

<b>Institution:</b> University College London		
<b>Unit of Assessment:</b> UoA 17, Business & Management Studies		
<b>Title of case study:</b> Improving monetization in mobile advertising using machine learning		
<b>Period when the underpinning research was undertaken:</b> 2009- 2014		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b> Bert De Reyck	<b>Role(s) (e.g. job title):</b> Professor	<b>Period(s) employed by submitting HEI:</b> 2007 – present
<b>Period when the claimed impact occurred:</b> 2014 – present		
<b>Is this case study continued from a case study submitted in 2014?</b> No		
<b>1. Summary of the impact</b> <p>In 2019, mobile advertising spending, i.e. advertising via smartphones or other mobile devices, amounted to \$190 billion worldwide. Working with Vungle Inc., one of the leading mobile advertising companies headquartered in San Francisco, Professor De Reyck built on his research on optimizing mobile advertising to develop and implement an ad-serving algorithm that incorporates machine-learning methods to optimize personalized ad-serving decisions. The algorithm was implemented in the Autumn of 2014 and is still in use today. In an A/B test versus the company's legacy algorithm, Professor De Reyck's algorithm generated an immediate 23% increase in revenue, in excess of USD1,000,000 per month. This allowed Vungle to accelerate its exponential growth (to 4 billion video views per month over 1 billion devices), increasing its revenues in the period between 2014 and 2019 to more than USD500M per year, ultimately resulting in the sale of Vungle in 2019 to the Blackstone Equity Group for more than USD750M.</p>		
<b>2. Underpinning research</b> <p>The advent of big data has created opportunities for marketing firms to customize their services to unprecedented levels of granularity. When a customer enters an advertising network, the vast amount of data available creates opportunities for advertisers to target the customer with a granularity that was impossible before, serving a personalised advertisement predicted to have maximum impact. However, utilizing the massive amount of available data to implement the most effective advertising campaign in real time is a nontrivial problem, further complicated by the fact that ad-serving decisions often need to be made in a matter of milliseconds in order to ensure a smooth user experience.</p> <p>The focal decision problem of advertising networks is ad serving, i.e., determining which ad to serve to each of the thousands of ad requests that arrive each second from devices worldwide. Professor De Reyck's 2003 article in <i>Operations Research</i> ([a]) contained the first ever-mathematical model to optimize mobile advertising, i.e. advertising on mobile phones. The algorithm used mathematical programming for deciding which ads to send out to which customers at what particular time, in order to maximize customer response and revenues from retailers paying for each ad broadcast. The model was location-sensitive, and struck a balance between quality (maximizing predicted effectiveness) and diversity (variety to reduce user fatigue) among ads broadcast. This model was later adapted for, and implemented in, the world's first mobile advertising company ([b]).</p> <p>In December 2013, the CEO of Vungle (2011-2017), one of the largest mobile advertising companies, contacted Professor De Reyck, with a request to investigate the efficiency of Vungle's ad serving algorithms. Vungle was familiar with Professor De Reyck's work on optimizing advertising (he attended a lecture by Professor De Reyck in 2011), and was wondering whether, with some modifications, the same methodology could be applied to enhance their offerings. The core service that Vungle offers is a platform that enables advertisers to embed their video ads within popular mobile gaming applications to encourage users to download and install new apps. Currently, Vungle displays more than 4 billion video</p>		

ads to over 1 billion devices. As the former CEO writes, “*At the time, Vungle engineers would spend an important amount of time trying to improve customer targeting. [...] We anticipated the benefits of [...] analytics [...] and requested Professor De Reyck and his team to take the lead on this.*”.

The resulting study carried out by Professor De Reyck ([c]) highlighted opportunities for improving customer targeting, and led Professor De Reyck to adapt his earlier approach ([a], [b]) to new smartphone technology using state-of-the-art big data analytics. Professor De Reyck and his team developed ad-serving algorithms based on machine learning models, which calculate the expected profit from displaying each ad and make allocation decisions, all in less than 50ms to enable an instantaneous response. The system includes the following innovative features ([d]):

- It incorporates a user-specific, real-time procedure that strikes a balance between sending a large variety of ads and sending ads of high quality, considering the user's level of engagement with the host application. This diversification mechanism exposes users who are highly engaged with the host application to a larger variety of ads, by taking into account their recent interactions with ads and signs of fatigue. For a user with lower engagement, the algorithms rotate ads at a lower speed, and gives higher selection probabilities to higher-quality ads.
- It reduced the time needed to train the models. The popularity of mobile games changes rapidly, and classification algorithms should consider fresh data that represent those changes. By implementing a two-stage training approach, the algorithm dramatically shortens training times and therefore incorporate more frequent data updates.

The ad serving system's software infrastructure uses an array of database technologies, thus allowing the system to retrieve, cleanse, and utilize data that account for more than 150 million ad requests per week.

