POLITECNICO DI MILANO
School of Industrial and Information Engineering
Master of Science in Management Engineering

The classification of Innovative Payments enabled by IoT technologies: census and evolution of its products & services

Thesis supervisor: Prof. Alessandro Perego
Thesis co-supervisor: Ing. Ivano Asaro
Ing. Matteo Risi

Author:
Marco Fiandrino, 927170

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Abstract

With the advancements of technology, the areas of application of the Internet of Things have grown dramatically. Such is the case that it has made itself present on almost every part of our day-to-day life, from the connections of our smartphones with smart speakers in order to play music once we arrive home, to the connections between voice assistants and coffee makers which can start functioning on command. Now it is time for such sophisticated systems to start enabling future forms of payment process. But; How does this network of interconnected objects really work? What are the characteristics of payment systems from which IoT objects can leverage? And finally; How is it that they will be able to conduct the intrinsic action of payment?

The work is aimed at describing the characteristics of payment systems as well as IoT systems, linking both to better understand how interconnected objects will be performing such process. The Literature chapter introduces both concepts and establishes a clear relation, culminating in the current description of available innovative payments. During this process, the Census was being conducted in order to identify current and future products and services that enable the payment action through the use of IoT technology. Once the Literature was finished, the Census was reviewed so as to eliminate any product or service that did not fit the provided definitions. Finally, an empirical analysis was made revolving the characteristics of the remaining products and services. The characteristics of the currently available products and services were first presented to define their present state. Then, the products and services that are currently on development were included, thus defining a future condition for such characteristics.

The work identifies the categories of Wearable Payments and Device-Free Payments as product/service oriented while Smart Object Payments and Voice Payments are considered network oriented. This means that the former leverage on a single type of product or service instead of profiting of access to the whole IoT network as would the latter. For the subcategories presented, payments made through smart cars have shown the most distinguishable growth, even incorporating fully autonomous M2M payments, that is, without any human intervention or assistance. Another worth mentioning development is the diversification on the uses of biometrics, with new advancements even voice biometrics may be available soon.

In the future, we should be on the lookout for the development of smart cars' payment services as well as biometrics' payment enabled services, as both characteristics have shown the most promising features.

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Executive Summary

The work looks to classify innovative payments conducted through smart products which leverage on the use of Internet of Things networks. It begins by denoting the similarities between payment systems and IoT systems, forming a clear pattern for the interconnected development of both. As a result, innovative payments are introduced, and with them the different smart products that enabled them. The classification is made through the census of currently available as well as on development products and services, where their enabling smart product was noted as well as their common characteristics. Then, an empirical analysis was performed to better understand those similarities and the consequences they might bring for the future development of this innovative technology.

Context Analysis & Literature

For the satisfaction of the simplest to the most robust of needs, there is probably a point along the line where an exchange of goods is made carrying with it the action of payment. This not only allowed for the integration of payments systems into our daily life, but for the need of them to be conducted on such a way that even a two-year-old could perform the action. It is because of this integration that the intricate methods of payment seem to appear simple. But, despite this conception, payment systems are fundamental to the functioning of all monetary economies and therefore should not be disregarded as a trivial matter. "If money is the lifeblood of modern monetary economies, payment systems are the circulation system. Failures in this circulation system risk a seizing up in the real and financial transactions they support, with potentially significant welfare costs" (Millard, et al., 2007, p. 2).

Now that the importance of payments systems has been established, and before beginning to describe the most innovative payment systems, we need to identify the main characteristics that such system has been incorporating along its evolution. It is only by the proper comprehension of those needs that we will manage to define a roadmap for the evolution of payments.

Money came into place to ease the conditions imposed by bartering systems, as it was rare for two agents to want each other's good at the precise time and in the precise quantity to perform such transaction (Boel, 2019) . Therefore, the first identifiable characteristic is the facilitation of transaction occurrence.

The development of banks allowed for the creation of account-based payment methods while helping to reduce transactions (Boel, 2019) . Furthermore, they contributed to the creation of fiat money, which provided greater security (as large transports of metals were vulnerable to theft) and scalability of transactions. This process identifies further requirements for payment systems, as with an increase in economic activity also comes an increase on transactable amounts.

As society continued its economic expansion, even cash became limited on its physical form. A new kind of monetary structure was needed, and so, digital payments were created. This new system profited from the connections enabled by machines to eliminate physical restrictions. A network was developed, and its interaction was open to everyone around the world. Although society do not adapt instantly to a newly introduced payment system, as it often takes time before its use becomes widespread. One explanation for this delay are network effects, but learning cost, lack of familiarity and the need to invest in software, Point of Sale (POS) devices and training are also contributing factors (Berger, Hancock and Marquardt, 1996; Farrel and Klemperer, 2003, cited in Cruijsen, Plooij, 2015). Despite this, the recent pandemic acted as an accelerator for the development of Innovative Payments as they do not only provide the already mentioned characteristics, but also help reduce the interaction between individuals, which consequently promotes social distancing.

Now that we reach to the current society and its forms of payment, it is important to better understand the technologies that enabled them. “The Internet of Things (IoT) represents the future of computing and communications. It is a world of information and communication technologies (ICTs) from anytime, anyplace connectivity for anyone; we will now have connectivity for anything” (Bhagyashri, et al., 2013, p. 24). The adoption of IoT leverages on the same principles mentioned for the evolution of payment systems evidencing the strong relationship among these two concepts. First, a strong growth is observed for IoT connected devices, forecasted to reach 50 billion devices by the year 2030 (Strategy Analytics, 2019), which guarantees the scalability of its network. Second, their selected connectivity will influence its data speed, signal coverage and battery life, all of which will consequently influence the cost among machine’s interactions. There are already developments surrounding Low-Power-Wide-Area connectivity in order to decrease costs associated with IoT networks. Third, an empirical study conducted by Kim et al (2010) found a positive relation between the security of payment procedures and perceived trusts, which were both shown to have an influence on electronic payment’s use. This justifies that security conditions on IoT objects will ultimately influence their use.

Finally, we arrived at the definition of the most innovative types of payments (as shown on Figure 1). The Osservatorio Innovative Payments from Politecnico di Milano (2020) finds four categories within *Innovative Payments*:

- **Wearable Payment**: Those conducted through wearable objects (such as Smartwatches).
- **Mobile Payment**: Those conducted through a Smartphone.
- **Smart Object Payment**: Those conducted through different Smart Objects than the ones mentioned on the categories above (such as Smart Cars or Smart Appliances).
- **Device-free Payment**: Those that do not require a device to conduct payment. This category refers to payments conducted either by payments conducted at PoS through biometric features or those which use in store sensors as well as AI systems to track the user's purchasing while on the shop.

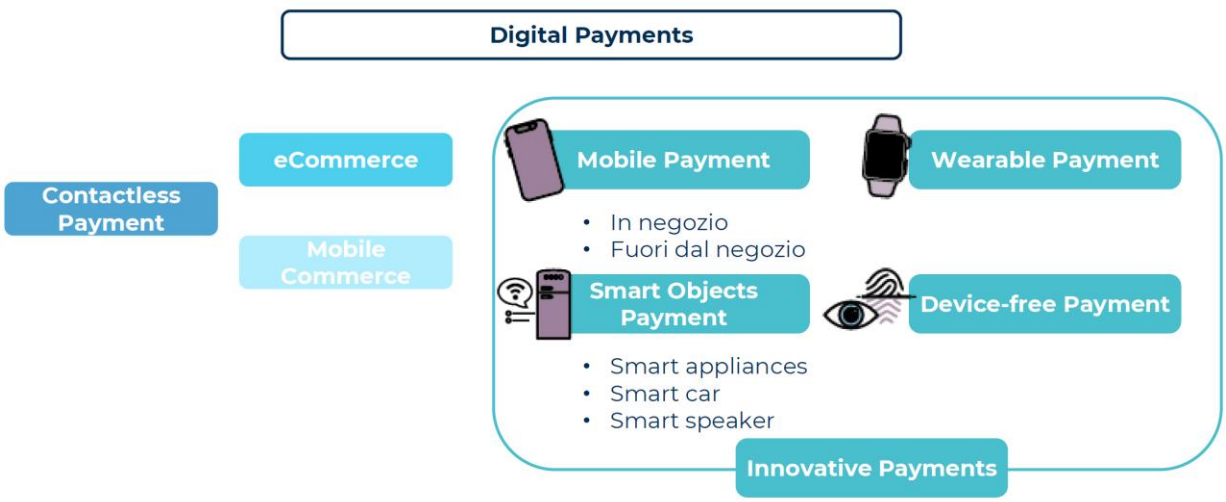

Figure 1: Digital Payments Framework - Source: Observatory of Innovative Payments (2020)

In spite of being a major component of Innovative Payments, the category integrating "Mobile Payments" will not be further examined, as it is the focus of this thesis to analyze the evolution of new forms of payment which distinguish themselves from existing ones and are enabled by IoT technologies. Instead, the category of "**Voice Payments**", which integrates payments conducted through voice assistants, will be added to provide a deeper understanding of the capabilities of this technology in relation with smart objects.

Methodology

The products/services identified through the Census have been further analyzed in order to assess their condition in the IoT environment. Therefore, its area of application, connectivity, and payment-enabled technology has been identified. The identification of this characteristics provides further insight on their development and recognizes which characteristics the future payment system will present.

To align the previous objectives with the following pieces of the research, some questions have been proposed:

1. *Which type of Innovative Payment predominating in the current market? Will it remain the same in the near future?*
2. *According to the classifications, are we able to identify a limit for the "smart-things" that can integrate payment applications?*
3. *Which are the main characteristics of innovative payments with respect to those of IoT devices? Are the currently used characteristics the best available in the market or is there any room for improvement?*

The Literature, which has already been introduced, offers a very distinctive workflow (see Figure 2). It begins with the first payment method and finishes with Innovative payments, denoting the characteristics that enables such systems along the way.

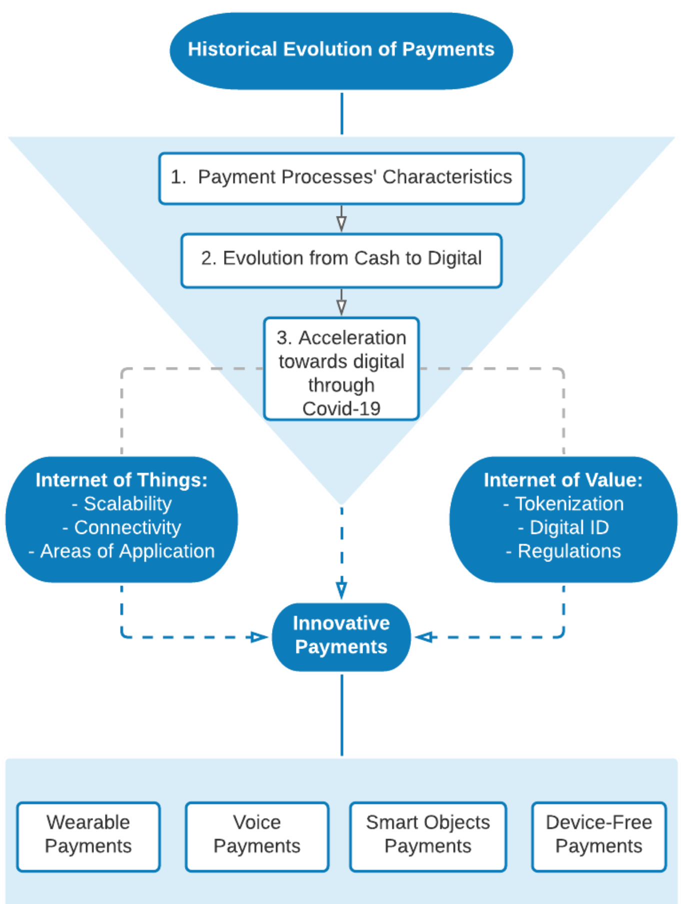

Figure 2: Literature Workflow

While researching the context of the thesis, different sources have been studied:

- Reports and Market Analysis' which include the tendencies and descriptions of the general technology implemented, as well as those that focus precisely on the conduction of payment through such technologies.
- Academic papers, Journal Articles and Conference proceedings.
- Websites and Articles from official entities such as the Smart Payment Association, Secure Technology Payment Alliance or even verified payment providers such as Visa and Mastercard.
- Reports and Workshops of the Observatory of Innovative Payments.
- Newsletters from different portals as well as the Observatory of Innovative Payments.

The Census began through the definition of the different payment areas according to the insights provided by the Literature. The classification required an iterative process through which the most relevant characteristics where selected and the current products/services re-evaluated. Such workflow is shown on Figure 3.

It is important to take into consideration that the latest reviewed was given on the 20th of March 2021. Since that point, the variables became static and any change in any of the products or services would not be noted.

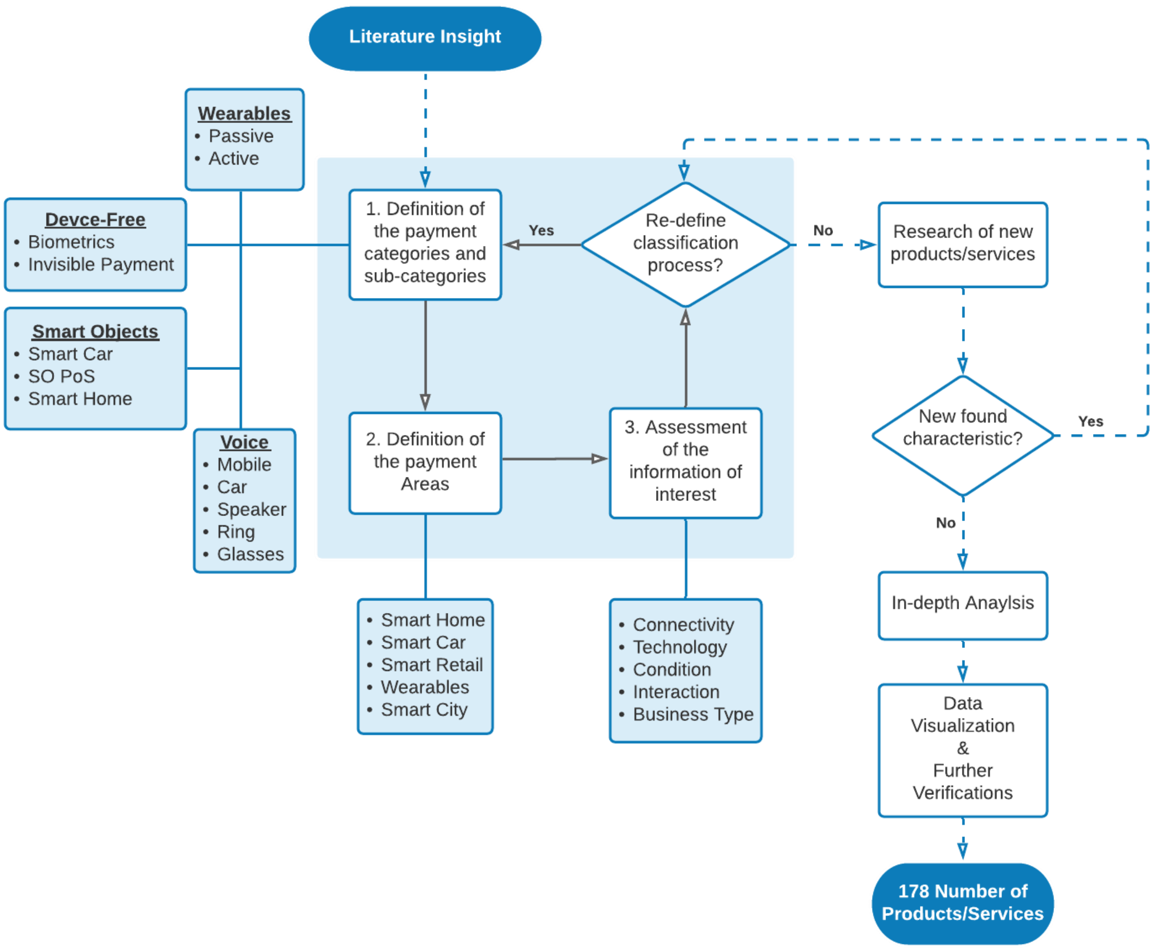

Figure 3: Workflow Census

The Classification Process (defined by steps 1. to 3.) allow for the identification of several subcategories within each section, all of them noted on Table 1.

Innovative Payment	**Category**
Wearable Payments	Passive
	Active
Voice Payments	Mobile
	Car
	Speaker
	Ring
	Glasses
Smart Objects Payments	Smart Car

	Smart Objects PoS
	Smart Home
Device-Free Payments	Biometrics
	Invisible Payments

Table 1: Innovative Payment's Categories

At the end of the Census, 178 products/services were identified and divided according to the table below. It is important to take into consideration that because each product or service can be in more than one category. An example would be a payment service done by voice while being integrated on a smart car, such service would be included in both Voice Payments and Smart Object Payments.

Category	**Product/Service**
Wearable Payments	70
Voice Payments	25
Smart Object Payments	51
Device-Free Payments	53

Table 2: Innovative Payments Products/Services - Source: Census

The research has been conducted mostly through secondary sources upon which the product or service was identified. Those sources are:

- Reports of different propositions for the use of the innovative technologies as a mean of payment.
- Websites and Articles from official entities such as the Smart Payment Association, Secure Technology Payment Alliance or even verified payment providers such as Visa and Mastercard.
- Newsletters from different portals as well as the Observatory of Innovative Payments.

After the product or service was identified, the website of the company developing such product or providing such service was researched in order to identify every mentioned variable.

The Empirical Analysis was structured in two chapters. The first described the distribution of the analyzed products/services within the Innovative Payments environment so to determine the involvement of payment service providers within each category and subcategory. It also examined the composition of each category and subcategory as to determine the market's smart product of choice. Both concepts set the basis of the analysis in order to provide a clear trend for the future development of Innovative

Payments. The second chapter contemplates the different variables selected during the Census and how they are influencing Innovative Payments' characteristics. This workflow is represented on Figure 4.

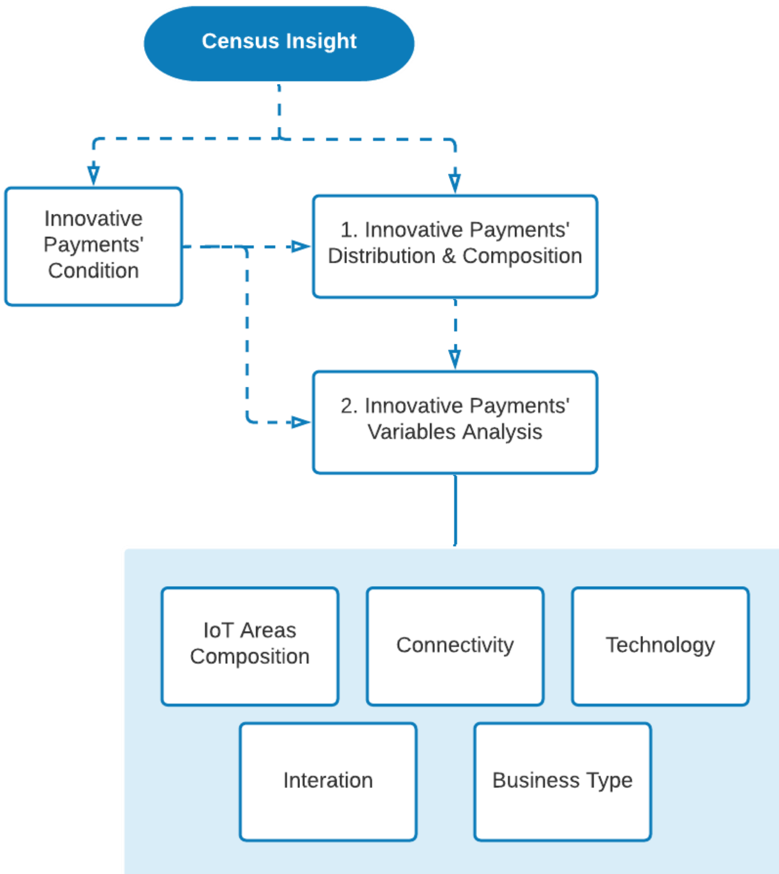

Figure 4: Workflow Empirical Analysis

The sources considered during the Empirical Analysis are:

- The Census Analysis.
- Reports and Market Analysis' which include the tendencies and descriptions of the general technology implemented, as well as those that focus precisely on the conduction of payment through such technologies.
- Websites of the products and services studied in the Census.

Empirical Analysis

The Empirical Analysis began with the presentation of the distribution and composition of Innovative Payments categories and subcategories. It was important to note the total number of products/services that were "Currently Available" (CA) as well as those including products/services "On Development" (OD). These are the basis upon which the entire analysis is made of (see Table 2).

