear at the top of the indexed product list. Ideally, products near the top of the indexed product list should provide users with a selection of relevant, diverse, properly optimized products. An ideal sorting option would place relevant products with an excellent overall balance of safety, health, and cost effectiveness over a wide range of diverse common searches at the top of the product list. Life cycle scores can implement these sorting options.

Life cycle scores provide a more objective foundation for searching the web for impact wrenches. However, life cycle scores do not rise to the level of being a scientific way to objectively select the "Best" impact wrench. Life cycle scores are still subjective and highly influenced by specific applications and user preferences. All levels of the e-commerce chain can sort products using life cycle scores to promote safer products. By having QR codes on store shelves, a purchaser could scan a QR code go to the e-commerce shopping website perform a thematic search then physically compare the top ten returned products for a more thorough product comparison. The best of the e-commerce user experience and brick and mortar retail experience can be blended together through smart phones apps.

There is a general lack of health and safety data such as hand-arm vibrations and sound power available through web searches. Impact wrenches with full sound and vibrations data generally had higher life cycle scores. Without safety and health data established models are at a disadvantage to new tools entering the stream of commerce who do have safety and health data available. Making safety and health data only increases life cycle scores improving the competitiveness of the tools and providing valuable information to purchasers, safety professionals, and workers. This academic-algebraic comparative example aims to encourage manufacturers to make their safety and health data available.

5. FUTURE WORK

A more complete description of the parameters and weightings for estimating life cycle scores with the thematic-common search methods should be published. Spreadsheets for implementing thematic searches should be published. The life cycle score methodology should be extended to take into consideration the ability to clearly identify the seller and required NRTL product approvals and certifications. As part of this research project, NIOSH will conduct laboratory testing to demonstrate how and what data should be collected and provide examples and guidance on life cycle scores.

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