Marketing attribution and Game Theory

A primer on multi-touch attribution and the Shapley Value Formula

What is marketing attribution and why is it important?

Measuring Marketing

Since the dawn of advertising marketers have faced the challenge of where to spend their ad budget to attain the best results. With the advent of digital marketing we'd expect the marketer's dilemma to have been solved through technology, and for a time it was (sort of).

"Half the money I spend on advertising is wasted; the trouble is I don't know which half." John Wanamaker (1838-1922) was a very successful United States merchant, religious leader and political figure, considered to be a "pioneer in marketing".

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~ John Wanamaker

AZ QUOTES
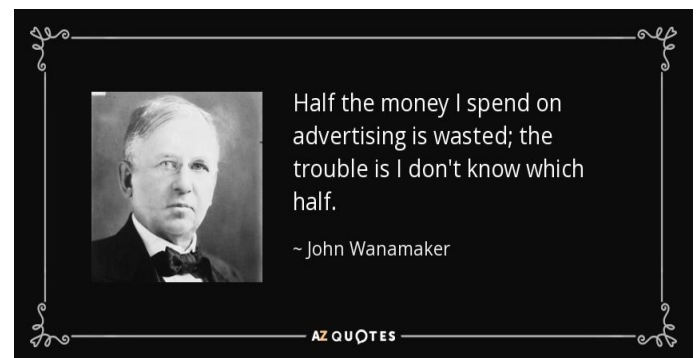
In the early days of Internet advertising you'd create an SEO friendly website, buy some keywords, maybe set up an email campaign and you're good to go. Measuring the number of sales that came from your keyword campaigns were fairly straightforward. Fast-forward to present day. Facebook and Instagram, LinkedIn, Twitter, Snapchat, Bing and Google, retargeting, personalized experiences, onsite chat, display ads, influencers.... The list of platforms and tactics has grown dramatically and with it the complexity of the customer journey. All these "touch-points" now play a role in influencing a customer to convert, so which ones get the credit? The answer is all of them, to a degree...

Understanding ROAS

Return on ad spend or ROAS is simply the amount of sales dollars resulting from a given advertising investment. This ratio of spend to income gives marketers insight into how well their campaigns are performing, but in the context of today's complex customer journey the interplay between advertising efforts and outcomes is not always apparent. Take, for example, an awareness campaign designed to reach as many people as possible. Its purpose is not to generate sales directly, but rather to *feed* other channels like email which in turn is geared more towards conversion. While the spend in each channel is discrete and predictable, the returns yielded are more difficult to quantify. Enter attribution modeling, a method of measuring the impact of a specific campaign on sales. Attribution modeling is critical to efficient and effective allocation of budget. Without it dollars are burned on underperforming campaigns and marketers fall victim to an unscientific "spray-and-pray" approach.

Attribution models

Traditional attribution models all have their pros and cons, however the biggest drawback they all have in common is that they are **heuristic models**, meaning they are based on rules or *heuristics*. These rules decide how to split the value of a sale among touch points:

Last Click - This is the most common model, probably because it's the simplest to implement, understand and explain to others. It ignores the majority of the customer's path and assigns the entire conversion value to the last touch or "last click". The shortcomings of this approach are obvious; if all the touch points prior to the last click are ignored then they're simply not being measured.

First Click - Like Last Click, this model places all the emphasis on the first piece of marketing to touch a prospective customer. It suffers from the same shortcomings as it ignores a large portion of the customer journey.

Linear - Linear attribution models distribute the conversion credit equally among all touch points along the path to purchase.

Time Decay - Time decay models distribute conversion credit based on touch point recency. The last click gets the most credit, followed by the 2nd last and so on.

The above models are all poor proxies for understanding what actually drove results. They are designed around convenience and ease of use but are ineffective at actually determining what is influencing customers. The biggest problem with all these models is that heuristics are arbitrary, inflexible and subject to bias.

Not just human bias but also platform bias. Each ad platform you employ wants to take credit for a sale thereby inflating their reported ROAS and driving you to allocate more of your ad budget. Take for example view-through conversions. These are journeys such that a

customer saw an ad and then (without clicking on said ad) went on to purchase. Facebook will attribute any purchase the customer made within a day of the ad view and within 28 days if the customer clicked on the ad. **Regardless** of what happens after the ad view or ad click Facebook takes all the credit.

There must be a better solution. Something that allocates credit intelligently, something that's evidence-based, built upon a foundation of performance data to determine the *lift* in value brought by each marketing touch point. These models have been called different names - multi-touch attribution, statistical attribution, algorithmic attribution, data-driven attribution, but essentially it means that there is an algorithm which allocates conversion value based on data rather than heuristics.