Innovative Payments	**Indicative Distribution of Products/Services (CA)**	**Indicative Distribution of Products/Services (CA + OD)**
Wearable	60	70
Voice	21	25
Smart Objects	36	51
Device-Free	39	53
Total	156	199

Table 3: Indicative Distribution of Innovative Payments Products/Services - Source: Census

The results of the first chapter, where the distribution, composition, and condition of Innovative Payments was analyzed, indicated that:

- The Wearable Payments category was found dominant with a 38 percent over total "CA" products/services, followed by Device-Free Payments (25%), Smart Objects Payments (23%), and lastly, Voice Payments (14%). Although its dominance is expected to decrease as the development for Smart Objects Payments and Device-Free Payments begins to rise.
- Passive Wearables were found to be the dominant subcategory which could be attributed to advancements in NFC technology. Even though new and strange wearables are being developed (such as smart nails (Phillips, 2020)), Active Wearables seem to be taking the lead in the future, as more wearables which use AI instead of NFC to conduct payments rise.
- Biometrics predominated over Invisible Payments by more than three times its size. It was also noted that there where new biometrics being developed, which would allow for a greater diversification of the payment technology.
- Smart Homes Payments are currently dominating Smart Objects Payments with a 53 percent overt total "CA" products/services. Although this category has not shown any development product/service, while Smart Car Payments and Smart Objects PoS Payments have seen almost 40 and 75 percent of developing products, respectively. This would redefine the composition by allowing Smart Car Payments take the lead.
- Voice Payments is the most subdivided category, and it is only expected to increase its number of payment-enabled products. Two new subcategories, Ring and Glasses, will be developed, expanding the reach of this type of payments. It was found that Mobile occupies the greatest part of the composition with 38 percent over the total number of products/services.

On the second chapter, each of the selected variables were analyzed by first introducing Innovative Payments as a whole and then going in deeper within its categories. The most prominent results found were:

- The Wearable IoT area is the one presenting the greater number of payment-enabled products/services while being closely followed by the Smart Retail area, which is mostly integrated by Device-Free products/services.
- The incorporation of Voice Payments within the Wearables IoT Area provides an extensive reach of its areas of application. This may produce greater interaction among smart products which might ultimately create more payment-related opportunities.
- The Smart City Area was composed by a combination of every Innovative Payment category, although it is mostly integrated by Wearables and Device-Free Payments.
- The IoT areas respecting Smart Car and Smart Home are both composed by Smart Objects Payments and Voice Payments. When adding "OD" products/services it was noted that the Smart Home IoT area remain static, which leads to believe that service providers are focusing elsewhere to build payment-enabled products.
- The connectivity type that predominated for every IoT Payment category was Unlicensed.
- Both Voice Payments and Smart Objects Payments were seen to heavily incorporate Cellular connectivity. More specifically, smart cars shown a greater incorporation of Cellular connectivity over Unlicensed. This implies that there is saving potential within the product, as Cellular connectivity was found to be the most expensive among the available choices.
- The Smart Car Payments subcategory was the only one that implemented LPWA connections, which was defined as the predominated connection for IoT networks (Yang, et al., 2017) for its aggregated value.
- On the categories Wearable Payments, Device-Free Payments and Voice Payments, their respective technologies (NFC, Biometrics, AI) predominated.
- Wearable Payments are expanding their choice of technology, including RFID and AI rather than NFC.
- Invisible payments offer both RFID and AI technologies to perform the payment action. When looking at "OD" products/services, we notice that this relation does not remain static as there is a slightly advantage for AI technologies. This does not come as a surprise but might suggest a greater trust of AI's tracking capabilities.

- Smart Car Payments will offer an increase use of Biometrics, while a decrease of their use of RFID. This suggests a further development of infotainment services (noted as "Buy-in Vehicle" in the Smart Car's composition) over the rest of the categories. In particular, services which do not focus on parking assistance, as it has been shown that those usually integrate RFID technology.
- Fully autonomous M2M payments were only found within a small percentage of the Smart Car Payments subcategory. Although it is expected to keep growing and might be an interesting area of analysis for future work.
- The Device-Free Payments category was the only one that saw a greater portion of B2B companies than B2C. An explanation for this phenomenon could be that the know-how required to build such system is extremely specific and completely different from the one required to run it. The situation differs from other types of payments as they seem to be more object oriented, which would not require such external expertise.

Conclusions

The conclusions were presented by following the same structure as the Empirical Analysis, that is, first an introduction of the Innovative Payments categories as a whole and then, particular focus was made towards each category. The most relevant findings were:

- The categories of Wearable Payments and Device-Free Payments can be defined as product/service oriented while Smart Object Payments and Voice Payments are considered network oriented. This means that the former leverage on a single type of product or service instead of profiting of access to the whole IoT network as would the latter.
- Wearable Payments were seen to be the one of the most mature services which, in the past, had leveraged on NFC advancement to expand Passive Wearables. Now, they seem to be decreasing and giving space to the development of new smart technologies which might include AI as a technology of choice.
- Biometric payments are expanding their technology's capabilities while also incorporating new sectors to developed (bars, dinners, banks, etc.). This suggests a greater trust over such technology, which might motivate consumers experience new types of payment methods.
- The development of voice biometrics might imply the incorporation of this type of technology within Voice Payments which would be an interesting advancement to look forward.
- Smart Home payments seem to have reach a growth impediment as there is no further development being made and innovative products have been discontinued.

- Smart Objects PoS payments is developing fast and should be considered as a central point for future analysis as it might provide unprecedent connections between objects and retailers.
- Smart Car payments did not only see one of the largest growths, but it was also the only category that incorporated fully autonomous M2M payments. It was found to be the only smart product besides wearables or smartphones that could perform such kind of payments because of the required access to a digital wallet, although it is not disregarded that virtual assistants may, in the future, have a limited access to a wallet and therefore, be able to perform such type of payments.
- Even though LPWA was noted on the Literature as the connectivity of preference by IoT systems, it has been shown that it is the least type of connection selected. This is an interesting finding that suggest Innovative Payments still have further improvements available.

The presented findings enhanced the current understanding of how Innovative Payments work, while providing an insight on what to expect for their development in the near future. Although, we must consider the main limitations of this work. First, the available information for Innovative Payments is scarce. The lack of data relating the use of smart products to conduct payments makes it difficult to dissociate the payment service from the product on itself. Once more data is available it would be possible to expand the on given information, particularly that related with fully autonomous M2M payments, voice recognition biometrics used through virtual assistants or Smart Objects PoS payments. All previous aspects could provide interesting insights for relations in between different Innovative Payments categories. Second, most of the smart products that have been analyzed had only been implemented in small areas and are still in need of testing around different environments. Both mentioned remarks are valid reasons to consider that the same category of innovative payment could developed differently either by technology or connections, depending on the area it is implemented. Third, the products/services analyzed could not be tested because of the presence of extensive entry barriers (either for availability or the requirement to purchase the object). The testing of such innovative services could provide insights on user experience which would be much more determinant for their future development than those gathered by technical characteristics. Finally, in spite most products/services are relatively new (where the articles that mentioned them were from 2018 forward), some of those that were incorporate in the analysis were mentioned in articles that dated as back as 2014. Although this does not invalidate the analysis done, a more accurate description of current smart products' payment related characteristics could be provided by conducting a future search which restricts the incorporation of products that have been released after a certain period.

1. Context Analysis & Literature

1.1 Premise

The chapter initiates with the "Historical Evolution of Payments" which analysis the transition of the oldest form of payment up to its most innovative form currently available in modern society. During such transition, particular characteristics that ultimately define a payment system are noticed and described.

After introducing the digital era and the effects that Covid-19 is imposing towards the advancement of payment systems, the chapter "Internet of Things" is presented. It is dedicated to the understanding of the enabling technology through which such innovative forms of payment will take place.

To associate the presented technology with the restrictions imposed by payment systems the chapter "Internet of Value" is introduced. On it, the intricacies regarding digital ID and payment regulations affecting such systems are described.

Finally, the most innovative forms of payments are presented. Each category is described in full through definition and means to conduct the payment process. At the end of each description the current market trends are presented in order to give a sense of orientation towards future development.

1.2 Historical Evolution of Payments

1.2.1 The Beginning of Payments

For the satisfaction of the simplest to the most robust of needs, there is probably a point along the line where an exchange of goods is made carrying with it the action of payment. This not only allowed for the integration of payments systems into our daily life, but for the need of them to be conducted on such a way that even a two-year-old could perform the action. It is because of this integration that the intricate methods of payment seem to appear simple. But, despite this conception, payment systems are fundamental to the functioning of all monetary economies and therefore should not be disregarded as a trivial matter. "If money is the lifeblood of modern monetary economies, payment systems are the circulation system. Failures in this circulation system risk a seizing up in the real and financial transactions they support, with potentially significant welfare costs" (Millard, et al., 2007, p. 2).

To begin to understand this seemingly simple process on its modern form, we should review its historical evolution alongside with the needs it was looking to fulfil. It is only by the proper comprehension of those needs that we will manage to define a roadmap for the evolution of payments.

An adequate place to start analyzing a concept is on its definition. According to the Collins Concise English Dictionary (2020), one of the definitions of the word 'payment' is "The act of paying". This seems to be the most general yet accurate description to begin this analysis, as any other definition holds within the word 'money' which would exclude the first ever method of payment, bartering. To barter is "to trade (goods, services, etc.) in exchange for other goods, services, etc., rather than money" (Collins Concise English Dictionary, 2020), and like every initial method it had noticeable constrains. "In practice, it rarely occurs that two agents each want each other's good, still less that they have the correct quantities of each good available to be able to agree on the terms of their trade, and then still less that these coincidences materialize at the exact time that both sides of the bargain desire the goods" (Boel, 2019, p. 52). On her paper, the author continues to explain how the value of money arrives from the easing of the conditions impose to conduct a barter, as it is no longer require for both agents to exchange goods or services directly. One of the agents could simply supply the other with the respected value he/she considers its good or service to be worth. Therefore, the first evolution of the payments system is conducted to reduce the constrains impose to perform a transaction or, in shorter terms, to facilitate transactions occurrence.

The regular conduction of trades acted as a catalyst for the society on which they were implemented. With an increasing number of transactions as well as higher value in transacted products, stronger markets came to develop, which directly impacted on its community´s growth. This expansion generated the opportunity for a financial entity to emerge, and so, banks came into existence. With the arrival of banks payment methods continue their development. They were not only able to internalize and reduce transaction costs, but most importantly, allowed for account-based payment methods with transfers across different accounts. Boel (2019, p. 53) states three forms upon which banks contributed to cost reduction: the innovation of multilateral settlement reducing the quantity of settlement asset needed by participants to meet their net obligations; the adoption of the clearing-house blue-print outside the capital cities (applied for note-based systems[1]); the implementation of assets convertible into specie[2] which all banks were willing to accept (also contributing to a decrease of transportation costs).

When taking into consideration the final aspect introduced by Boel as well as the vulnerability to theft that large amounts of assets (precious metals or other commodities) were subjected to when being transported, is not difficult to understand why the next step on the evolution of payments was the

[1] A note base system was such where the banks would issue notes against the current commodity (specie) used for payment.

[2] Specie is metallic money in all its forms (gold or silver traditionally).

development of currency in the form of fiat money. This advancement allowed growing communities to comply with two new needs: security and scalability.

Payment methods are required to evolve increasing its transactable amount in accordance with economic activity growth. As society continued its economic expansion, even cash became limited on its physical form. A new kind of monetary structure was needed, and with it came a whole new type of payment methods.

1.2.2 From Cash to Digital

According to Humphrey (1995, pp. 6-7), "[electronic payments] take the form of automatic deposit of payroll, Social Security, or retirement benefits directly into a checking account at a bank. For recurring monthly payments, it is also sometimes possible to have a checking account debited electronically for the monthly amount involved. (…) However, the really important aspect of electronic payments concerns the networks that are used to transfer very large sums of money each day—the wire transfer networks". In this short paragraph Humphrey provided a description respecting the beginning of e-payments as well as its main benefit, networking scalability. An important distinction needs to be made upon this evolutionary step. Although it may appear similar to the feature mentioned on the formation of fiat money, the interconnectable factor provided by the creation of a digital network should be regarded as one of the greatest advancements on the payment industry. It is only thanks to this network that:

- We are now capable of conducting purchases from vendors across the world while on the comfort of our homes.
- Machines can interact with one-another enabling the development of revolutionary payment instruments.

But before continuing with the technological advancements provided by the digital insertion, it is imperative to mention that cash is not yet gone. Even though the world is rapidly transitioning towards digital means, it still has a long road ahead before cash becomes completely outdated. Professors Callado Muñoz and Utrero González (2004, p. 173) conducted an analysis on the changing trends in payment systems considering European countries, specializing on new member states during the years 1996-2003 that compares the use of non-cash electronic transactions as a percentage of total volume non-cash transactions and cash as a percentage of narrow money (see Figure 5). On their words: "The analysis illustrates that the usage of cash in accession countries has fallen, although it continues to have an important role in the functioning of these economies".

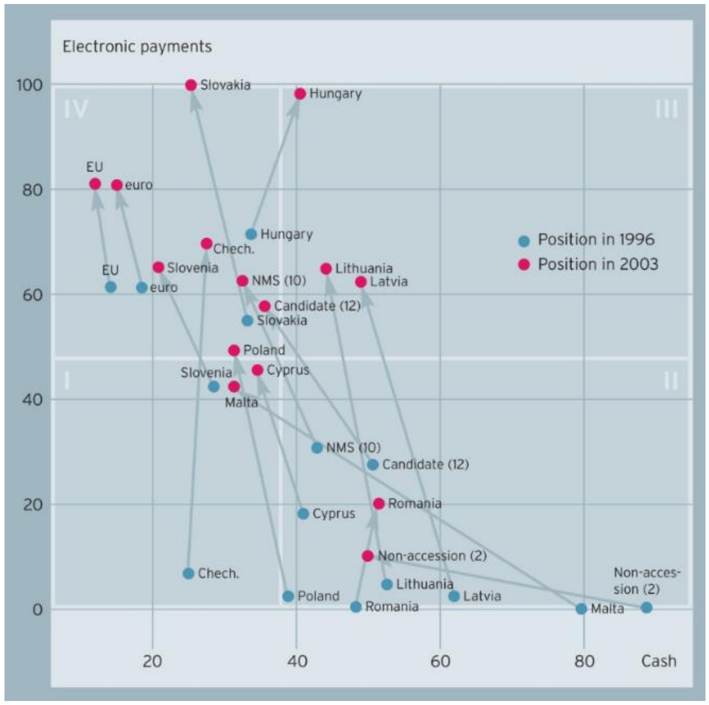

Figure 5: Non-cash electronic transactions as a percentage of total volume non-cash transactions, and cash as a percentage of narrow money: 1996-2003 – Source: EPC

On a global scale the same phenomenon can be observed for retail, through the years 2012-2020(F[3]), on Figure 6[4]. In 2012 digital retail sales spend accounted for a 9%, where in 2020 it is foreseen to be 24% (a 15% increase), while traditional means (cash) are expected to decrease its use by the same amount. (Niederkorn, et al., 2016, pp. 33-34). This allows us to think that the ongoing trend, started at the very least in 1996, its still far from over.

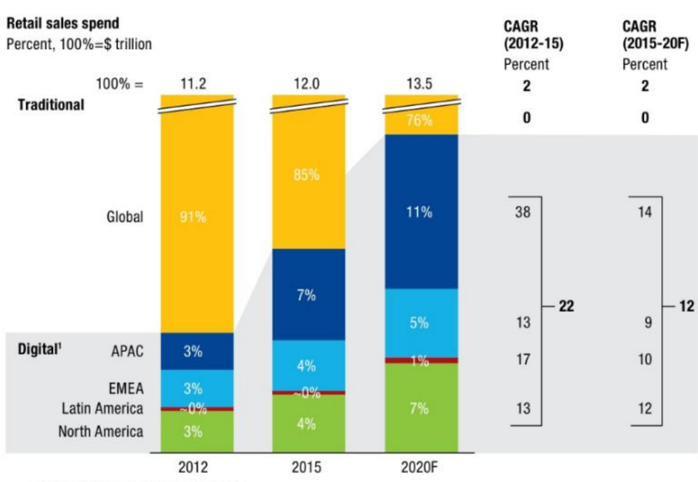

Figure 6: Global Retail Spend, Digital Vs Traditional - Source: McKinsey Global Payments Map

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[3] F: Forecast

[4] Where APAC refers to Asia Pacific and EMEA refers to Europe, the Middle East and Africa.

At this point it has become evident that consumers do not adapt instantly to a newly introduced payment system, as it often takes time before its use becomes widespread. One explanation for this delay are network effects, but learning cost, lack of familiarity and the need to invest in software, Point of Sale (POS) devices and training are also contributing factors (Berger, Hancock and Marquardt, 1996; Farrel and Klemperer, 2003, cited in Cruijsen, Plooij, 2015). Furthermore, it not only takes time for the improvements on electronic payment systems to be incorporated by society, but each society adapts differently towards these improvements. On their paper, Cruijsen and Plooij (2015) mentioned how the importance of regional variables, such as consumer's perceptions on payment instruments characteristics (transaction speed, cost, safety, and user-friendliness) as well as socio-demographic factors, has increased along with the complexity of the instruments and are fundamental when considering how to influence payment behavior. Hayden (2014) establishes a roadmap for transforming a payment system infrastructure which begins with the identification of use cases that will benefit from an enhanced payments system, the selection of critical end-user features and functionalities. This leads us to believe that there will not be two different locations adopting the same electronic payment system, and even if there where, it would not take their users the same time to fully adopt it. Figure 7 is a clear reflection of this statement, as it shows the diverse selection of payment instruments according to a specific region.

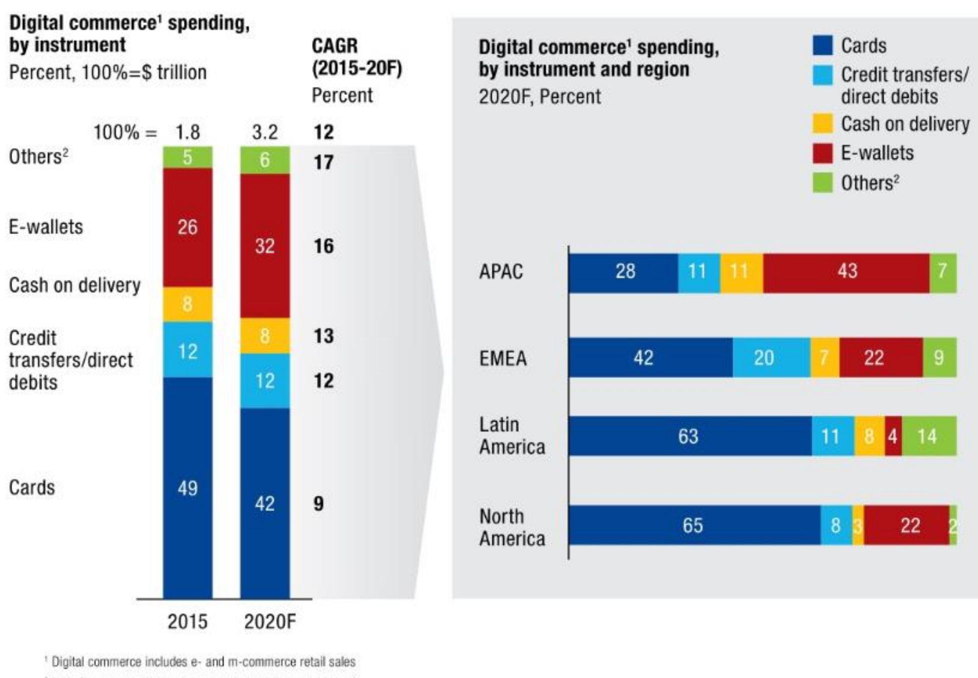


Figure 7: Digital Commerce Spending by Instrument and Region - Source: McKinsey Global Payments Map

Even though the adoption of electronic payments systems may seem stretch in time, it should be noted that it is far less than the extended period it took for the bartering system to evolve into currency. As Niederkorn et al (2016, p. 35) stated, “digital payment behaviors are not only diverse and often locally defined-they also evolve far more rapidly than traditional-and ingrained-payments”. The evolution of this new forms of payment will depend upon each region’s socio-demographic factors, as well as user’s perception towards new payment instruments. With these in mind is that we move on to analyze the effects and alterations that the recent pandemic have brought upon us, and what this means towards the development of payment instruments.

1.2.3 COVID-19 Acceleration

The COVID-19 crisis has shown the criticality of the payment systems upon each country’s economy. As most of the world initiated its lockdown to smooth the curve and pass the pandemic without collapsing its health system, only essential resources such as food and remedies were obtained in person, every other “not critical” need would be cover only if the retailer had its digital establishment up and running. For the payment’s industry this meant that an acceleration of the previously mentioned trends would be required to sustain global economy. As Johnson 2020 (cited in P20, 2020, p.6) stated, “the move from cash to card to electronic transactions was already happening, but I think that convergence will progress much faster now.”

Even when considering extreme measures to provide a sense of security, the use of cash is still falling at an accelerated pace. Bruno et al (2020, p. 2) from McKinsey & Company states, “despite attempts to sterilize cash (using ultraviolet rays, ozone, or heat treatments, for example), the use of cash and other paper payment methods is declining. (…) Cash withdrawals at ATMs are down dramatically-by more than 50 percent-in many European countries”. This process can clearly be seen on Figure 8, which represents the fall of volume for ATM weekly transactions on the United Kingdom. Furthermore, Richards 2020 (cited in P20, 2020, p.3), Head of Market Development at NatWest said: “(…) we saw cash machine withdrawals decrease by over 70 percent and cheque usage almost halve. At the other end of the scale, online and mobile activations and ecommerce transactions have increased”.