### 3. References to the research

[a] De Reyck, B. and Degraeve, Z. “Broadcast scheduling for mobile advertising”, *Operations Research*, 2003, 51 (4), 509 – 517. <https://doi.org/10.1287/opre.51.4.509.16104>

[b] De Reyck, B. and Degraeve, Z. “MABS: Spreadsheet– based decision support for precision marketing”, *European Journal of Operational Research*, 2006, 171 (3), 935 – 950. <https://doi.org/10.1016/j.ejor.2005.01.009>

[c] Grushka-Cockayne, Y., Lichtendahl, K.C., De Reyck, B. and Fragkos, I. “A/B testing at Vungle”, Darden Case UVA-QA-0821, 2018. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3213752](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3213752)

[d] De Reyck, B., Fragkos, I., Grushka-Cockayne, Y., Lichtendahl, C., Guerin, H., Kritzer, A. “Vungle Inc. improves monetization using big-data analytics”, *INFORMS Journal on Applied Analytics*, 2017, 47(5), 454-466. <https://doi.org/10.1287/inte.2017.0903>

The underpinning research was conducted by Professor De Reyck, Professor at the UCL School of Management, in collaboration with Ioannis Fragkos, Associate Professor at the Rotterdam School of Management, and Professors Yael Grushka-Cockayne and Kenneth C. Lichtendahl from the Darden School of Business at the University of Virginia. Professor De Reyck was the principal investigator.

Evidence of the quality of research is provided by publications in key peer-reviewed journals, and award nominations.

#### 4. Details of the impact

The ad-serving system was first implemented by Vungle in 2014, and is still in operation today. Professor De Reyck's team performed several A/B (comparative) tests to compare the algorithm's performance with that of Vungle's legacy algorithm. The results showed an immediate 23% increase in revenue, equivalent to an increase in revenue of more than \$1 million per month. This allowed Vungle to accelerate its exponential growth (to 4 billion video views per month over 1 billion devices), increasing its revenues in the period between 2014 and 2019 to more than USD500,000,000 per year, ultimately resulting in the sale of Vungle in 2019 to the Blackstone Equity Group for more than USD750M ([1],[2],[3]).

The CEO of Vungle noted, *"These early intriguing findings resulted in a set of sophisticated algorithms to optimize our mobile advertising targeting, with the first algorithms tested in April 2014, with fascinating results: a massive 23% uplift in eRPM (expected revenue per thousand impressions), our main [performance] metric. [...] This unprecedented improvement [...] gave Vungle a tremendous edge over our competitors, which we have sustained [...]."*

Additionally, the detailed data exploration and analyses that were required to develop the new system revealed several key managerial insights, which allowed Vungle to detect the effects of higher-order interactions among features that have significant predictive power. For example, the probability of a user responding to an ad video was found to be positively correlated with the volume level of the device ([d]). Although this seems intuitive in hindsight, it was not a factor that mobile advertising companies were considering at the time, principally because there was no ability to modify the sound volume. However, a closer analysis revealed that some ads were strongly affected by sound volume, whereas others were not; once Vungle knew the sound volume, it could display the best ad for each volume setting. The CEO of Vungle continues, *"The benefits started realizing long before the project was completed. The team's visualization tools revealed interesting habitual patterns of our users that were not known to us beforehand" ([1]).*

The team also interfaced algorithms with the technologies Vungle was using, allowing their engineers to roll out the algorithm to full traffic. At the end of the implementation, Professor De Reyck helped Vungle to set up an independent data science team. As Vungle CEO concludes, *"The impact of this project went far beyond the successful implementation of this particular project. Professor De Reyck created and installed a resident data science team in Vungle, led by one of the original team members [...], who has been leading several important follow-up projects [...], all of which have their origins in the work done by his team." ([1]).*

In November 2020, the Head of Data Science at Vungle, wrote ([3]) *"Vungle's data science team, initially seeded by Professor De Reyck, has since grown to a global group of 14 professional data scientists and machine learning engineers, spanning America, Europe, and Asia. Algorithms built by the data science team now drive \$500 million in annual revenue, and form a core part of the company's intellectual property. In fact, Vungle successfully completed an acquisition by the private equity firm Blackstone in 2019, in large part due to the competitive advantage provided by our data science team's decisioning algorithms. Going back to Vungle's earliest days, Professor De Reyck and his team really took us from zero to one in terms of our application of data science to the business, and helped start a snowball rolling toward the tremendous business outcomes we have seen since."*

He continues ([3]) *"Even today, Vungle's data science team continues to invest in the core project of conversion rate prediction that Professor De Reyck and team kicked off during their original engagement with the company. Some of our most important new products, such as a dynamic bidder for bidding into a new-to-the-industry in-app auction format, are currently being built on top of the conversion rate prediction models that evolved from that engagement. In short, the original work of Professor De Reyck's team laid a foundation for data science at Vungle, and we cannot overstate the impact that the application of data science has had since, and continues to have, on the success of our business."*

The impact of the underpinning research was recognised in the nomination this research received from the *Institute for Operations Research and Management Science (INFORMS)*,

as a finalist of the *Daniel H. Wagner Prize for Excellence in Operations Research Practice* [4], and through its publication in the journal *INFORMS Journal on Applied Analytics* [2], a journal dedicated to exemplary cases of research with substantial impact outside academia.

#### 5. Sources to corroborate the impact

[1] Testimonial from Founder and former CEO of Vungle.

[2] De Reyck, B., Fragkos, I., Grushka-Cockayne, Y., Lichtendahl, C., Guerin, H. and Kritzer, A. "Vungle Inc. improves monetization using big-data analytics", *INFORMS Journal on Applied Analytics*, 2017, 47 (5), 454-466. <https://pubsonline.informs.org/doi/10.1287/inte.2017.0903>.

[3] Testimonial from Head of Data Science at Vungle.

[4] The case study was a finalist for the 2016 *INFORMS Daniel H. Wagner Prize for Excellence in Operations Research Practice*: <https://www.informs.org/Recognizing-Excellence/INFORMS-Prizes/Daniel-H.-Wagner-Prize-for-Excellence-in-Operations-Research-Practice>