Multi-touch attribution with Shapley

Game theory is the study of mathematical models of strategic interaction among rational decision-makers, i.e. players. It has applications in social science, as well as in logic, systems science and computer science. Cooperative game theory specifically deals with coalitions of players, how they function as a team and their resulting collective payoffs.

The Shapley value is a solution concept in cooperative game theory. It was named in honor of Lloyd Shapley, who introduced it in 1951 and won the Nobel Prize in Economics for it in 2012. The concept works like this, given a set of N players, subsets of players form coalitions. A coalition's value is the total payoffs it generates when its players work together. The Shapley value of a player is the player's total earned payoffs (across all the coalitions that player participated in). Essentially, the Shapley value is a measure of a player's average marginal contribution to each coalition.

In the context of digital marketing, the players of the game are touch-points (channels, campaigns, ads), and the various ways in which the touch-points interact with customers throughout their journey form the coalitions. Cooperative game theory and the Shapley value provide a data-driven way to measure touch-point influence and fairly divide the conversion credit, based on their individual contribution to the total payoff.

An Example

Let's work through an example to illustrate the concept. Say that your company made $510556.88 in revenues during the month of October. During that period your marketing team advertised usings Email, Facebook and Google. So let's look how these channels performed in their various coalitions.

Coalition	Channels In Journey	Audience	Conversions	Sales
S1	Facebook	19960	300	$13972.00
S2	Google	16356	300	$19300.08
S3	Email	38864	400	$295366.40
S4	Facebook + Google	4200	150	$20000.00
S5	Email + Google	2878	100	$120876.00
S6	Facebook + Email	762	25	$14630.40
S7	Email + Google + Facebook	426	12	$26412.00

The table above shows customer journeys for prospective customers. The audience shows the number of people exposed to the channels. Conversions is the subset of the audience that purchases and Sales is the dollar amount of those purchases.

The next step is to define our characteristic function *v*. The characteristic function assigns a value to each coalition to signify its worth, this worth represents payoff that the players can generate when they play together.

To define our characteristic function we will use conversion rate in dollars (sales/audience). We'll then use that number to normalize the sales figures and audience sizes across the different journeys.

Coalition	Channels In Journey	Audience	Sales	Conversion Rate $/audience member
S1	Facebook	19960	$13972.00	0.7
S2	Google	16356	$19300.08	1.18
S3	Email	38864	$295366.40	7.6
S4	Facebook + Google	4200	$20000.00	4,76
S5	Email + Google	2878	$120876.00	42.0
S6	Facebook + Email	762	$14630.40	19.2
S7	Email + Google + Facebook	426	$26412.00	34.34

One thing to note about our new table is that we can see that performance, measured above as sales per audience member, improves as the number of touchpoints in the journey increase. Intuitively this feels right, the more marketing a person engages with the higher the likelihood they will purchase. The tables above reflect real world data, where such principles typically hold true. However, it is possible for an ad or campaign to be a detractor, and adversely affect the probability of purchase. Such detractors will mark themselves as poor players which negatively affect the team's payoff. More on that later...

Our characteristic function for each coalition will use the conversion metric and apply it to each audience where that coalition exits as a subset. To illustrate we'll use coalition S1, aka Facebook.

We'll add the value that Facebook gets playing alone 19960 * 0.7 which equals our sales for S1 of $13972.00. Then we'll add every coalition where S1 is a subset (in other words, everywhere Facebook is a touchpoint), coalitions S4, S6 and S7. By applying the conversion rate metric to those three audiences we get

$(4200 \times 0.7)+(762 \times 0.7)+(426 \times 0.7) = 3771.60$

added to our starting value for S1

$13972.00 + 3771.60 = 17743.6$

So our characteristic function for v for S1 (written as v(S1)) is 17743.6. We'll proceed in this manner with each coalition of size 1, followed by coalitions of size 2, etc. until we've exhausted all the coalitions.

The coalition containing all the players (S7) is known as the grand coalition The grand coalition's worth should be equal to the total payoff, in our case this is total sales for the month of October $510556.88 we wish to attribute back to Facebook, Google and Email.

This produces the table below:

Coalition	Channels In Journey	Conversion Rate $/audience member	Value Function $v(S_i)$
S1	Facebook	0.7	17743.6
S2	Google	1.18	28154.8
S3	Email	7.6	326268.0
S4	Facebook + Google	4,76	59230.09

S5	Email + Google	42.0	464181.68
S6	Facebook + Email	19.2	356960.8
S7	Email + Google + Facebook	34.34	510556.88

We are now ready to apply the Shapley value formula for each player i which looks like this:

$$\varphi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!\,(n - |S| - 1)!}{n!} (v(S \cup \{i\}) - v(S))$$