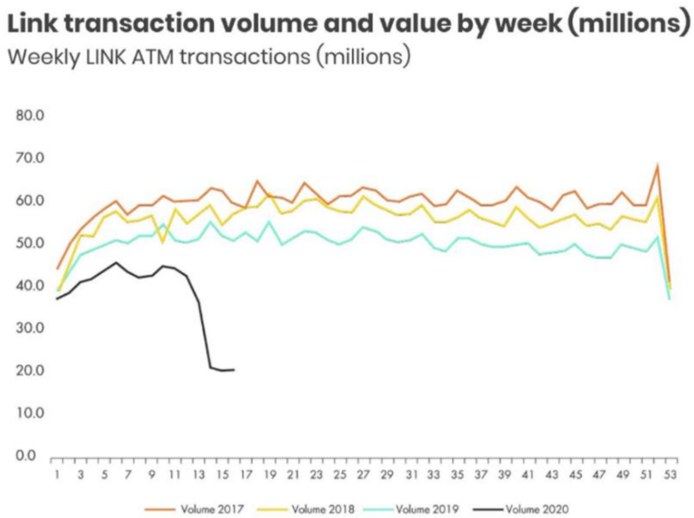


Figure 8: Weekly LINK ATM transactions – Source: Link, 11:FS

Probably the greatest shift of all has been conducted over retail shoppers. A study conducted by PYMNTS.com on which 2437 US consumers were interviewed, found out that 48 percent of all retail shoppers, 19 percent of grocery shoppers, and 15 percent of restaurant goers have shifted their preferences and now perform those activities through online means (see Figure 9) (PYMNTS.com, 2020). It is not only the change on itself that should be taken into consideration but the intention of consumers to keep increasing their online activities even after the pandemic ends. The same study identified that “49 percent of retail shoppers say they are shopping online more often now than they did before the pandemic and plan to continue these habits” (PYMNTS.com, 2020, p. 8). The same applies for 43 percent of grocery shoppers and 36 percent of restaurant customers who are ordering takeout online (see Figure 10).

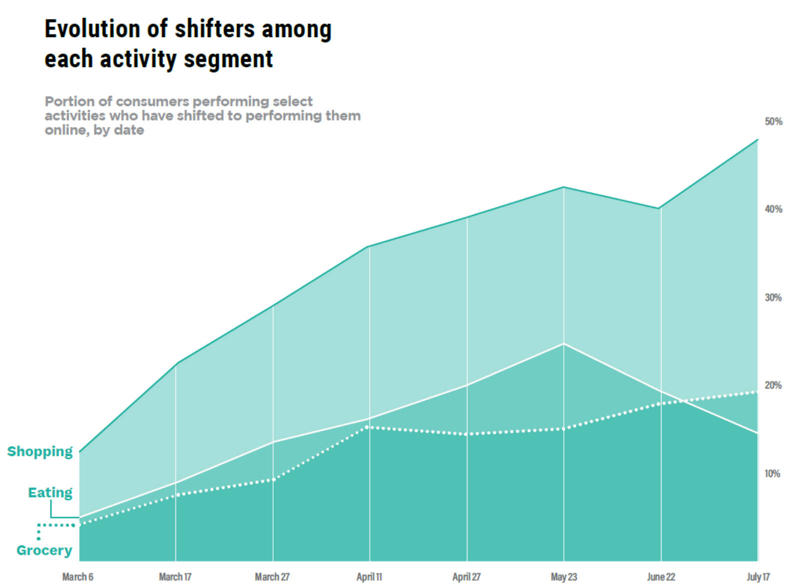


Figure 9: Shifting Consumers Activities - Source: PYMNTS.com

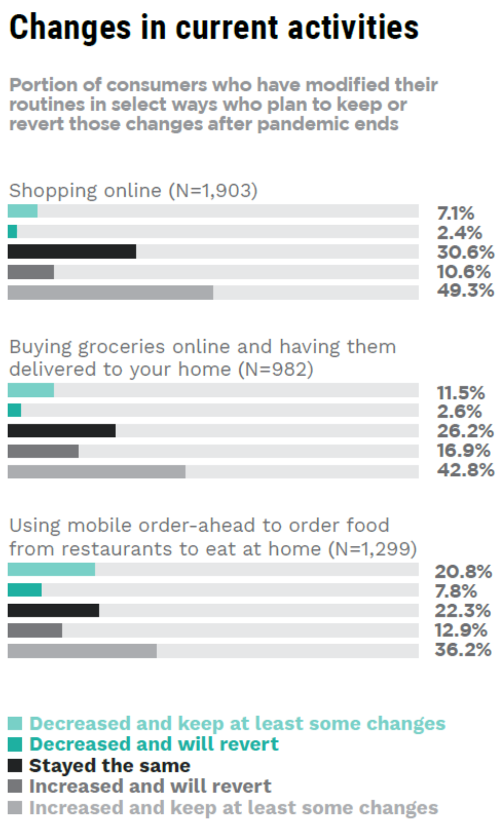


Figure 10: Change in Payment Options After the Pandemic Ends - Source: PYMNTS.com

Although it seems that a radical change is being made towards e-commerce, not all is lost for physical retailers. Contactless payments seem to be on the raise, enabling their businesses to keep operating in a "regular" way. Bruno et al (2020, p. 2) states, "[contactless payments] are rising strongly despite the overall contradiction, as the perceived hygienic security is higher than it is for normal POS payment". A study conducted by Mastercard on consumer behaviors in 19 countries around the world showed how contactless payments experience an extraordinary growth due to health concerns with the handling of cash. "As consumers increasingly seek out ways to quickly get in and out of stores without touching terminals, Mastercard data reveals over 40 percent growth in contactless transactions globally in the first quarters of 2020. Further, 80 percent of contactless transactions are under US$25, a range that is typically dominated by cash" (Mastercard, 2020). Another study conducted by Wakefield Research (2020) on behalf of Visa, over 8 diverse markets, 4500 consumers and 2000 small and micro businesses (SMBs) found that; "Nearly half [of the consumers interviewed] (48%) would not shop at a store that only offers payment methods that required contact with a cashier or shared machine like a card reader." The same study also states that; "one-third (33%) of small businesses report they have accepted less or stopped accepting cash since COVID-19." (Wakefield Research, 2020) This analysis not only means that consumers are changing their payment's preferences, but merchants are responding towards those preferences and redefining their payment acceptance capabilities.

Even with all the increments on usage of innovative technologies, the entire payments industry will still suffer from a global contraction because of the pandemic. Bruno et al (2020, pp. 2-5) states, "we expected revenue growth in global payments to turn negative. Instead of growing by 6 percent, as projected by our 2019 global payments report, activity could drop as much as 8 to 10 percent of total revenues, or a reduction of US$165 billion to US$210 billion-comparable to the 10 to 11 percent revenue reduction in the wake of the global financial crisis in 2008-09" (see Figure 11). However, in accordance to previously given facts, they also found a "triple-digit growth in nontravel e-commerce, remote ordering and low-value contactless payments."

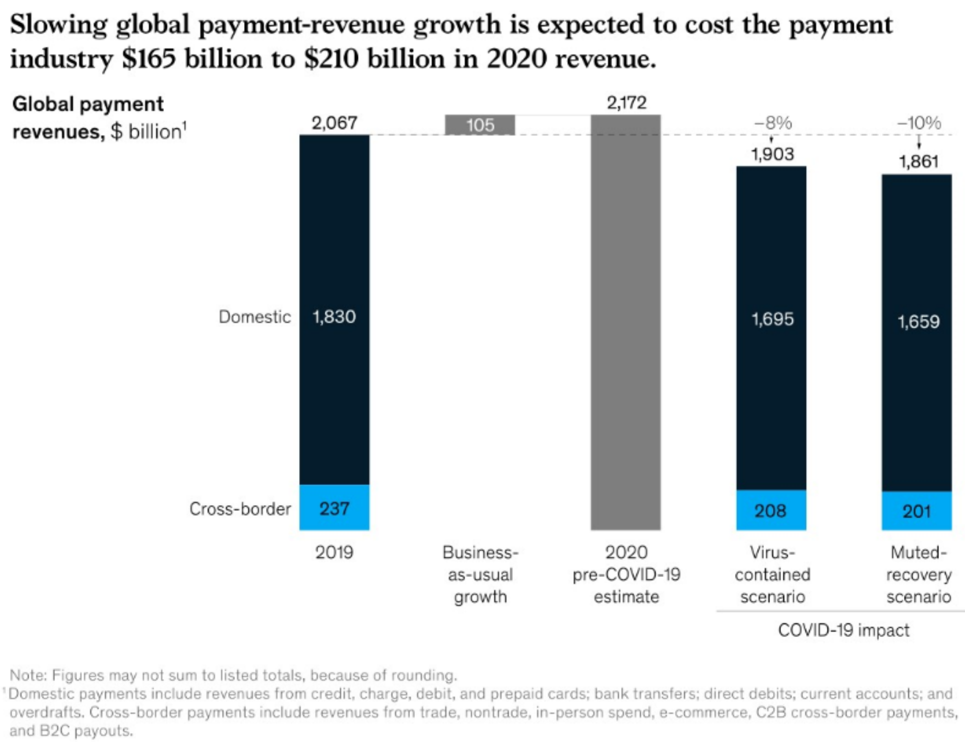


Figure 11: Slowing global payment-revenue growth – Source: Eurostat; Federal Reserve Board; Worldometer; Global Payments Map, Panorama by McKinsey, McKinsey analysis.

The fear arising from becoming infected after touching any type of surface has accelerated the already existing transformation from cash to digital, but it has also propelled the evolution of a new form of payment instruments, those incorporating Internet of Things technologies. These innovative solutions incorporate e-commerce alternatives as well as contactless technologies, benefiting in full of every aspect previously mentioned during the chapter. As Sandys 2020 (cited in P20, 2020, p.3) puts it, "in order to respond effectively, the industry has been forced to fly the airplane while building it. This ability to innovate in the midst of a global public health crisis that has thrown up unprecedent economic and practical hurdles must be celebrated". But it was only because of the advancements of new networking technology that these innovative instruments manage to generate an adequate response at a time in need. Nakajima (2012) attributes the remarkable evolutions made on payment systems to the development of Information Technology (IT). In his own words, "the progress of IT has enabled the advancement of payment processing and created some enhanced payment systems" (Nakajima, 2012, p. 8)

Therefore, before analyzing these new forms of payment instruments it is important to better understand the technologies that enabled them, its adoption throughout the world and its capabilities as well as its limits.

1.3 Internet of Things

"The Internet of Things (IoT) represents the future of computing and communications. It is a world of information and communication technologies (ICTs) from anytime, anyplace connectivity for anyone; we will now have connectivity for anything" (Bhagyashri, et al., 2013, p. 24). Basically, it represents an ecosystem of interconnectivity between Machine-to-Person (M2P), or most importantly, Machine-to-Machine (M2M). It differentiates itself from any previous known system as it not only allows for communication among diverse physical environments but for the adaptation or response of machines through the consideration of real-time outside information. Bhagyashri, Manikanta and Suresh (2013, p. 25) confirm this by defining M2M interaction as a set of two mechanisms, Sense and Act. Through Sense, a machine is able to obtain raw data from various things involved in the infrastructure while drawing useful information using its perception and interference. This capability is enabled by several communication networks such as the internet, Near-Field-Communication[5] (NFC) and Radio-Frequency Identification[6] (RFID), microprocessors, or sensors. Once the machine is knowledgeable, it can perform the Act mechanism, which involves an adequate response for the situation at hand. By considering an environment of not one, but several of these smart interconnected objects, is that we realize the true potential of this technology.

[5] NFC is a "contactless protocol for mobile devices specified by the NFC Forum for multi-market usage" (European Payments Council, 2019, p. 11).
[6] RFID is a "technology that uses tiny computer chips to track items such as consumer commodities at a distance" (Collins Concise English Dictionary, 2020).

A scheme of the integration between IoT devices, the Cloud or Enterprise System and outside world is shown on Figure 12. This representation takes into consideration that small size IoT devices can act as sensor nodes to detect or perceive different phenomena and transmit such observed data to the centralized systems. (Pasalic, et al., 2016, p. 486)

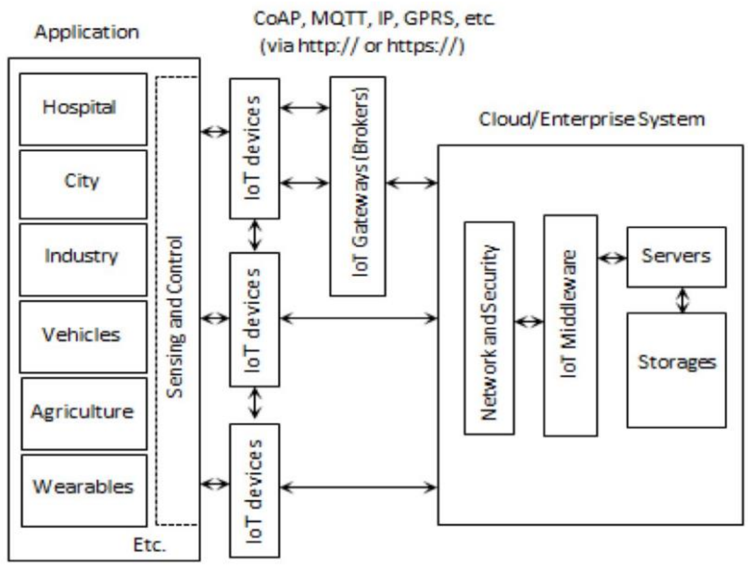


Figure 12: IoT Principal Architecture

The adoption of IoT will leverage on the same principles mentioned for the evolution of payment systems evidencing the strong relationship among these two concepts and allowing for a clearer understanding on the development of innovative payment instruments. Therefore, for machines to be able to harness the full potential of this network, numerous conditions need to be fulfilled:

- A high diffusion of smart technologies.
- Higher data speed with greater signal coverage.
- Lower cost and extended battery life allowing for continuous monitoring.
- A higher level of cybersecurity protection.
- An increasing sentiment of trust from people towards machines.

1.3.1 Network Scalability

The first step for the IoT interface to be operational is the diffusion of connected devices. This will allow for network scalability which increases the variety of data gathering and active responses available from machines. An article conducted by Patel et al (2018, p. 15) states, "consumers are more connected than ever, owning an average of four IoT devices that communicate with the cloud. Globally, an estimated 127 new devices connect to the internet every second." Additionally, Strategy Analytics (2019) found 22 billion

IoT connected devices in use around the world while forecasting a growth of 44 percent by the year 2030, which would account for a total of 50 billion connected devices (see Figure 13).

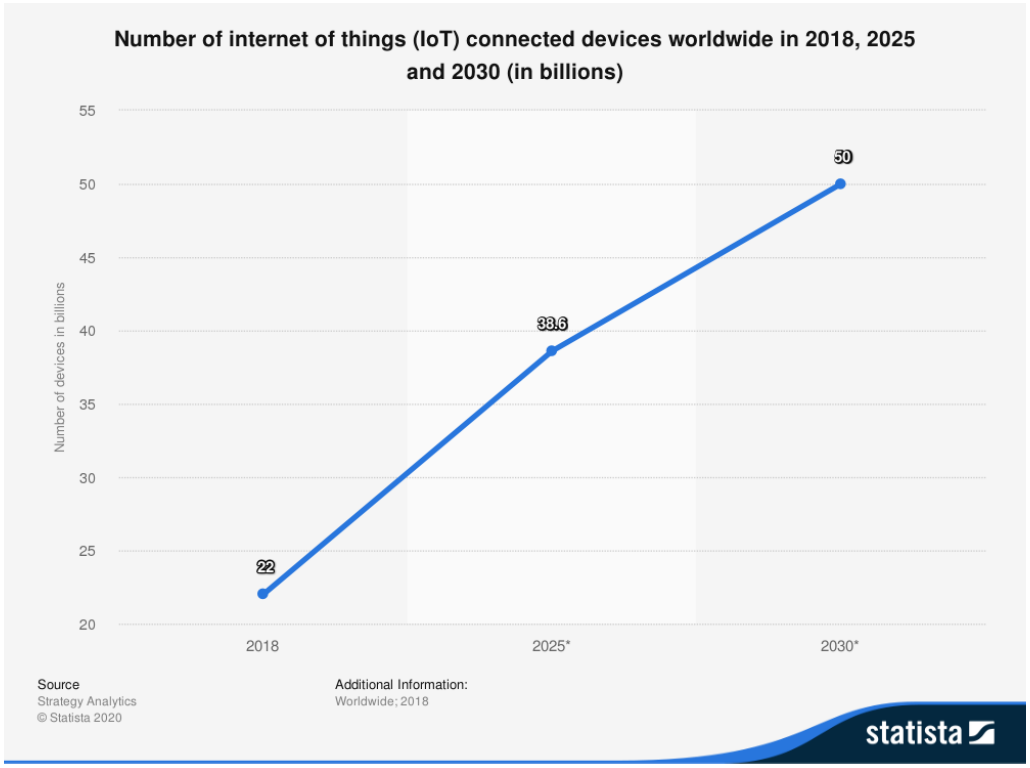


Figure 13: Number of IoT Connected Devices Worldwide - Source: Strategy Analytics 2019

The same tendency can be found when analyzing the increase on financing for startups operating with this technology. A research conducted by the Observatory of Digital Innovation (2019) from Politecnico di Milano considered the financing given to 540 startups, identifying a growth trend both of total funding and average funding (see Figure 14[7]).

[7] It should be clarified that the value recorded for 2018 considered only 7 months of the year (until the end of July). Therefore, it was expected the total value of 2018 to be 50 percent greater than the one recorded for 2017.

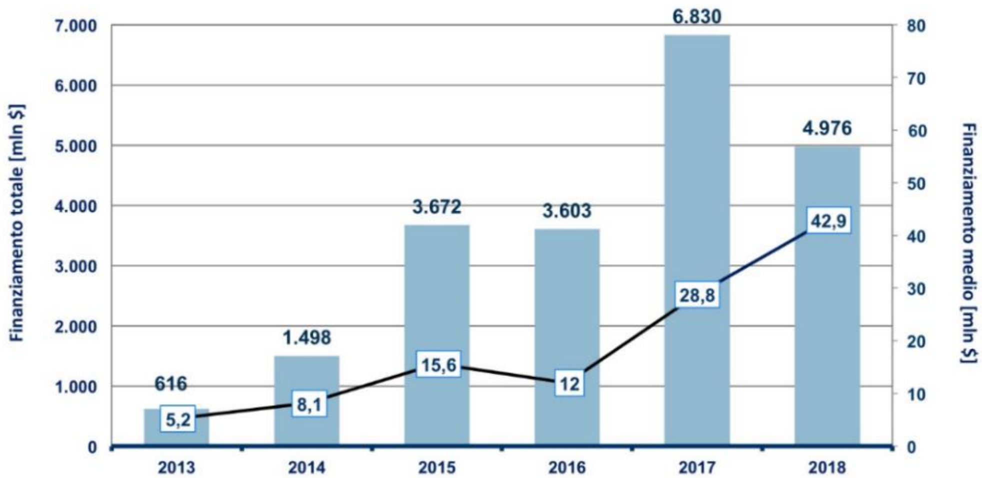


Figure 14: Average and Total Financing Distribution per Year - Source: Observatory of Digital Innovation

Every fact given has established the continuous growth of this technology for years to come. For the payment system, this means a greater capacity to reach diverse markets through more than a single payment instrument in an instant form. We could begin to forget of reaching a retailer through its web page. Even more so reaching him/her in person on a physical store. As this system evolves, so do our possibilities of conducting payments through different objects, being those objects anything from smart-cars and smart-phones to smart-fridges or smart-speakers. As long as it is connected to the network it will be capable of performing the action of payment, which in some cases (as we will later see) might not even require our authorization.

1.3.2 Connectivity & Cost

The connectivity chosen for operation among IoT devices will determine its data speed, signal coverage and battery life, all of which will consequently influence the cost among machine's interactions. "When contemplating their options for IoT connectivity, companies must choose among solutions from four categories: unlicensed; low power, wide area (LPWA); cellular; and extraterrestrial." (Alsén, et al., 2018, p. 92) (see Figure 15). Alsén et al (2018) descrives de categories as follows:

- *Unlicensed*: Solutions not exclusively licensed to a particular company, allowing the public to access them on any IoT device that uses this technology. Examples of this connectivity type are Wi-Fi, Bluetooth, Zigbee and Z-Wave.
- *Low-Power, Wide-Area*: Solution that offers reliability as well as lower costs. Even though it hast yet to be diffused worldwide, some companies have developed proprietary LPWA technologies. Examples of proprietaries networks are Ingenu, Link Labs, LoRa, Sigfox and Weightless, while non proprietaries networks NB-IoT, LTE machine-type communications or extended-coverage GSM.

- *Cellular*: Solution associated with high reliability but also higher costs. Examples include 4G LTE and 5G technology.
- *Extraterrestrial*: Includes satellite and microwave technologies. It has the higher costs of them all, making it the less ideal connectivity type for IoT purposes.

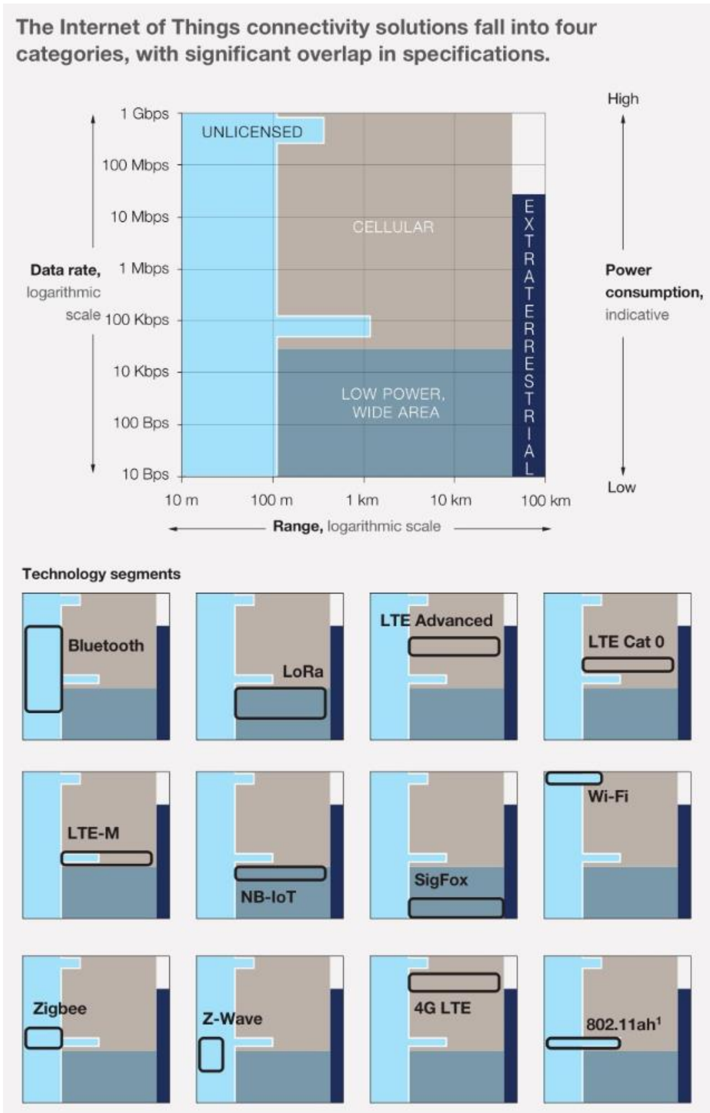


Figure 15: IoT Connectivity Solutions – Source: Alsén et al (2018)

From all the available alternatives, the one that option that predominates as an IoT network enabler is LPWA. It does not only provide an extension to battery life (which is identified by Yang et al (2017) as one of the two main limitations of IoT devices, the other being computing power), but it is also associated with the lowest costs. On 2018 only 20 percent of the global population was covered by LPWA networks, but their availability is growing rapidly. By 2022 it is expected that 100 percent of the population will have LPWA network coverage. (Patel, et al., 2018, p. 15)

There is even the development of a specialize type of LPWA, narrowband IoT or NB-IoT, for the sole purpose of enabling IoT connections. The 3rd Generation Partnership Project is an organization looking to standardize this type of networks. As it is unclear which network within the spectrum will predominate and become more popular, every platform vendor must produce IoT products compatible with every existing NB-IoT on the market. This strategy guaranties that devices can communicate although it creates additional complexity and product cost. After a clear connectivity service emerges on the market, the spread of IoT will become even faster and cheaper than ever before. (Alsén, et al., 2018, pp. 94-99)

Figure 16 serves to remark the growth of LPWA connections while also distinguishing the development of NB-IoT, as it is expected to surpass LoRa connections in 2022 by an approximately amount of 20 million. This difference shortens by 10 million on the year 2023, but still considers NB-IoT as the number one available LPWA network with 739.8 million connections (IHS, 2019).

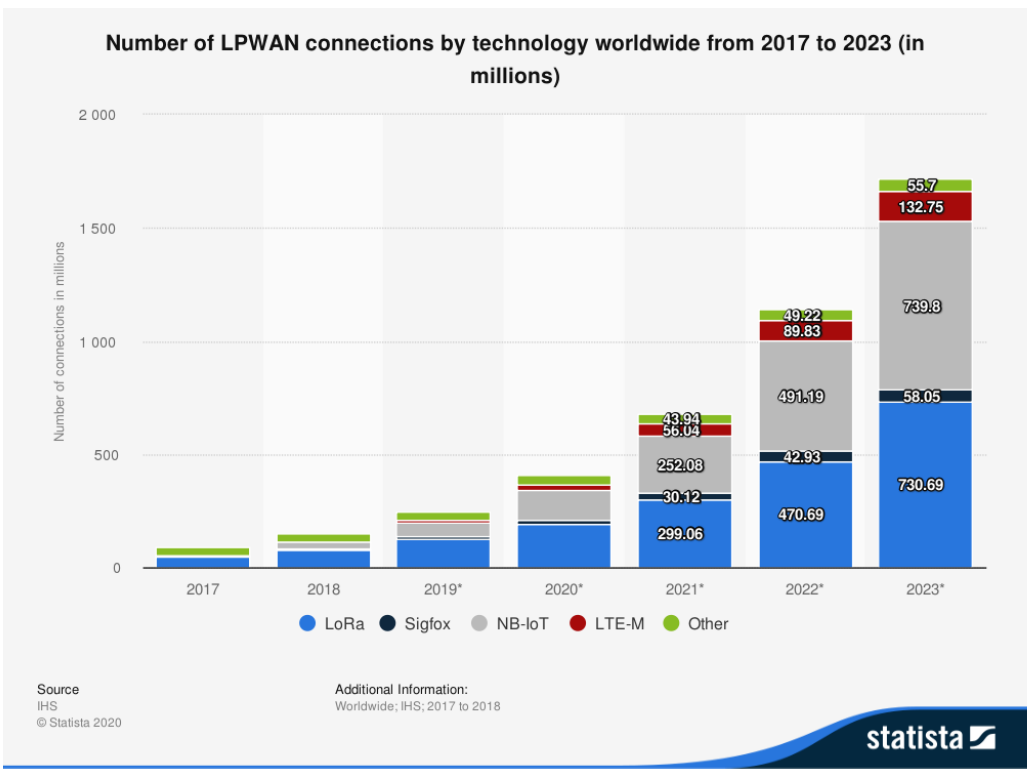


Figure 16: LPWA Network Connections - Source: IHS, Statista 2020

1.3.3 Cybersecurity & Trust

As the number of devices and available connecting networks grow, so do the sheer number of cyberattacks. A survey conducted on IoT-involved experts found that 75 percent consider IoT security either important or very important, with increasing relevance in the years to come, but only 16 percent say their company is well prepared for the challenge (Bauer, et al., 2018) (See Figure 17).

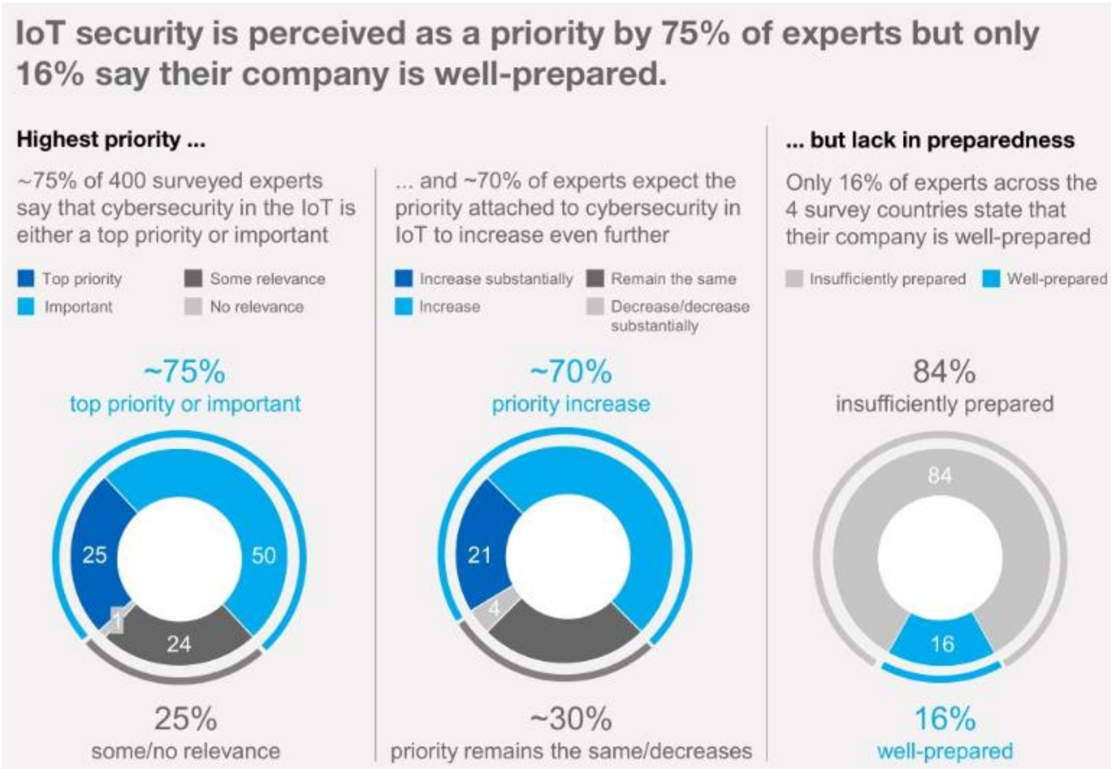


Figure 17: IoT Perceived Security – Source: McKinsey Global Expert Survey on Cybersecurity in IoT 2017

Even though this survey may arise some concerns towards IoT adoption, when analyzing the main reasons indicated for the lack in preparedness ("Lack of Prioritization", "Unclear Responsibility"[8] and "Lack of Standards and Technical Skills") we notice that these are not consistent with an enterprise operating in the industry of payments where security is clearly a main priority and there is a well define team in charge of conducting such functions. Therefore, is no farfetched to consider that payment instrument's developers are positioned under the 16 percent of "well-prepared" companies.

Despite believing that payment firms are prepared to handle cybersecurity and privacy threats, it is still relevant to consider these characteristics as they have been shown to influence electronic payment systems' use in several ways. An empirical study conducted by Kim et al (2010) found a positive relation between: the technical mechanisms utilized to ensure payment security during the transaction process on the internet; well-defined electronic payment procedures (how the payment is conducted); security statements on electronic payment websites; and perceived security as well as perceived trust. They also found that perceived security positively influences perceived trust, and that both factors have an impact on electronic payments' use. Similarly, a research conducted by PYMNTS.com (2020) found that strong

[8] In some organizations it has proven difficult to determine which unit (IT security, production, product development, customer service) should take the lead. (Bauer, et al., 2018)

data security and privacy policies where the main factors attributed by consumers for building trust with a vendor (see Figure 18). Which, according to a study conducted by McCole et al (2010), positively influences attitude towards online purchasing. These facts lead us to believe that security and privacy are not just important when regarding the payment instrument by itself, but also influence a consumer's perception of a vendor. Consequently, it would be accurate to affirm that these characteristics have a direct as well as an indirect influence on the use of electronic payment systems and should be regarded as extremely important for the implementation of new payment instruments.

Figure 18: Five Greatest Factors to Consider for Building Trust - PMNTS.com

1.3.4 Main Areas of Payment Application

Even though every machine present in the IoT system has the potential of being able to conduct payments by itself (even an industrial machine might order its own supplies when needed), there are certain areas within the IoT world which have a stronger relation when it comes to the development of payment instruments. The Observatory of Digital Innovation (2019) has identified fifteen areas of application for IoT technologies, from which five strictly relate to innovative payment solutions although more may be incorporated in the future as this technology develops. So far, the areas of interest for this thesis are:

- *Smart City*: Monitoring and management of elements in a city (such as public transportation, traffic management, parking lots) and the surrounding environment to improve their livability, sustainability, and competitiveness. The objective is to reduce the presence of cash adding seamless payment experiences.

- *Smart Home*: Solutions for the automatic and/or remote management of systems and connected objects of the home with the aim of reducing energy consumption and improving comfort, safety of the home and people inside. The possibility of conducting payments extend from utility bills to automated supply ordering or even the automated called of a manufacturer/retailer in case a smart appliance requires a maintenance checkup.
- *Smart Car*: Connection between vehicles or between them and the surrounding infrastructure for the prevention and detection of accidents, the offer of new insurance models and/or geo-referenced information on traffic. Payments take into consideration regular in-car purchases (e.g. gas, parking, drive-throughs) as well as alternatives you might have not consider before (movie or theater tickets, amazon in0car deliveries, etc.)
- *Smart Retail*: Monitoring of customer behavior within the store in order to improve the experience for the user and increase sales. Solutions that enable greater visibility into supply operations for optimize inventory management and reduce the likelihood of in-store stock-outs. A new form of retail will emerge from this functionality, unattended retail, where invisible payments will be conducted as there is no need for any physical interaction between the buyer and the seller.
- *Wearable*: Wearable objects (such as watches, glasses, clothes etc.) which, through screens and sensors, allow to the user the continuous monitoring of parameters as well as the conduction of payments by interacting with a POS terminal.

Figure 19 provides an insight on how four out of five of the previously mentioned subsystems are being developed by evidencing the amount of revenue each provides (IC Insights, 2018). As one may have thought, the fact that “Smart Retail” does not appear within the five most profitable subsystems is an indication of how new this category is.

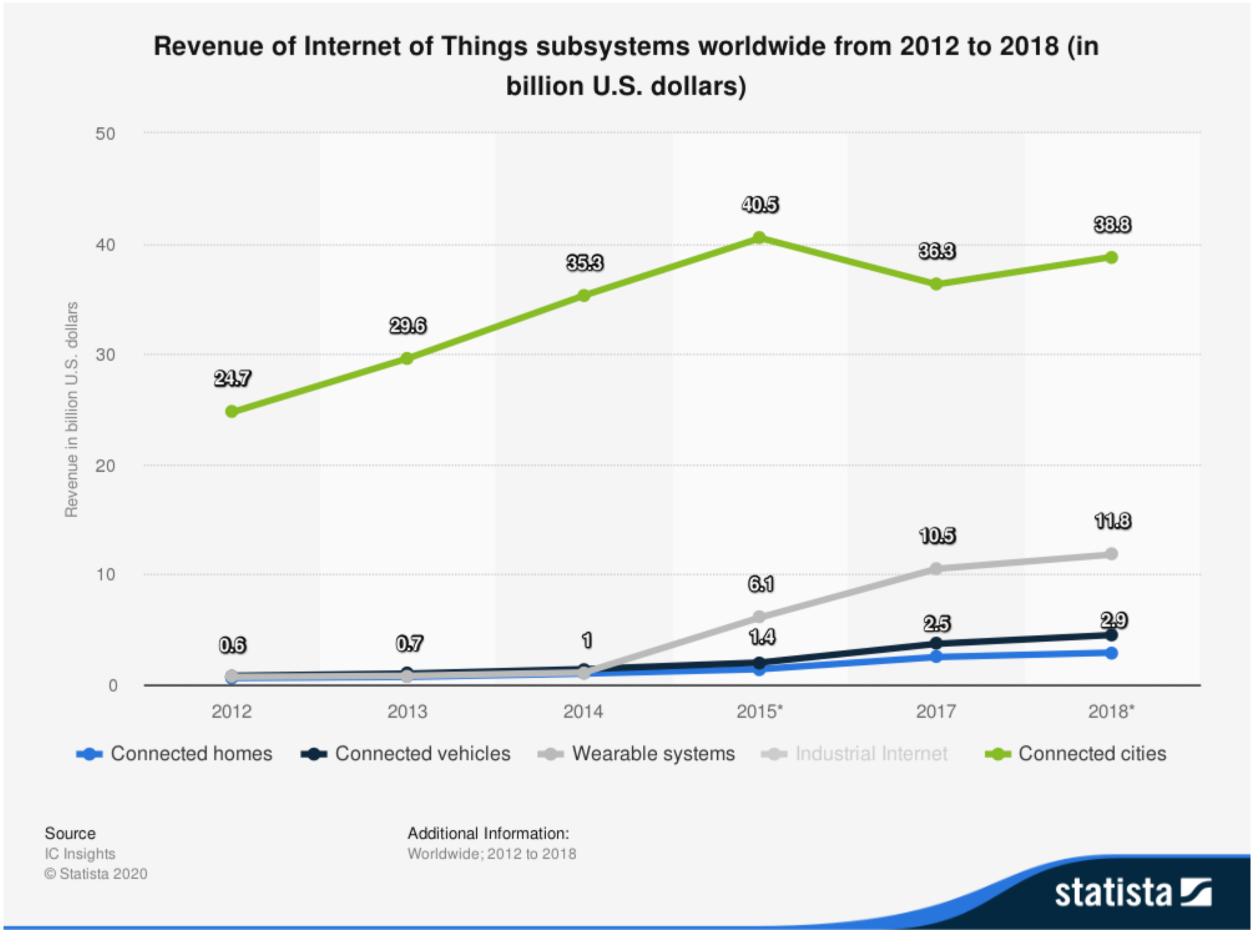


Figure 19: Revenue of IoT Subsystems - Source: IC Insights, Statista

1.4 Internet of Value

Now that we have understood the most relevant aspects concerning IoT we can finally make the transition into the Internet of Value (IoV), where the full potential of payment in IoT will developed by incorporating unique payment systems into a network which integrates national commercial banks, electronic payment systems that are developed by third party institutions, or those developed by governmental entities (Tomic & Todorovic, 2017).

Tomic and Todorovic (2017, p. 100) identified two key tasks for the designing of these integrated system: "(…) [the] creation of devices' digital identity or its integration through identity of the owner and achieving cost effectiveness of transactions including micropayments". As it has already been established how costs can be reduced through the implementation of proper connectivity settings, we will focus mainly on the first task.

1.4.1 Digital Identity & Tokenization

Along with the progress of technology and all its benefits, there also came advancements on security risks such as fraud and identity theft. As criminals increase their technological capabilities, new means of validation and protection of data are required. Digital identities are introduced not only as a measure for machines to be identified, enabling interaction among one another, but also as a secure way to comply with regulations impose for security measures.

A report conducted by Jumio and PYMNTS.com (2020) analysis how the development of digital identities through the use of biometrics is a key factor used to build trust upon sharing economy platforms. They found that 35 percent of U.S. consumers (up from 26 percent last year) have used a two-factor identification (a main requirement needed to comply with Strong Customer Authentication), while 77 percent will more likely engage in a business' services if identity verification was improved. Besides, the Boston Consulting Group (cited in Finextra Research Ltd, 2020, p. 11) predicted that the identity authentication and fraud solutions market will boom from US$12 billion in 2018 to a staggering US$28 billion in 2023. This is approximately the same value (US$27.8 billion) predicted for the face and voice biometrics market by 2027 (Jumio; PYMNTS.com, 2020). Adding both market trends to the current need presented by consumers serve to further guarantee the development of these functionalities.

In spite of the benefits and necessity of providing a digital identity service, it would prove challenging for a company operating exclusively on the technology sector to develop an identification system. As users grow more knowledgeable of how technology works, specifically how their personal data can be used and the difficulty of retrieving or deleting such data, their confidence on how these companies employ and keep their data diminishes. The Ponemon Institute (2020, pp. 2-3) release a study sponsored by ID Experts reveling that 86 percent of adults are very concerned about how Big Tech firms use their personal data, while 77 percent stated they "rarely or never have control of their personal data". In order to solve this issue, technology firms and financial institutions must not compete on identity and security, but rather work together to ensure that customers trust and use the authentication services in place. Because banks have already authenticated most of their customers, and customers trust their bank enough to allow the gathering of their personal data, the transfer of such data towards an online solution will be a far easier process than the implementation of a straight-forward digital identity service by a new organization. A survey conducted by Finextra Research Ltd (2020) found that 52 percent of consumers said that they would be more likely to complete a new account application with a bank if the entire process was online.

Even though a clear point has been made supporting the level of trust consumers have on banks as being the greatest among financial institutions, a recent survey conducted by Anan, Mahajan and Nadeau (2019, p. 6) on digital payments penetration in the US found that iOS users indicate a similar level of trust in Apple than in financial institutions, while Android users selected PayPal as the most trusted entity for financial services (see Figure 20). This does not mean that digital wallet providers are more suitable to develop digital identity services on their own, but it would be a feasible course of action for future consideration.