Which can be interpreted as

$$\varphi_i(v) = \frac{1}{\text{number of players}} \sum_{\text{coalitions excluding } i} \frac{\text{marginal contribution of } i \text{ to coalition}}{\text{number of coalitions excluding } i \text{ of this size}}$$

Shapley Explained

Like an average Shapley begins with a summation. The summation looks at the **marginal** contribution of each player. This is done by subtracting one value function from another. In our case take Facebook. If we want to measure Facebook's marginal contribution to a coalition we take a coalition with Facebook and from it subtract the same coalition with the Facebook player removed. For example

(Email + Google + Facebook) - (Email + Google)

Which is

v(S7) - v(S5) or 510556.88 - 464181.68 = 46375.2

By summing all such weighted marginal values for Facebook and diving by the number of players gives us the total attributed earnings for Facebook which come to $31667.

The Shapley value formula is similar to a weighted average, where the quantities in the summation are the marginal contributions of each player weighted by the combinations of players in coalitions. By applying the Shapley formula to each player we get our attribution values for all three channels.

Channel	Sales Attribution
Facebook	$ 31667
Google	$ 90483

Email	$ 388405
Total	**$ 510556**

As we can see the total aligns with our sales figure for October.

Properties of the Shapley Value

The Shapley value formula has some desirable properties that lend itself well to marketing attribution. The first such property is **marginalism,** Shapley only measures the marginal contribution a player adds to the team. In our example Facebook was rewarded credit beyond the $13972.00 it earned alone because it provided *lift* in the other journey where it participated.

As a consequence of the above, Shapley has a second desirable property known as **the Null Player** property which states that if a player is part of a coalition but does not provide any contribution, their payoff is zero. This means that channels or touch-point that simply exist on the path to purchase but don't provide lift are not rewarded attribution credit. In real world results this can often be observed with Organic Search. Organic Search is often seen mid-way through a customer journey because of the way URL bars in browsers work. People frequently type a partial URL, brand or store name into the URL bar as a method for navigating to a site via search results. This means an Organic Search visit will be on the path to purchase if they buy but Shapley credits this for what it is, a null player. Organic doesn't earn credit for just being on the team, it has to add lift.

Finally, the most important and desirable property of Shapley is that it is the *only* payment formula that fairly divides payoffs among the players. This can be proven mathematically, however the proof is outside the scope of this paper.

It should also be noted that the Shapley value formula is not a black box, it is a well known, transparent and accepted algorithm for solving payoff sharing problems. More info on the Shapley Value formula can be found here.

The Shapley multi-touch attribution advantage

A holistic view of digital marketing performance

Siloed marketing performance data is arguably the biggest issue facing marketers today. The plethora of different platforms and tools, each with its own reporting functionality result

in a myriad of problems when attempting to accurately account for return on ad spend. Competing channels often take credit for the same sale, use different attribution models with different lookback periods and report ROAS metrics that never reconcile with actual sales.

The customer journey, although composed of different touch points, needs to be measured holistically to see exactly which channels are influencing sales and by how much. Accurate data supports better, more confident data driven marketing decisions.

Allocate Budgets Effectively

Eliminate the guessing game of allocating budget to the right channels and tactics to drive sales, revenue and other outcomes. Clear and concise insight into the customer's path to purchase allows marketers to invest wisely in the right mix of channels. By integrating spend data with sales and journey analytics, multi-touch attribution addresses Wannamaker's dilemma and gives marketers their *true* return on ad spend, minimizing wasted digital marketing investments.

Prove the value of your campaigns

Today's savvy digital marketer knows that anywhere between a few to a dozen marketing touches are needed for a customer to convert. Efforts spent upstream on awareness, audience growth and building mindshare pay dividends downstream with increased customer interest and conversion. Without multi-touch attribution the downstream, causal relationships between channels and tactics can be murky, making it difficult for marketers to justify their efforts. In a bid for self preservation they tend to rely on vanity metrics. The Shapley value formula approach to attribution specifically measures these causal relationships and elucidates the impact of spend anywhere in the sales funnel.

Remove Bias

We are all subject to bias. Everything from confirmation bias to self-serving bias shapes our decisions. By collecting and presenting the data to defend opposing views or support your original decisions bias can be mitigated. Biases also exist in the platforms, tools or agencies we employ to execute on digital campaigns. An all encompassing attribution solution holds each of these to task and examines results impartially.

Conclusion

For a time simplistic, easy to use attribution models were enough. With the emergence of new platforms marketers begin to employ a multitude of tactics to take advantage of new technology. Customer journeys began to get more complex and less predictable. The de facto attribution models couldn't keep up and more likely than not presented inaccurate data on the performance of campaigns. Shapley multi-touch attribution addresses these challenges and uses Nobel prize winning concepts from game theory to correctly attribute results and give marketers accurate ROAS metrics.