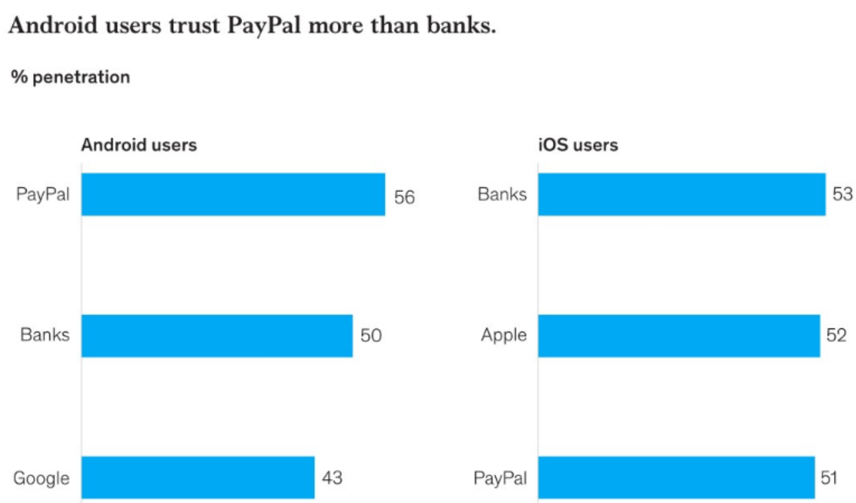


Figure 20: Penetration Shown by Mobile Users in the US - Source: McKinsey 2019 Digital Payments Survey

Now that the link between banks and future payment service providers has been established it seems logical to explain the measure of protection of sensitive data known as "tokenization", as this already established process will work directly with digital identity services allowing for the secure conduction of payments while reducing the risk of diffusion of sensitive data. Basically, it requests a Token Service Provider (TSP) to generate a token device for a specific merchant to conclude a transaction. The token device will be kept instead of the sensitive information of the client, such as credit card numbers or personal details. That token only works between that specific client and merchant combination, as a different token will be generated for a different merchant. This process improves securitization by encoding the client's sensitive information and by allowing not only each token to work with its specific merchant but also forming a different type of token depending on its intended used, as the token form for ecommerce is not the same type as those form for IoT payments. (Macmillan, 2017)

Figure 21 shows the path that takes place once a consumer tries to purchase an object through an IoT device which complies with tokenization security service. The Payment Account Number (PAN) is not used directly, instead a Token PAN is created. (Visa, 2017)

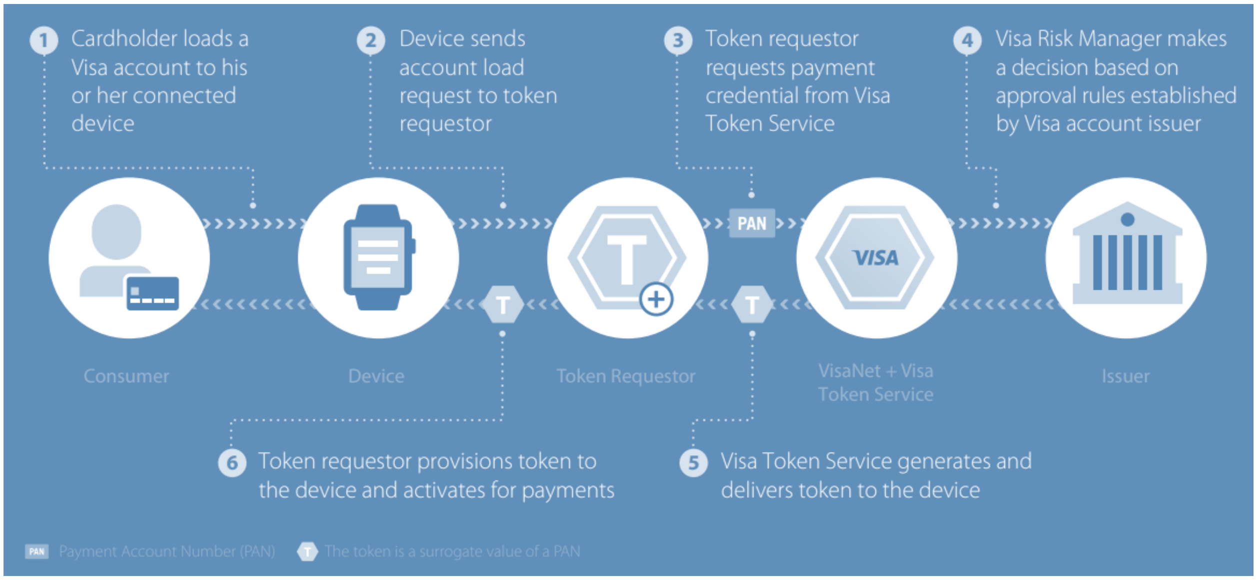


Figure 21: The Tokenization Process - Source: Visa Ready Program

Macmillan (2017, p. 7) states, “tokenization would be required to protect whatever payment credentials were used, but just as important would be the use of domain controls and probably other restrictions”. To solve the issue of domain controls we have already introduced digital identities. The combination of both concepts will enlarge the path mention on Figure 16 by adding a step previous to the consumer, where he identifies himself through his digital identity service provider, and only then the token track is able to start. This will allow for the payment instrument to be compliant with SCA directives as mentioned under the second Payment Services Directive (PSD2).

1.4.2 Regulations

After analyzing the development of digital identities and its capacity to integrate different institutions for the creation of innovative payment instruments it will be imperative to examine the new regulations which any payment service provider must comply. This is the PSD2. Finextra (2020, p. 11) defines it as “a solution for how data is securely and efficiently shared by banks with third party providers (TTPs), the regulation provides top-down consistency for each party in the value chain”. A roadmap for the implementation of this new regulation can be seen on Figure 22.

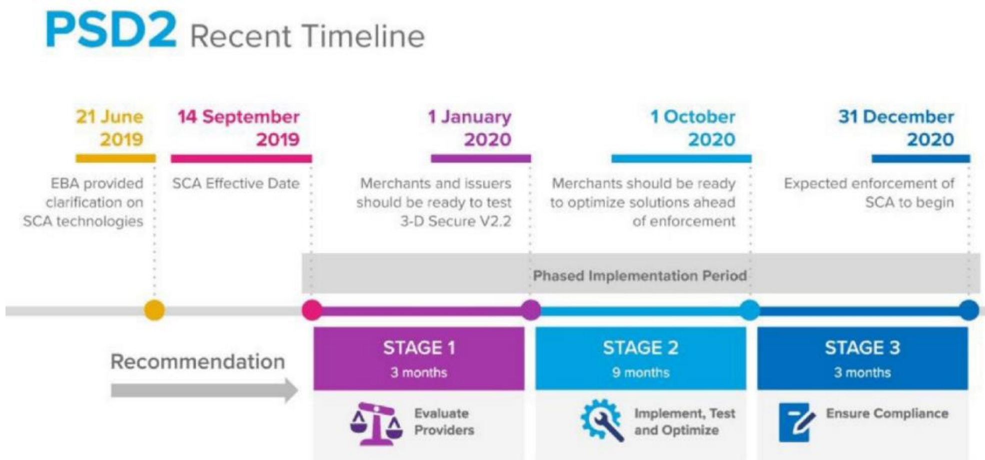


Figure 22: PSD2 Roadmap - Source: Signifyd

Being compliant with SCA means having a multi-factor authentication which is integrated by two out of three features: Possession (what we have); Knowledge (what we know); Inherence (what we are). A combination of the first plus the second or third feature is required to be considered compliant. The Possession segment takes the form of a trusted device, which has already been verified, while the Knowledge or Inherence is a form of password which needs to be remembered (such as a PIN code or swiping pattern) or a biometric code (such as fingerprint or facial recognition) (Antelop Solutions, 2019). This last segment is truly interesting, as it will be shown that new types of payment instruments are being develop specializing on this technology, which will not only enable the payment mechanism but comply with one of the two needed factors of SCA simultaneously. Finextra (2020, p. 13) states, "it is hope that SCA will engender trust for consumers when using the difital payments system with its hightened identification requirements". Trust is an essential for the adoption of new payment solutions as it influences a user's perspective which simultaneously influences its environment.

1.5 Innovative Payments

Now that we have understood the needs that payment instruments must satisfy, the technology available to do it, how they are able to conduct the action of payment and the new regulations that they are required to comply, it is finally time to introduce the most innovative solutions that satisfy such conditions. It is important to remember that these are being developed at this very moment, therefore most of the presented alternatives will not be fully operational or not widely diffused.

The Osservatorio Innovative Payments from Politecnico di Milano (2020) finds four categories within *Innovative Payments*:

- **Wearable Payment**: Those conducted through wearable objects (such as Smartwatches).

- **Mobile Payment**: Those conducted through a Smartphone.
- **Smart Object Payment**: Those conducted through different Smart Objects than the ones mentioned on the categories above (such as Smart Cars or Smart Appliances).
- **Device-free Payment**: Those that do not require a device to conduct payment. This category can be divided in two sub-categories, **Biometric Payments**, and **Invisible Payments**. While the first refers to payments conducted through the identification of the features of a certain buyer, the second enables payments through a combination of in-store sensors and digital identity of the user (such as Amazon Go stores).

In spite of being a major component of Innovative Payments, the category integrating "Mobile Payments" will not be further examined, as it is the focus of this thesis to analyze the evolution of new forms of payment which distinguish themselves from existing ones and are enabled by IoT technologies. Instead, the category of "**Voice Payments**", which integrates payments conducted through voice assistants, will be added to provide a deeper understanding of the capabilities of this technology in relation with smart objects.

An identical structure will be followed for the analysis of every instrument to allow for an easier comparison between every instrument. First, the technology that enables the instrument to conduct payments will be define, as well as its most relevant characteristics. Second, market tendencies such as users' adoption of the instrument or the instrument's market value growth will be made explicit to determine the reach of this technology in the upcoming years.

1.5.1 Wearable Payments

1.5.1.1 Definition & Characteristics

The Secure Technology Alliance Payments Council (2017, p. 6) defines a wearable device as "a small electronic device that is worn or easily carried, incorporates one or more technology-related functions, and supports contactless transactions using technology that complies with ISO/IEC 14443[9]". The most popular form of such devices are smartwatches and smart bands, but they also extend to smart glasses, smart jewelry or any other type of smart clothing equipped with sensors that tract and record the user's data (Wang, 2015; Cing & Singh, 2016, cited in Borowski-Beszta & Polasik, 2020). It is because of their capability to collect and track data that wearable devices have greatly develop on the fields of health care, medicine and fitness (McCann and Bryson, 2009, cited in Dehghani & Dangelico, 2017).

[9] The ISO/IEC 14443 composes a set of protocols that define the characteristics of proximity cards, radio frequency power, signal interface and transmission protocol.

Bezhovski 2016 (cited in Lee et al, 2020, p. 3) defines wearable payment as "the use of a smart wearable device that is attached physically to the user in buying products and services anywhere and anytime". To conduct proximity payment, wearables use NFC technology. It allows for wireless communication, enabling data transfer at an approximate distance of 10 cm (Leong, Hew, Tan & Ooi, 2013, cited in Borowski-Beszta & Polasik, 2020). It serves as an extension of a wireless ISO/IEC 1443 standard, created to unify existing standards of proximity communication, as well as to enable the intuitive, secure, and simple exchange of data between users of NFC devices (Borowski-Beszta & Polasik, 2020). Even though Smartphones have access to this functionality through NFC technologies as do wearables, on this thesis they will not be contemplated as part of the "Wearable Payments" spectrum.

Wearable Payments can be classified into two categories: Passive (includes a chip/secure element that has an operating system, payment, and ISO/IEC 1443 interface and the energy required to function is obtained from the electromagnetic field created by the POS reader, so they do not need a battery) and Active (they include the same functionalities as Passive Wearables but require battery power to function and have a much more sophisticated feature set: available memory, pre-installed software, support for external "wallet" applications compliance to a wider set of standards). This allow for Passive elements to be available for any device that can hold a tiny chip and an antenna, while Active elements require a battery and often an external controller (Fidesmo, 2017; Secure Technology Alliance Payments Council, 2017).

1.5.1.2 Market Tendencies

Now that we understand what wearables are and how they conduct the intricate action of payment it should be useful to visualize the market reach of this technology as well as its current used as a payment instrument.

A study conducted by Dehghani & Dangelico (2017) which analyses the development trends of wearable technologies through the amount of granted patents considering their forward and backward citations[10] saw a steady increase between 2006 and 2013 (from 28 to 94) with a dramatic rose that led to 575 patents in 2015. This would indicate that wearable devices development started to take off somewhere between 2014, although it does not stop there. The astonishing growth continues, as indicated by a forecast developed by Cisco Systems (2019) which shows that the number of devices has more than doubled in

[10] Forward citations are the number of citations made by subsequent patents (Hegde, Deepak and Bhaven Sampat, 2009, cited in Dehghani & Dangelico, 2017), while backward citations refer to the number of citations made to previous patents (Messeni Petruzzelli, 2011, cited in Dehghani & Dangelico, 2017).

the space of three years, increasing from 325 million in 2016 to 722 million in 2019, and forecasted to reach 1.1 billion divices by 2022 (see Figure 23). According to Deloitte (2019), revenues from wearable devices are expected to reach US$25 billion in 2020.

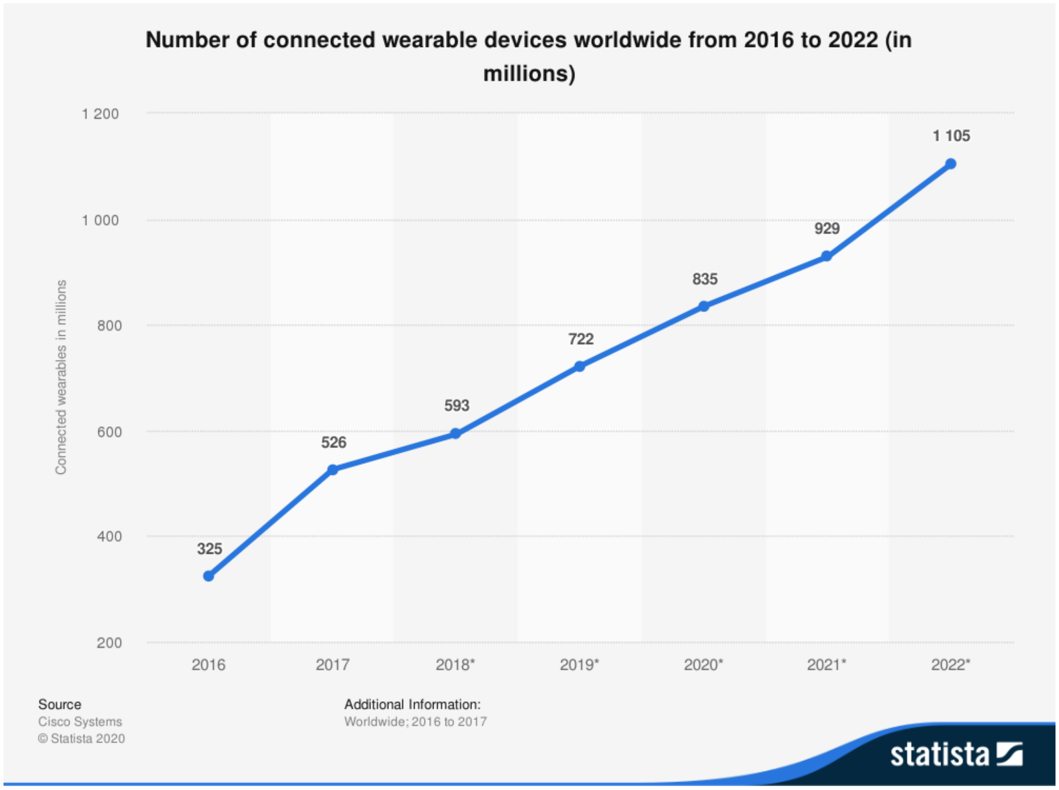


Figure 23: Number of Wearable Devices - Source: Cisco Systems, Statista 2020

Respecting payment-enabled wearables, ABI Research (2020) forecasts US$7.2 billion in global revenue from the sale of payment-enabled wearables in 2024. It describes this phenomenon to be "driven by a surge in contactless payment adoption, as a result of growing usage of contactless cards and NFC-enabled mobile payments". Furthermore, Business Intelligence 2017 (cited in Secure Technology Alliance Payments Council, 2017) estimated that 62 percent of wearable device shipments will include payments functionality by 2020. Both facts serve to indicate the importance of expanding wearables payment functionalities reaching with each year a greater proportion of total worldwide distributed wearables.

1.5.2 Voice Payments

1.5.2.1 Definition & Characteristics

Voice Assistants, also called Virtual Personal Assistants (VPA) or Intelligent Personal Assistants (IPA) are systems that utilize AI and Natural Language Processing (NLP) to "understand customers speaking in a variety of environments, access and languages" (Singh, et al., 2019, p. 1). Although they do not limit just to understanding. After recording a user's command through its embedded microphones, the IVA sends the recording to the cloud, where an NLP server interprets the recorded voices as well as embedded emotions, and produces an appropriate response (Knight, 2016, cited in Han & Yang, 2018). Is by this process that they are able to provide "professional/administrative, technical, and social assistance to human users by automating and easing many day-to-day activities" (Han & Yang, 2018, p. 619). IVAs can even leverage on the increasing technological advancements and interconnectable capabilities provided by IoT systems to be used as hub devices for smart homes. Through IVAs, residents can even control home appliances such as televisions, refrigerators, washing machines and lights.

Augusto and Nugent 2006 (cited in Yang & Lee, 2019, p. 66) go a step further and consider that; "if IVA devices learn individuals' life patterns, schedules, and tastes by using artificial intelligence algorithms such as deep learning, proactive smart home services will be realized that do not need people's intervention". But it is not enough learning what people want, how a machine complies with the desire function is just as important. A research conducted by McKinsey Quarterly confirms that consumers are satisfied when a bot gets a task done, but they are delighted when there is a more personal, emotional element to how the bot does it. This goes beyond Artificial Intelligence (AI) into the realm of artificial emotion (AE) which encompasses attribute such as tone, attitude, and gestures that communicate feelings and build an emotional connection (Coumau, et al., 2018, p. 75).

Every aspect mentioned provides an insight on the functionalities currently available for IVAs as well as their future direction of development. A visual representation of IVAs capabilities is shown on Figure 24.

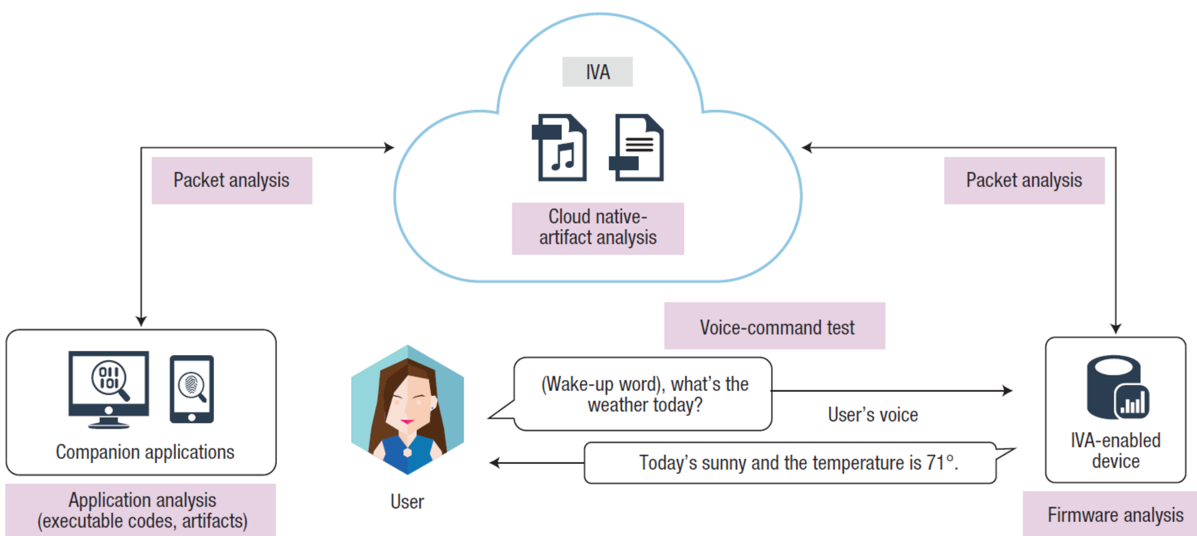


Figure 24: IVA Interaction Process - Source: (Chung, et al., 2017)

As it has been established, IVAs can be used to interact with multiple devices, but they can also be integrated into multiple devices. Although it was not until recent developments in speech recognition that they started to become widely used. Nowadays, NLP tools can interpret languages correctly more than 95% of the time. This allows for their insertion in appliances ranging from phones and laptops to smart speakers and TVs (Ba, et al., 2020). A study conducted by Voicebot.ai (2020) analysis the adoption of IVAs and positioned different IoT products according to their diffusion in a "Diffusion for Innovation Map" (see Figure 25). On this report we find that, even though people tend to associate IVAs with smart speakers, their diffusion is being made primarily on smartphones and cars. A previous report conducted by Voicebot.ai & Voices.com (2019) confirms this is also true when considering a brands side, as it is more important for automobile brands to have a voice application than it is for smart speaker developers (see Figure 26). This allow us to believe that IVAs will not only be a primary component for smart speakers, but it would be even more important in future car's development.

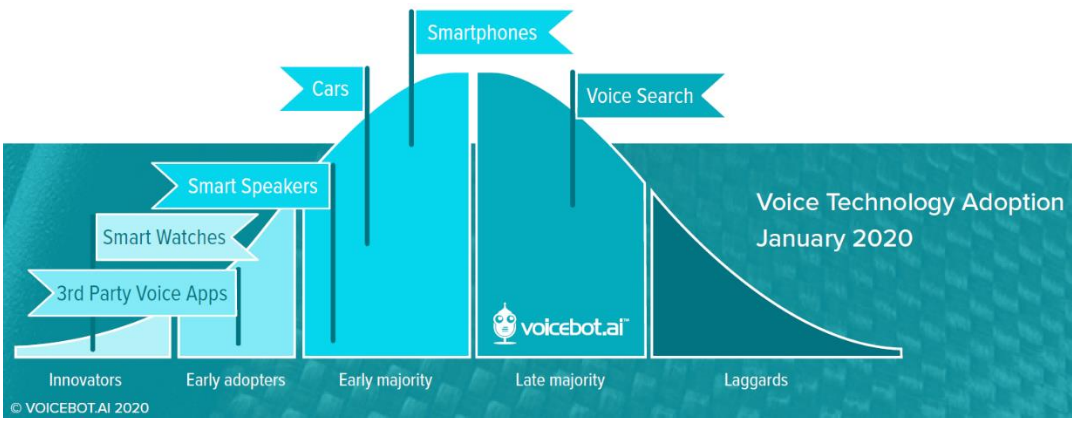


Figure 25: Diffusion for Innovation Map - Source: Voicebot.ai (2020)

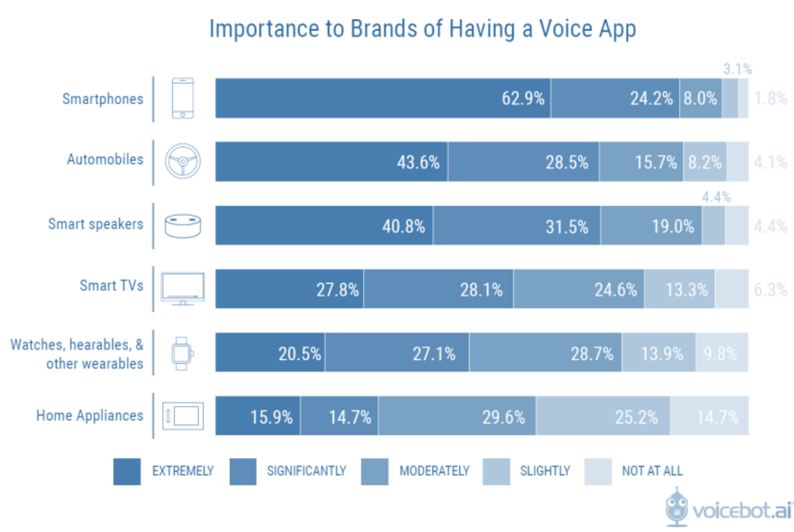


Figure 26: Brands IVAs Importance - Voicebot.ai (2019)

Payment capabilities within the mentioned objects are enabled by the user's voice assistance payment service provider. Even though they required the usual verification methods, such as insertion of a PIN number or confirmation through a separate device (such as mobile), technological advances are allowing for voice recognition to be used as a verification (Clark, 2020a). This would allow for biometrics to become a regular confirmation method to conduct payments through any IVA-enabled device.

Going back to generalize view of IVAs, Singh et al. (2019) formulates three categories according to which one can evaluate IVAs-enabled device's performance:

- Question-Answer Assistant: Evaluated based on the relevance of the answers to the questions.
- Task Assistant: Evaluated based on the number of tasks successfully completed by the assistant in a defined period.
- Social Assistant: Evaluated based on the frequency and duration in which the assistant is successfully keeping the customer engaged to the interaction.

They establish that an IVA incurring the actions of payment should be "positioned as a combination of Question-Answering Assistant and a Task Based Assistant" (Singh, et al., 2019, p. 2). This is because, it not only requires performing tasks (payments), but it also needs to provide answers to any question the user might have during the process. As a result, they concluded that cognition was one of the main attributes an IVA needed to perform accurately, and to achieve it, the main obstacle to overcome is ambiguity in the sentences used by customers.

Even though misinterpretation should be of great concern when conducting payments, it should not be the only one. User's voice recordings pose a privacy risk as they constitute personally identifiable information. Liao et al (2019, p. 102) state that "in the event of a data breach, an adversary could access users' detailed IPA usage history and potentially infer additional information about users' lifestyles and behavioral patterns through data mining techniques".

1.5.2.2 Market Tendencies

After understanding IVAs main characteristics, is important to analyze the market tendencies in order to determine in which direction (and how fast) the market is moving.

Voicebot.ai and Business Wire (2020) estimates that the current number of IVA in use will double by the year 2024, reaching 8.4 billion (see Figure 27). This will allow for the global voice recognition market to increase from US$10.7 billion in 2019 to US$27.16 billion in 2025, accounting for a CAGR (from 2020 to 2025) of 16.8 percent (Mordor Intelligence, 2020).

Furthermore, Gartner 2016 (cited in Han & Yang, 2018) anticipated that 3.3 percent of global households will have adopted virtual personal assistant-enable wireless speakers by 2020 and expected that more than one unit or even one per room can be installed by users', due to their ease of use and their natural intuitive model.

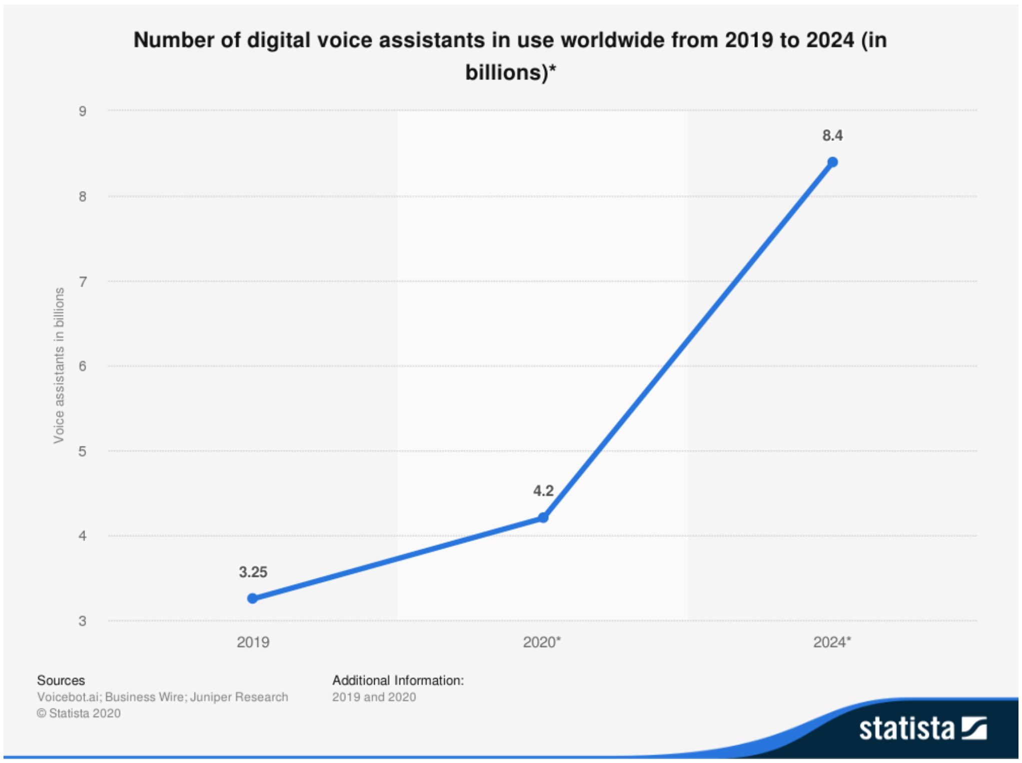


Figure 27: Number of IVA in use - Sources: Voicebot.ai, Business Wire, Juniper Research

In the US, household penetration of IVA devices (such as smart speakers) was 32 percent in 2019 and it is expected to increase to 51 percent by 2022 (Tiwari et al, 2019 cited in Ba, et al., 2020). Moreover, Voicebot.ai (2020) found that 14.3 percent and 4.9 percent of US smart speaker owners made purchases by voice on a monthly and daily basis respectively, in 2020. Compared with their previous issue report (in 2019), monthly users declined a 0.7 percent, while daily users raise a 1 percent. This can be considered as an indication of the transition of the product from the "Early Users" into the "Early Majority" categories within the diffusion map.

1.5.3 Smart Objects Payments

1.5.3.1 Definition & Characteristics

"The combination of the Internet and emerging technologies such as nearfield communications, real-time localization, and embedded sensors lets us transform everyday objects into smart objects that can understand and react to their environment. Such objects are building blocks for the Internet of Things" (Kortuem, et al., 2010).

According to the previously given definition every object we have already talked about can be classified as a smart object. As establishing every IoT system within the same classification will render it meaningless, it is imperative to apply some restrictions before moving forward. First, as it is the focus of this thesis to analyze the evolution of the payment methods through IoT technologies, only payment-enabled objects will be considered within the scope of interest. Second, to avoid an object entering more than one category, wearables should not be included within this classification. Although, this does not strictly apply to the objects considered within the Voice Payment category (such as smart cars or smart speakers) as they will be analyzed for its conditions as an object and not by the AI system which enables its functioning. Finally, the restrictions applied will leave three main categories remaining: Smart Cars; Smart Objects PoS; Smart Homes.

Smart Cars

Park et al (2019, p. 1) described a smart car as "a car that not only improves traffic safety by driving and controlling itself like a robot, but also entertains passengers and supports their productivity by connecting them to the internet". In this first description we are presented with the main features that characterize a smart car (enhance driving capabilities), while also encountering some secondary features that boost this technology capabilities (entertaining and supporting productivity). They decided to divide the services provided by smart cars according to their connectivity, encountering three categories: Driving Assistance; Infotainment; IoT Hub. The first, referring to support of movement and driving of the vehicle. The second, enhancing comfort and entertainment while driving. The third, utilizing embedded services in the existing IoT system (Park, et al., 2019, p. 2). Each category is then divided in subcategories for a better segmentation of their analysis (See Figure 28).

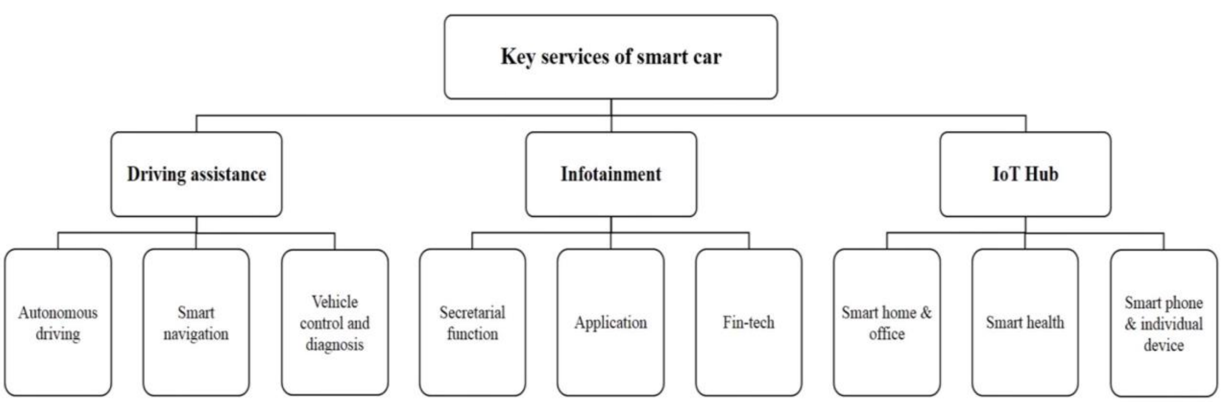


Figure 28: Key Services of Smart Car – Source: Park et al (2019)

Remembering once more the focus of thesis regarding payment, is that we shall give special attention to the "Fin-Tech" section. It covers all type of financial transactions that could take place through the vehicle's financially enabled service. The main source of information that enable further subdivision of this section was the Census which allow for a subdivision of two categories:

- *Buy-In Vehicle*: Accounts for every type of purchase the user is able to perform while in the vehicle, considering, but not limited to: Gas/Fuel; Food (pre-order of car drive throughs); Parking; Tolls. While for the purchasing of physical items such as fuel or food it leverages on an AI system integrated in the vehicle (which conducts the purchase in the same way it was described on the "Voice Payments" section), instead, for parking or toll transactions it uses a RFID device. An example of the last implementation is introduced by Idris et al (2009, p.108) on which it distinguishes that an RFID system used for parking payment, as it requires the user to activate such system to start the transaction and deactivate it to indicate end of transaction, and that used for EZPass systems which immediately deducts the payment from the user's account.
- *Car Wallet*: The vehicle has its own digital wallet which allows it to conduct purchases or collect points through affiliation to reward programs. The smart car requires a digital ID and access to a digital card which allows it to conduct payments without any assistance of users in or outside the car. An example is provided on a paper published by Jamil & Kim (2019) which propose a "novel blockchain-based payment mechanism for electric charging in smart vehicles". Basically they are proposing using a blockchain system which could allow the smart car to charge itself by connecting to a smart pump.

Smart Object PoS

Smart Object PoS belong to the Smart Retail area of application, as they are objects that not only improve user experience when interacting with a retailer but also serve as check-out. Because this is a very innovative category there is not much information available. The main subdivisions were obtained through the Census analysis and verified on scientific papers. The type of Smart Object PoS that have been identified are:

- *Smart Carts*: They implement RFID technology to scan products and while calculating the total paying price. Once the customer finishes its shopping, the billing system at PoS receives the information through wi-fi where the payment is conducted regularly. Kumar Yadav et al (2020) proposes a smart cart which implements the previously mention technology and "helps people to maintain social distance avoiding long queues". In the context we are currently living, is more important than ever to consider the benefits that this technology brings, not only for their improve functionalities but as a facilitator to keep the necessary precautions in order to avoid the spread of infectious deceases. Notice that even though the model proposed by Kumar Yadav does not strictly conduct the action of payment, this is not the case for every type of smart cart. While leveraging on the same technology, there are some designs which contemplate integrating billing capabilities onto the cart itself (Grupta, et al., 2013; Yewatkar, et al., 2016).

- *Smart Mirrors*: They implement Augmented Reality (AR) through cameras and sensors, depending on the design it can even include a Kinect system (Liu, et al., 2016). Considering their functioning, "customers can use the smart mirror to compare various products at the same time through virtual fitting with 360-degree vogue and augmented reality, or to assist with purchase decisions by communicating with neighboring acquaintances" (Hwangbo, et al., 2017, p. 7). Although is not just by "assisting with purchase decisions" that they are involved in the purchasing process, some models may even "provide the function of "virtual shopping"" (Li & Hu, 2014, p. 153), which would allow the customer to finalize the order through the mirror, therefore, completing the payment process.

Even though only two type of objects are being presented, the need of limiting human interaction may push this type of technologies into further and faster development than ever before.

<u>Smart Homes</u>

"Smart Homes technologies include domestic devices and appliances that are connected via a network, are capable of communicating with one another and can be remotely monitored, accessed, or controlled from any location in the world by phone or the Internet" (Aldossari & Sidorova, 2018, p. 1). For connectivity as well as recognition of each available device, sensors are used. They detect the location of the interconnected objects as well as measure and store different types of data (temperature, energy usage, open windows, etc.) (Balta-Ozkan, et al., 2013). From this integrated network two systems were identified, Smart Grids and Smart Appliances.

Smart Grids are defined as "electricity network that can intelligently integrate the behavior and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies" (FAQs about ETP Smart Grids, 2013, cited in Toft, et al., 2014, p. 392). Even though they allow for a better insight in the amount of energy appliances consume, culminating into energy savings and cost reduction (Stragier, et al., 2010; Park & Cho, 2017), as they do not allow for the user to conduct the action of payment we will not be considering any further during the analysis.

Smart Appliances are objects connected to a network whose primary objectives are to "(…) increase home automation, facilitate energy management, and reduce environmental emissions" (Al-Sumaiti, et al., 2014, p. 294). As established in the previous paragraph, even though the facilitation on energy management may induce cost saving, we shall only consider those objects that "increase home automation" as it is in such aspect where payment-enabled objects are located. With this condition in mind, and considering the findings retrieve from the Census, three subcategories have been identified:

- *Smart Speakers*: They are defined as "a hands-free speaker powered with digital voice assistants using two-way voice computing technology based on cloud computing" (Amazon. 2017; Martin, 2017, cited in Koo, et al., 2017). Among its functionalities, smart speakers allow to transfer money, shop online, access banking services, conduct person-to-person payments or even make donations (Lee, et al., 2020). As already mentioned on the "Voice Payments" description, these payment capabilities are enabled by the user's voice assistance payment service provider and have been showed to allow verification through traditional methods or even biometrics (Clark, 2020a).
- *Smart Fridge*: This type of objects is equipped with RFID and sensors that allows them to identify all products stored within them (Rothensee, 2008), providing for better management capabilities. They allow to identify which items are about to expire or missing in order to follow a certain recipe (Miniauoui, et al., 2019). With such information then the user is able to directly place an order to a linked grocery store within the fridge (Samsung, 2021).
- *Other Smart Appliances*: This category is integrated by objects capable of ordering their own supplies (batteries, coffee, ink, etc.). One of the distinguishable services in this category is Amazon Dash. The Amazon Dash button "allows customers to remotely order a given product by the mere press of a button" (Hocket, 2015, cited in Farah & Ramadan, 2017, p. 55). As its definition states, it allows to order replenishments of the given product it is associated with, making it a sort of "wildcard" within the objects of this category. Gerpott and May 2016 (cited in Farah & Ramadan, 2017) denote its main functionality as simplifying the purchasing process by diminishing the number of steps required to complete a purchase, thus enhancing convenience while maintaining the overall perceived value of the final product received. Even though it has been discontinued in

2019 (Walton, 2019), it still serves as a perfect example of how any given product is able to enter this category.

1.5.3.2 Market Tendencies

Every category previously mentioned shows a consistent growth which means an impulse for the development of smart objects technologies. Before getting to the actual data, it is important to mention that because we are dealing with expected valuation, the market value indicated will be diverse from one source to another, this would allow for discrepancies within the composition of a certain category. Although despite the actual number, the growth rates are consistent within every cited source.

Moving onto the first category, Connected Cars are projected to reach 76.3 million deliveries by the year 2023, accounting for a 40 percent growth from its previous value of 51.1 million in 2019 (AP., 2019). This remarkable growth will be reflected on its market value which is expected more than triple on a period of five years, starting at 54 billion U.S. dollars in 2020 and reaching 166 billion by 2025 (MarketsandMarkets, 2020). Deepening into Infotainment services, the number of comfort services (those that integrate payment capabilities) is rising. Statista (2018) has forecasted its number to reach 0,9 million subscriptions in 2023 (See Figure 29). The increase on subscriptions allows for Infotainment services to achieve a market value of 55 billion U.S. dollars by 2027, considring a projected annual growth rate of 10.7 percent between 2019 and 2027 (MarketsandMarkets, 2020).

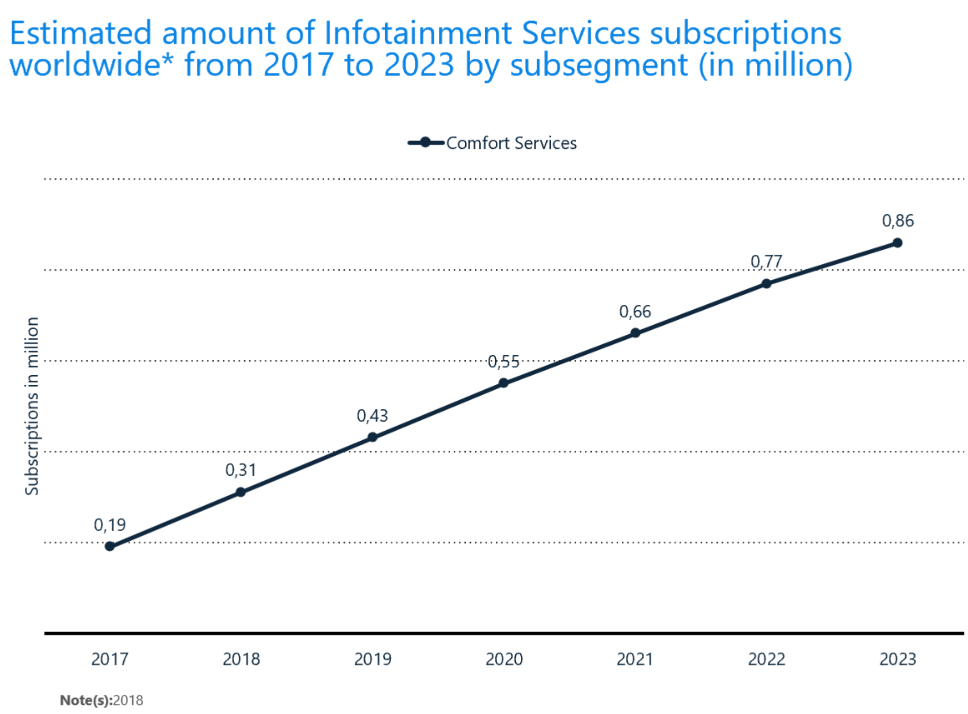


Figure 29: Estimated amount of Infotainment Services subscriptions worldwide – Source: Statista (2018)

For its innovative features, there is not much information relating Smart Objects PoS market tendencies. Even though Smart Carts are being implemented, it has not yet reached a stature significant enough for it to be individualized when considering smart objects trends. This is not the case for Smart Mirrors which, thanks to its appearance on the fashion industry, has reach a market value of 2.82 billion U.S. dollars in 2018 and is anticipated to increase at a compound annual growth rate of 9.41 percent, reaching 4.42 billion U.S. dollars by 2023 (GlobeNewswire, Research and Markets, 2018).

Differently from the previous segment, Smart Homes offer detail information on its trends as its services and market size continue to grow. As shown on Figure 30, the number of Smart Homes is expected to be 482,8 million in 2025 (Statista, 2020a), obtaining a market revenue of more than 175 billion U.S. dollars for the same year. We can expand even further into the categories of "Home Entertainment" and "Smart Appliances" which account for a combine total of 83 billion U.S. dollars, being the latter the segment with the greatest output of them all (Statista, 2020b) (See Figure 31).

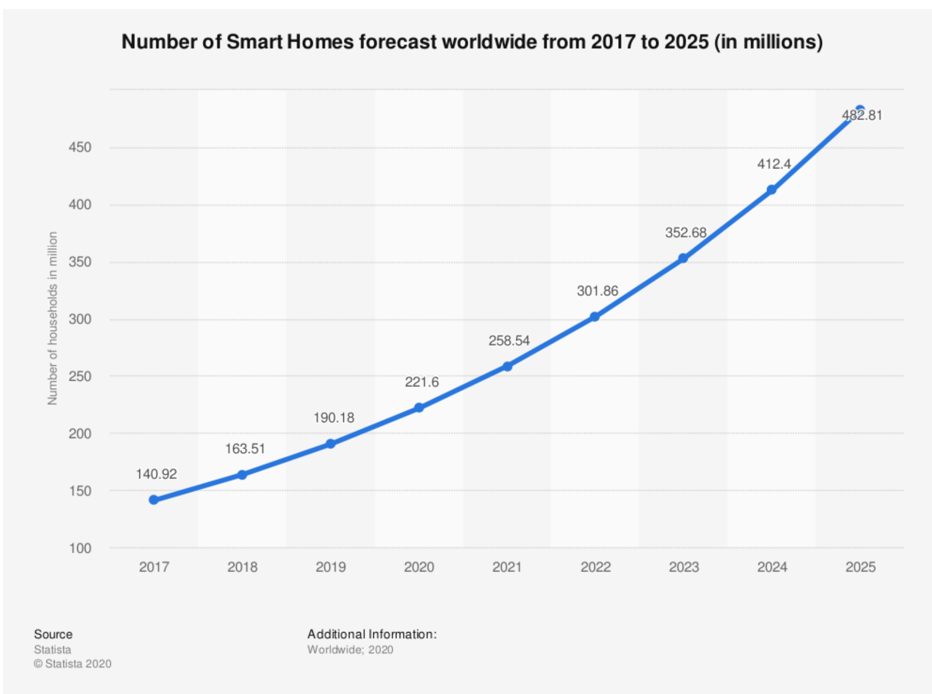


Figure 30: Number of Smart Homes forecast worldwide - Source: Statista (2020a)

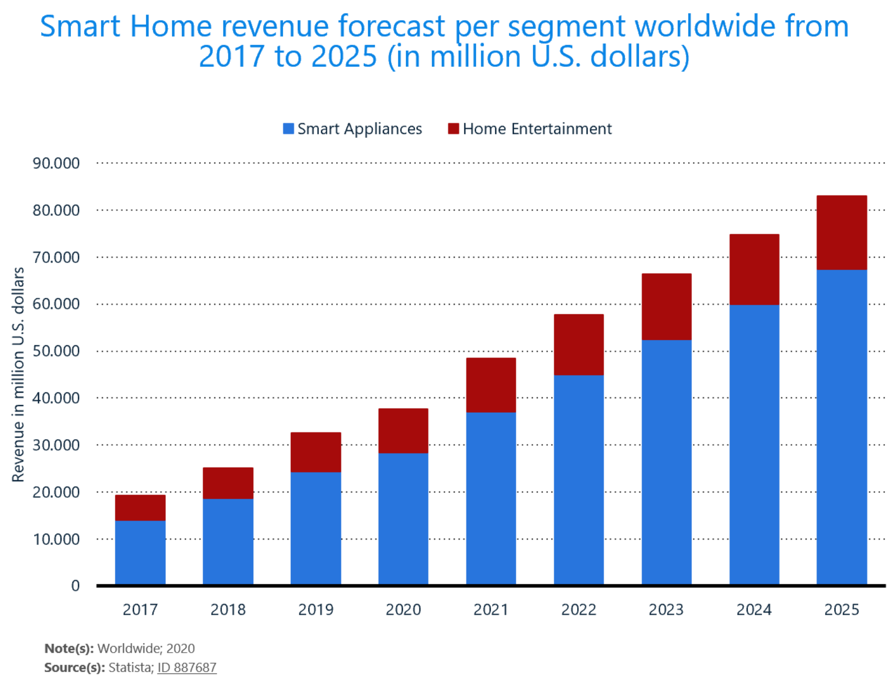


Figure 31: Smart Home Revenue Forecast Worldwide - Source: Statista (2020b)

Specifically, within the Smart Home section, Smart Speakers' unit sales are expected to reach up to 409,4 million units in 2025, with a parallel increase on its market revenue growing up to 35.5 billion U.S. dollars in 2025 *(Loup Ventures, 2019)*. This consistency is not present in every type of Smart Object. In the case of Smart Fridges, analysis made from different sources (306 Research Reports and The Business Research Company) determined for its market value range to be located between 0.65 and 2.5 billion U.S. dollars in 2020, while projecting a value of 1.96 billion by 2026 or 4.56 billion by 2025 respectively *(Statista, 2021)*. Finally, Smart Appliances are expecting to hit a household penetration of 11.5 percent by 2025, which would be an increase of almost 7 percent from its expected value in 2021. The expected annual growth rate between the indicated period is of 16.11 percent, which would account for a total market volume of 67.6 billion U.S. dollars by 2025 (as shown on Figure 27) *(Statista, n.d.)*.

1.5.4 Device-Free Payments

1.5.4.1 Definition & Characteristics

As mentioned at the beginning of the "Innovative Payments" section, Device-free Payments are those that do not require a device to conduct the payment action. While being the most innovative payment category, many retailers are already implementing such solutions which is why they are essential for the analysis. Two subcategories have been identified during the research and later on verified by the Census:

- *Biometric Payments*: "Biometrics is a process used to identify or authenticate an individual's identity using any of a series of physical or behavioral characteristics" (Clodfelter, 2010). Biometric systems required two stage operations, enrollment, and authentication. During the enrollment, the reference biometric is captured, processed, associated with other identity attributes, and finally, encoded and stored in a centralized database (Prabhakar et al, 2013; Bolle et al, 2004, cited in Clodfelter, 2010). Then, during the authentication phase, a comparison between the captured sample and the corresponding enrolled during the reference stage is performed (Smart Payment Association, 2018). As biometric properties are not lost, transmitted, or stolen, they are considered more secure and convenient than traditional passwords (Unar et al, 2018, cited in Zhang & Kang, 2019). Despite fingerprint biometrics have recently increase their used as payment verification methods for its inclusion in cards, it will not be further considered on this thesis, as it is the objective of this section to focus on the offers that retailers provide when using biometrics, which would invalidate the consideration of smart cards. The types of biometric authentications that will be considered are:

- *Face Recognition*: It analyzes distinct facial features such as eyes, nose and mouth. The identification errors have been reported to vary from 2,65 percent up to 50 percent depending on the recognition method and the environment in which it develops (Phillips et al 2002, cited in Clodfelter, 2010; Tiagman et al 1992, cited in Zhang & Kang, 2019)
- *Voice Recognition*: It "(…) works by cross-checking 100 unique identifiers and includes both behavioral features such as speed, cadence, pronunciation, and physical aspects including the shape of the larynx, vocal tract and nasal passages" (Nasonov, 2017, p. 5).
- *Palm Biometrics*: "Hand geometry measures the form and size of the whole hand, its palm and fingers" (Baird 2002, cited in Clodfelter, 2010).
- *Finger Vein ID*: It consists of transmitting near-infrared light through the finger to acquire veins patterns. This solution is considered an improvement with respect to fingerprint biometrics as it is contactless and therefore more hygienic, and it is not affected by dryness or roughness. However, the technology cannot be miniaturized like fingerprint and is therefore, not suitable for being on a card (von Graevenitz, 2007).
- *Behavioral Biometrics*: "The technology captures over 500 points of behavior, such as hand-eye co-ordination, pressure, hand tremors, navigation and scrolling, to create a unique user profile. Using continuous authentication, it is able to recognize anomalies in behaviors from the point of login and throughout the entire session" (Nasonov, 2017, p. 6).

- *Invisible Payments*: For its innovativeness, several names have been given to this technology, the ones that struck the most are “Intelligent Point of Sale and Transaction System” or I-POST and “Self-Service Technologies” or SSTs. Independently of the name chosen they both refer to the same process. Kahn (n.d., p. 1) defines this technology as “an automated checkout system that allows the user to walk in a store, collect his items and exit the store”, while Curran et al 2003 (cited in HA, 2020) went a step further and defined it as “a virtual realm where products and services exits as digital information and can be delivered through information-based channels”. The first definition presents a clear image of the process the consumer has to take in order to conduct the purchase, while the second one, establishes the exchange of information that is occurring in the background. Depending on how the system was built, different technologies allow for the payment process to occur. One example would be the “Just Walk Out” technology presented by Amazon, which, through the use of computer vision and machine learning, “detect[s] when customers take or return products from shelves and collect the information in a virtual cart, which is being charged off the customer’s Amazon account later on. (…). The necessary equipment for the future shopping experience with Amazon Go is an Amazon account and a smartphone with the Amazon Go app” (Amazon 2019; Polacco & Backes 2018, cited in Hattula, et al., 2020). Even though the previous description mentioned the use of a smartphone, as it is only required to identify the consumer’s account and linked it to his/her payment credentials with no further interaction during the purchasing process, this is still considered to be a “Device-Free Payment”. Another example which implements different technologies is given by Khan (n.d.). He proposed a system that uses object detection and facial recognition algorithms to process the authentication of the client and the state of the object. When exiting the store, the classifier sends the data to the backend server which executes the payments. Differently from the first example, a smartphone is not required to begin the purchasing process, making this system a more accurate description for this payment category.

1.5.4.2 Market Tendencies

The global biometrics market is forcasted to almost tripple its value of 19.08 billion U.S. dollars in 2020, reaching a total amount of 55.42 billion by 2027 (The Insight Partners, 2019) (See Figure 32). From the individual subcategories, the ones with the greatest value to account for are Voice and Facial Recognition. The former estimated to increase from 10.7 billion U.S. dollars in 2019 to 27.16 billion by 2025 (Mordor Intelligence , 2020), while the latter is estimated to go from 3.2 billion U.S. dollars in 2019 to 7 billion by 2024 (MarketsandMarkets, 2020).

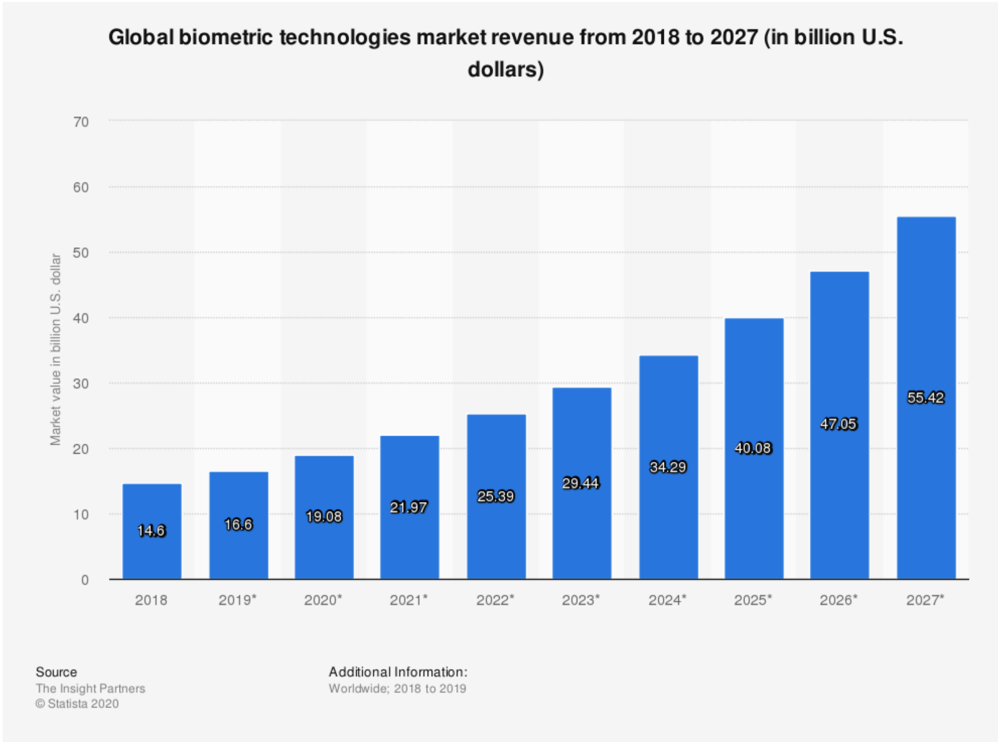


Figure 32: Global Biometric Technologies Revenue - Source: The Insight Partners (2019)

Unfortunately, because of its innovativeness, there is not much information present about the other subcategories or even about the expected value of Device-Free Payments. Having said this, and considering the financial (cost reduction, increase customer loyalty, etc.) as well as health related benefits (social distancing, diminishing queues) that these technologies bring, one would expect to see an increase of its implementation for the use of innovative payment systems.

2. Methodology

2.1 Objectives

Now that a clear picture of the current payment scenery has been presented it is important to redefine the objectives of the thesis.

The Literature already provides a distinctive path towards where the thesis is heading, that is, trying to provide an insight on defining payment methods to come. To do so, the most innovative payment methods have been investigated and classified according to each category's characteristics. For example, while Wearables and Smart Objects have been classified according to the object conducting the payment action, Voice Payments and Device-Free payments have been classified according to the technology which enables the payment action.

The products/services identified through the Census have been further analyzed in order to assess their condition in the IoT environment. Therefore, its area of application, connectivity, and payment-enabled technology has been identified. The identification of this characteristics provides further insight on their development and recognizes which characteristics the future payment system will present.

To align the previous objectives with the following pieces of the research, some questions have been proposed:

4. *Which type of Innovative Payment predominating in the current market? Will it remain the same in the near future?*
5. *According to the classifications, are we able to identify a limit for the "smart-things" that can integrate payment applications?*
6. *Which are the main characteristics of innovative payments with respect to those of IoT devices? Are the currently used characteristics the best available in the market or is there any room for improvement?*

Now that the objectives have been identified, is important the modality through which such goals will be achieved. For the innovativeness of the products and the diversity of the areas analyzed, the research has not only integrated B2C products and services, but B2B as well.

Finally, this thesis is an extension of the research analysis conducted by the Observatory of Innovative Payments from Politecnico di Milano. As shown on Figure 33, the Observatory had predefined the areas of Innovative Payments (Wearable Payments, Mobile Payment, Smart Object Payments, Device-Free Payments), from which three areas were included in the analysis while the Mobile Payments where replace by Voice Payments, restricting the analysis in order to include IoT objects which differ from smartphones.

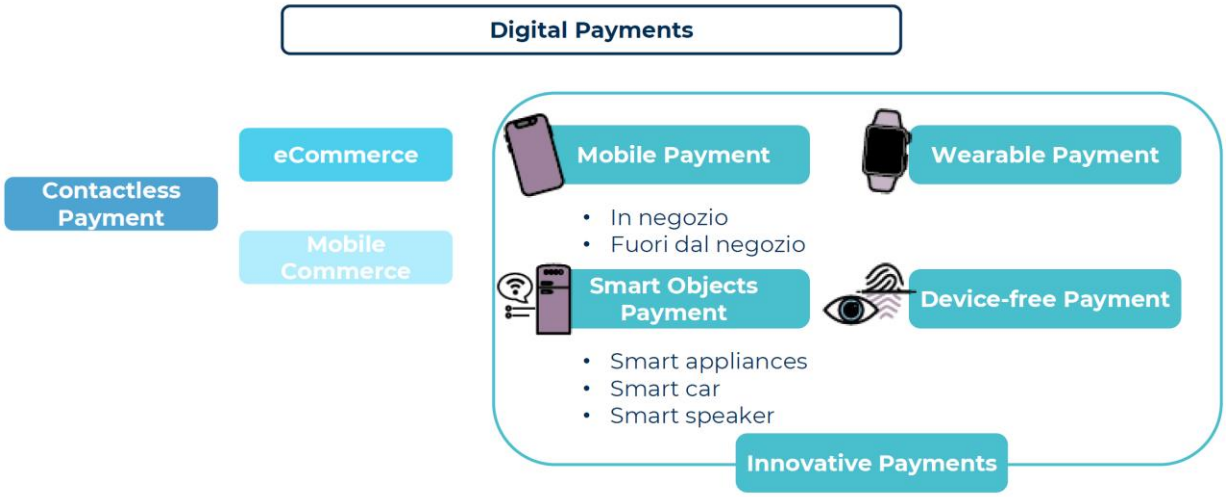


Figure 33: Digital Payments Framework - Source: Observatory of Innovative Payments (2020)

The findings provided by the Observatory are often mentioned along the thesis and used a reference to measure and contrast the quality of the data as well as the results derived from the analysis.

2.2 Context & Literature

The Literature research is divided in four chapters (See Figure 34). First, the Historical Evolution of Payments sets the context, starting from the oldest payment method (bartering), while moving ahead in time until the development of Digital Payments. The chapter ends by mentioning how the beginning of the Covid-19 Pandemic is helping to accelerate technological advancements, imposing even further than ever before, the jump towards digital payments. The aim of such chapter was to introduce the first payment methods, its objectives, characteristics as well as the needs they were trying to fulfill. As mentioned at the beginning of the chapter, it is only by the proper comprehension of those needs that we would be able to define a roadmap for the evolution of payments. Second, the Internet of Things concept is introduced as a technology that leverages on machine interaction, networking, and connectivity. It is at this moment that the relation between payment's methods characteristics and this technology becomes apparent, making it almost predictable to determine that future payment trajectory will be developed upon it. Third, the realm of the Internet of Value has been defined. On this chapter, the framework on which the Internet of Things has been restricted by defining the necessary requirements upon which this technology needs to comply in order to enable the payment process. Finally, considering every previous chapter, the scenario is set to start defining Innovative Payments. The four categories identified by the Observatory of Innovative Payments were clearly describe according to their payment-enabling technology as well as their most common objects (watches, speakers, cars, etc.). This description was followed by analyzing the current market tendencies of each category, allowing for a better comprehension of the direction the market is currently taking, and will take in the near future.

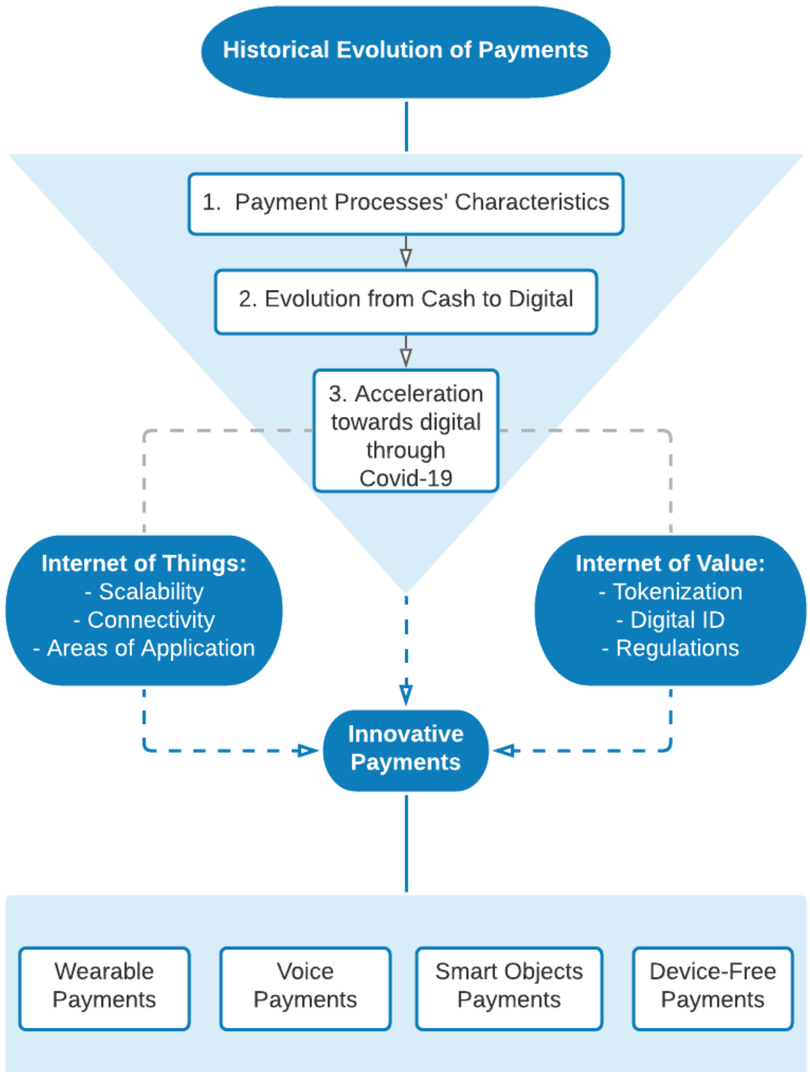


Figure 34: Literature Workflow

While researching the context of the thesis, different sources have been studied:

- Reports and Market Analysis' which include the tendencies and descriptions of the general technology implemented, as well as those that focus precisely on the conduction of payment through such technologies.
- Academic papers, Journal Articles and Conference proceedings.

- Websites and Articles from official entities such as the Smart Payment Association, Secure Technology Payment Alliance or even verified payment providers such as Visa and Mastercard.
- Reports and Workshops of the Observatory of Innovative Payments.
- Newsletters from different portals as well as the Observatory of Innovative Payments.

2.3 Census

The research began through the definition of the different payment areas according to the insights provided by the Literature. Although, because the Literature started at the same time as the research, the payment areas where re-define as further knowledge of such areas was gathered. This allowed for an iterative process to take place. The search for a greater amount of payment products/services permitted a better understanding of the needed classifications, which re-define the previously selected process. To comply with the new definitions, previously selected articles had to be re-analyzed. It was not until the Literature was finished that the Census' characteristics stopped being modified that the "Graphs and Verify Results" process began. The workflow established through the Census analysis can be visualized through Figure 35.

An important consideration must be made at this point. As their name mentions, Innovative Payments are in fact innovative, which makes it for an interesting insight to consider not only available products and services but also those that are on development. The following mentioned categories will be constructed by considering such products and services with the aim of contemplating every possible characteristic available within a near future.

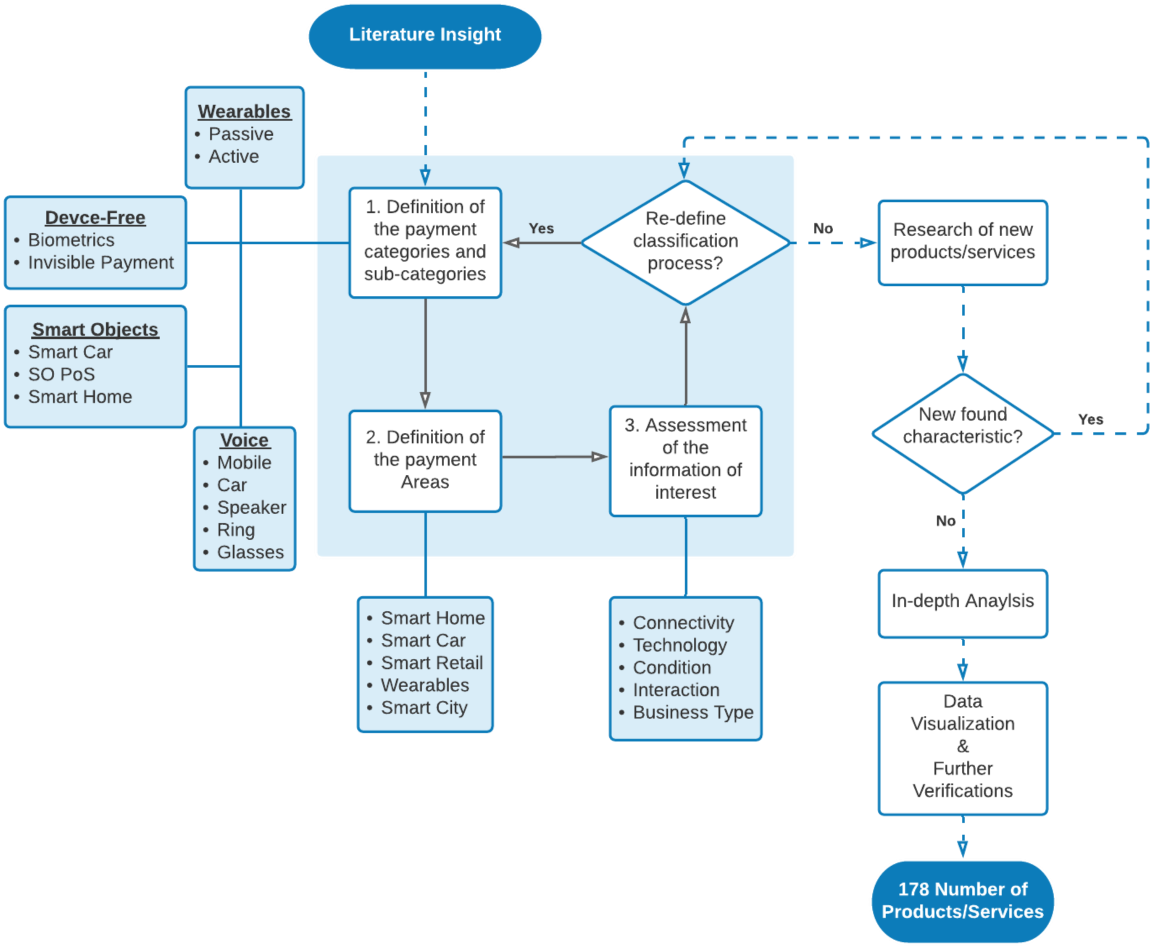


Figure 35: Workflow Census

2.3.1 The Classification Process

The classification process is integrated by three main components:

1. *Definition of the payment categories and subcategories.*
2. *Definition of the payment areas.*
3. *Assessment of the information of interest.*

At the beginning of the analysis two approaches were contemplated. A first approach contemplated commencing the analysis through the different categories of Innovative Payments (Wearables, Voice, Smart Objects, Device-Free) and proceed to classify them within the areas of interest of the Internet of Things environment. A second approach looked to go on the opposite direction, that is, starting from the areas of interest and then classifying the products/services within the Innovative payments' categories. The main distinction between both approaches is that the second classification was meant to be exclusive, meaning that one product or service should not be classified into two categories. As Voice Payments are strictly related to Smart Objects and Wearables it seems implausible to provide a classification which distinguishes completely one payment method from the others. Therefore, it was decided that Innovative Payment's products and services would be able to enter in more than a single payment category but would then be classified into an exclusive payment area. A clear example of this situation would be a Smart Car that allows payments using a Virtual Assistant, as such service would be included in two Innovative Payment's categories simultaneously (Smart Objects Payments and Voice Payments).

Before exposing the final categories and subcategories, it is important to mention that with the advancement of the research, plausible categories increased in order to cover each of the payment-enabled products/services found. This process was in constant review until an accurate analysis of the previous literature was reached. In most cases, the Literature allow for the validation of certain categories and the elimination of additional ones. This was not the case for "Smart Objects PoS", where there was not enough information available to provide a clear set of categories. In such case, the categories identified through the Census where considered. The final categories are represented on the following table.

Innovative Payment	**Category**
Wearable Payments	Passive
	Active
Voice Payments	Mobile
	Car
	Speaker
	Ring
	Glasses
Smart Objects Payments	Smart Car
	Smart Objects PoS
	Smart Home
Device-Free Payments	Biometrics
	Invisible Payments

Table 4: Innovative Payment's Categories

2.3.1.1 Wearable Payments

The Literature confirm the subdivision of two Wearable Payment's categories, Passive and Active. Recalling the definitions presented in the literature, the main difference between both categories is that

Active wearables incorporate smart functions and therefore require more sophisticated hardware as well as a battery, while Passive wearables are "simpler" and just incorporate an NFC chip to regular objects such as watches or bracelets.

The subcategories identified refer to the type of wearable that is used by the product or service to conduct the action of payment. The tables below denote such subcategories.

Passive							
Watch	Ring	Bracelet	Glasses	Key Fob	Gloves	Shirt	Nail

Table 5: Passive Wearables Subcategories - Source: Census

Active				
Watch	Ring	Bracelet	Fitness Tracker	Glasses

Table 6: Active Wearables Subcategories - Source: Census

From all the selected three types of Passive wearables stand apart:

- Gloves: Used mainly at Olympic games where NFC chips were added to the contestant's gloves in order for them to promote and use remote payments.
- Shirt: NFC chips were incorporated on the sleeves of the shirt to enable the action of payment.
- Nail: A single article was found which introduced the notion of incorporating NFC payments into manicures for users to store personal data. Phillips (2020) mentions that in the future it is expected to also conduct payment methods.

2.3.1.2 Voice Payments

The categories within Voice Payments were made according to the objects that enabled the AI which would then conduct the action of payment. Through the Census, five categories emerged: Mobile; Car; Speaker; Ring; Glasses. Furthermore, each category was then divided on one or more subcategories according to the system that allow for the purchasing process to take place (See Table 7).

Mobile		**Car**			**Speaker**				**Ring**	**Glasses**
Android	iOS	Echo Auto	SirusXM	Xevo	Echo	HomePod	Google Nest	Tmall Genie	Echo Loop	Echo Frame

Table 7: Voice Subcategories - Source: Census

2.3.1.3 Smart Objects Payments

The Literature confirm the subdivision for Smart Objects Payments of two out of three categories: Smart Car; Smart Home. The Smart Object PoS category was identified through the Census and incorporated in order to distinguish those objects that allow for the payment process to take place at PoS, as they would not be considered in the Device-Free Payments' solutions.

For the Smart Home and Smart Objects PoS, its subcategories were identified according to the type of object that carried the payment process. Instead, as Smart Cars are already considered an object, the subdivision was made according to the type of payment that was conducted, that being: by the consumer and inside the vehicle ("Buy-In Vehicle"); by the car itself through an integrated wallet ("Car Wallet"); by other type of means not cover by the previous subcategories ("Other"). Table 5 shows such subdivisions.

Smart Car			**Smart Objects PoS**		**Smart Home**		
Buy-In Vehicle	Car Wallet	Other	Smart Cart	Smart Mirror	Other Smart Appliances	Smart Speaker	Smart Fridge

Table 8: Smart Objects Subcategories - Source: Census

Some special considerations regarding the categories noted as "Other":

- For Smart Car Payments, an innovative solution was proposed by Amazon which involved the use of Smart Cars as a point of delivery. The consumer provides a description of its vehicle as well as a one-time key through which the Amazon courier would be able to open such vehicle, leaving the merchandise inside of it (Hawkins, 2018). It was decided to incorporate this innovative service in the analysis because of the promising characteristics it provided for future use of Smart Cars.
- For Smart Home Payments, the subcategory "Other Smart Appliances" integrate smaller objects such as coffee machines, dishwashers or even toothbrushes that with the advances of technology are now able to order its own replenishments.

2.3.1.4 Device-Free Payments

As it was established on the Literature, Device-Free Payments are categorized into Biometrics and Invisible Payments. For Biometrics, the subcategories contemplated the type of biometric that was implemented to conduct the action of payment. For Invisible Payments, no subcategory was identified as the number of services found within this category are still few to subdivide them any further.

Biometrics					**Invisible Payments**
Facial Recognition	Voice Recognition	Finger Vein ID	Behavioral Biometrics	Palm Biometrics	

Table 9: Device-Free Subcategories - Source: Census

A particular consideration was taken for services within the Facial Recognition subcategory, as they also contemplate Iris Recognition systems. This type of biometric leverages on the distinctiveness of the iris, which is even more unique than snowflakes. For this reason, it is considered to be a promising environment within the Biometric Payment categories. Although, it is also seen as intrusive by consumers, which would explain why not many payment service providers opt to use such method (Clodfelter, 2010). For the rest of the analysis, such services would remain included in the Facial Recognition subcategory.

2.3.1.5 IoT Payment-Integrated Areas

The IoT payment-integrated areas considered during the Census were already defined in the Literature. Below, a further description of the agencies that were considered within each category with an explanation of those products or service providers that might be thought to be included within a different category.

- *Smart City*: Integrating the services provided by public transport agencies, parking agencies and banks. The parking agencies considered within this category are those that do not focus on the improvement of a particular smart car, but on delivering a solution which would benefit the entire environment around the city. An example of such a service provider would be *AppyParking* which improved the parking disposition around cities of the United Kingdom (North Yorkshire County Council, 2019).
- *Smart Home*: The obvious integration of this area are those products and services within Smart Object Payments that belong to the Smart Home category. But it also incorporates a few services, or more precisely VAs, strictly belonging to the Voice Payments category and developed by banks. Virtual Assistants as Oleg and Erica were developed to help with the assessment of financial decisions as well as recently incorporating not financial related actions (Finextra, 2019a; PYMNTS, 2019). Because one would expect to take care of such decisions from the comfort of their home, and after a review of the rest of the IoT areas definitions, it was decided to include them in such area.
- *Smart Car*: The products or services integrated within this area refer to Auto Manufacturers, Infotainment service providers as well as FinTech's developing the system for vehicle's autonomous payments. An example of a company in the last-mentioned industry is *Car IQ* which is developing a system through which vehicles would be able to make themselves any required payment (Finextra, 2019b).
- *Smart Retail*: This area integrates several Innovative Payment categories. The most obvious inclusions are Smart Objects PoS within Smart Objects payments and Invisible Payment within Device-Free Payments, as both subcategories relate to retailers' offers improvements towards

consumers. This is also the case for some of the Biometric services identified. The particularity within this area comes with the inclusion of some Voice Payment categories, such as *Pay* by Twilio, which steps in by helping customers finalize the payment process after being talking to a VA (Wiggers, 2018). This new approach provided by retailers is restricted to the boundaries of a regular home as one can use *Pay* through any device that incorporates a VA. For this reason, it was only logical to include such service within the Smart Retail area.

- *Wearable*: This area integrates wearable's products as well as service providers that may improve such products capabilities.

2.3.1.6 Variables of Interest

Through the Census, several variables of interest were identified. The ones finally selected to implement during the Empirical Analysis were:

- *Connectivity:* As it has been seen in the Literature, the different connectivity areas are a major component of the cost of the final IoT object. By understanding which type of connectivity predominates on each Innovative Payment category is that we can get an insight of the level of sophistication of such category. From the types mentioned in the Literature only three will be analyzed as Extraterrestrial connections are not implemented in IoT payment-enabled objects/services.

Connectivity		
Unlicensed	LPWA	Cellular

Table 10: Connectivity Types - Source: Literature & Census

- *Technology:* This variable contemplates the technological mean that enables the payment action. The Literature provided a description for each Innovative Payment category on how the technology works. On the Census, at least one of such technologies were identified for each object or service found. The type "Other" was implemented for products or services which specified the use of Bluetooth, Wi-Fi or other additional technology which assisted on the payment process.

Technology				
NFC	Biometrics	RFID	AI	Other

Table 11: Technology Types - Source: Literature & Census

- *Condition:* This variable identifies the current condition of the object or service. If we are able to buy the object or hire the service, then it is noted as “Currently Available”. Instead, if it is still in production, it is noted as “On Development”. Finally, if the product or service has been discontinued and is no longer available, it is noted as “Unavailable”. This last type was still incorporated in the analysis as it provided an interesting insight on were IoT payment services try to be incorporated and failed. The comparison within the previously mentioned types of the products presented on each Innovative Payment category will provide an overview of where the industry was, is and will be in the near future.

Condition		
Currently Available (CA)	On Development (OD)	Unavailable (U)

Table 12: Condition Types - Source: Census

- *Interaction:* This variable was determined to identify fully M2M payments and distinguish them from the rest. With that being said, the type H2M includes every product or service which requires human interaction to conduct or even start the payment process.

Interaction	
H2M	M2M

Table 13: Interaction Types - Source: Census

- *Business Type:* This variable refers to the regular Business-to-Customer and Business-to-Business identification. An interesting insight could be provided by identifying the percentage of each business type within each Innovative Payment category.

Business Type	
B2C	B2B

Table 14: Business Types - Source: Census

2.3.2 Research of New Products/Services

The research has been conducted mostly through secondary sources upon which the product or service was identified. Those sources are:

- Reports of different propositions for the use of the innovative technologies as a mean of payment.
- Websites and Articles from official entities such as the Smart Payment Association, Secure Technology Payment Alliance or even verified payment providers such as Visa and Mastercard.

- Newsletters from different portals as well as the Observatory of Innovative Payments.

After the product or service was identified, the website of the company developing such product or providing such service was researched in order to identify every mentioned variable.

2.3.3 In-Depth Analysis

After identifying a reasonable number of products and services, and defining the categories as well as the variables of interest, an In-Depth Analysis was made to measure that every select product or service was only coherent with the analysis while being singularly counted. As the research was mainly done through news articles, which in many cases do not denote the name of the product or service (for it being still in development at the moment the article was release), it was necessary to review every gathered product/service and to eliminate those that had been double counted.

The In-Depth Analysis also eliminated from the database companies which have developed technological advances that may influence future payment instruments but failed to mention the implementation or diffusion of such technology for the payment area.

The result of the analysis was the identification of 178 products/services within the parameters established for Innovative Payments. Table 15 denotes the amount of each product/service for each category. It is important to mentioned that because some products/services appear on more than one Innovative payment category, the sum the whole will be more than the 178 products/services found.

Category	Product/Service
Wearable Payments	70
Voice Payments	25
Smart Object Payments	51
Device-Free Payments	53

Table 15: Innovative Payments Products/Services - Source: Census

Below, each category's products and services have been illustrated individually.

Wearable Payments			
Mastercard Digital Enablement Service	bPay Wearable Payments Technology	Token Ring	Curve
Ring	Global Platform Enhance Security	McLear Ring	Cash Cuff
Get	Armani Exchange Watch	Xenxo S-Ring	Four Levent
Bee	Moscow Bank Payment Ring	Echo Loop	Timex Watches

Tappy	Michael Kors Watch	Echo Frame	SwatchPAY!
Garmin Wearables	Amex Wearables	Fidesmo Pay	Scallop Smartwatch 2
Octopus’ O! ePay service	ultra-low-cost NFC tags	Pingit Wearables Store	Motiv Ring
Xiomi Wearables	Citadele Wearables	Triwa Watches	Fitbit Pay
Apple Pay Express Transit	Titan Pay	Armilion	Commonwealth Bank - Wearable
Fitbit Wearables	Purewrist GO	Australian Grand Prix Corp	ASB Bank - Wearale
K Wearables	Apple Cash	Guess Wearables	PayWear
Boom Watches	AEKLYS	Compass Wristbands	Bankwest Halo
K-Pay Wearables	MTA's Contactless Payment	Carnival Wearables	FastPay
Ur&Penn Watches	Gloves Payments	Fossil's Watch	Diesel Smartwatch
KBC Wearables	Keyble	STMicroelectronics	Riyad Bank Wearables
Berg Watches	Moscow's Public Transport	O-CITY	Wells Fargo's Wearables
Snapdragon Wear 3100 Platform	Lanour Beauty Lounge's Nail Wearable	Discover's Contactless Fitness	Olympic Games NFC
OMNY	ABN Wearables		

Table 16: Wearable Payments Products/Services - Source: Census

Voice Payments			
Walmart's Voice Order	Domino's Voice Order	Alexa	Google Express
Oleg	Fuel Loyalty	SiriusXM e-wallet	Tmall Genie
PayByPhone's Parking	Mastercard Priceless Experiences	On-the-Go Mobile Ordering	Echo Loop
Paymentus' Bill Payment	Pay	Google Assistant	Echo Frame
Erica	Argos Voice Shopping	Flipkart	Rivian Cars
Interflora	Echo Auto	Xevo Market	Telenav Vehicles
Voice Match			

Table 17: Voice Payments Products/Services - Source: Census

Smart Objects Payments			
AppyParking	Interflora	Jumbo Smart Cart	Hyundai Digital Wallet
Walmart's Voice Order	Echo Auto	Oral-B Guide	Amazon Key-In Car
JLR Smart Wallet	Family Hub	August's Wi Fi Smart Lock	Sem Parar RFID
Amazon Dash Replenishment	Voice Match	Dash Buttons	PayByCar
PayByPhone's Parking	Alexa	Honda Dream Drive	Digital Vision
Google Express	SiriusXM e-wallet	Fuel Loyalty	Car eWallet
Car IQ	Tmall Genie	Brother’s Printers	Marketplace
Daimler Truck	Google Assistant	Pay	FridgeCamTM
Paymentus' Bill Payment	Domino's Voice Order	Argos Voice Shopping	LTE-M button
BMW Labs Online Ordering	Mastercard Priceless Experiences	Uconnect Market Commerce Platform	Mastercard's Smart Mirror
Genesis GV70 SUV	Audi's RFID	Rivian Cars	Mercedes S-Class

Xevo Market	Shop Time app	Telenav Vehicles	Dash Cart
KroGO	Fuel Payments	Car-to-Cloud	

Table 18: Smart Objects Payments Products/Services - Source: Census

Device-Free Payments			
Fujitsu Facial Recognition	Banno Digital Platform	ClearConnect Kiosk	Tucano Coffee Biometrics
Amazon One	PalmSecure Technology	Shop Anywhere	The Alchemist Biometrics
Sberbank Take & Go	Biocatch biometrics	Face Pass	PayByFace
CaixaBank	Bio-IDiom	Xpay	Pivo Face Pay
UST Walk-In, Walk-Out	Bending Machines	VivoGreen Invisible Payments	Standard Checkout Technology
LG CNS	PayEye	PeasyPay	PopPay
Just Walk Out	Monoprixs' Self Service	Alipay in Subway	FacePay24
FacePay	Windows Hello	Onfido's Face biometrics	Nets Finger Vein Payment
Amazon Go Grocery	PayMyTuition	Voice Kiosk	FingoPay Vein ID
Circle K Autonomous Checkout	Redrock's PalmID software	Bus Rapid Transit Facial Recognition	SnapPay Facial Recognition
x5 Retail	VeriTrans Biometrics	Smile to Pay	Hungry? Face it
NatWest	Biometric Signature ID	Face Pay	Selfie2Pay
Shopic	Riddletag Biometrics	Paytm Soundbox	Alipay Box
Kazakhstan's Public Transport			

Table 19: Device-Free Payments Products/Services - Source: Census

2.3.4 Data Visualization & Further Verification

After every product and services had been verified, it was the time to re-assess the variables while gathering a further insight from visual representation of the data.

Some variables (as the "Condition") were re-examined directly in order to incorporate the latest status of the product or service, while others were investigated by its outliers denoted in the graphs which will be later introduced in the Empirical Analysis.

It is important to take into consideration that the latest reviewed was given on the 20th of March 2021. Since that point, the variables became static and any change in any of the products or services would not be noted.

2.4 Empirical Analysis

The Empirical Analysis will be structured in two chapters. The first will describe the distribution of the analyzed products/services within the Innovative Payments environment so to determine the involvement of payment service providers within each category and subcategory. It will also examine the composition of each category and subcategory as to determine the market's smart product of choice. Both concepts will set the basis of the analysis in order to provide a clear trend for the future development of Innovative Payments. The second chapter will contemplate the different variables selected during the Census and how they are influencing Innovative Payments' characteristics. Its objectives differ depending on the combination of the variables:

- The variable "IoT Areas" will be used to understand where the considered companies are located and what are the complementary attributes of such locations.
- The variables "Connectivity", "Technology" will help to determine if the selected path by companies working on the development of smart, payment-enable, products is the optimal course or if there is still room for improvement. It will also help to better understand how smart products conduct the action of payment and the advancements of networking that the use of different technologies signifies.
- The variable "Interaction" will analyze the peculiar aspect of fully autonomous Machine-to-Machine payments and their development within Innovative Payments.
- The variable "Business Type" will analyze the interconnections needed to develop such payment systems with a look onto the companies instead of the product/service.

During the entire process the Conditions of each variable will be taken in consideration by using the products/services that were noted as "On Development" as a way to understand what is to come for Innovative Payments.

The workflow just described is represented on the figure below.

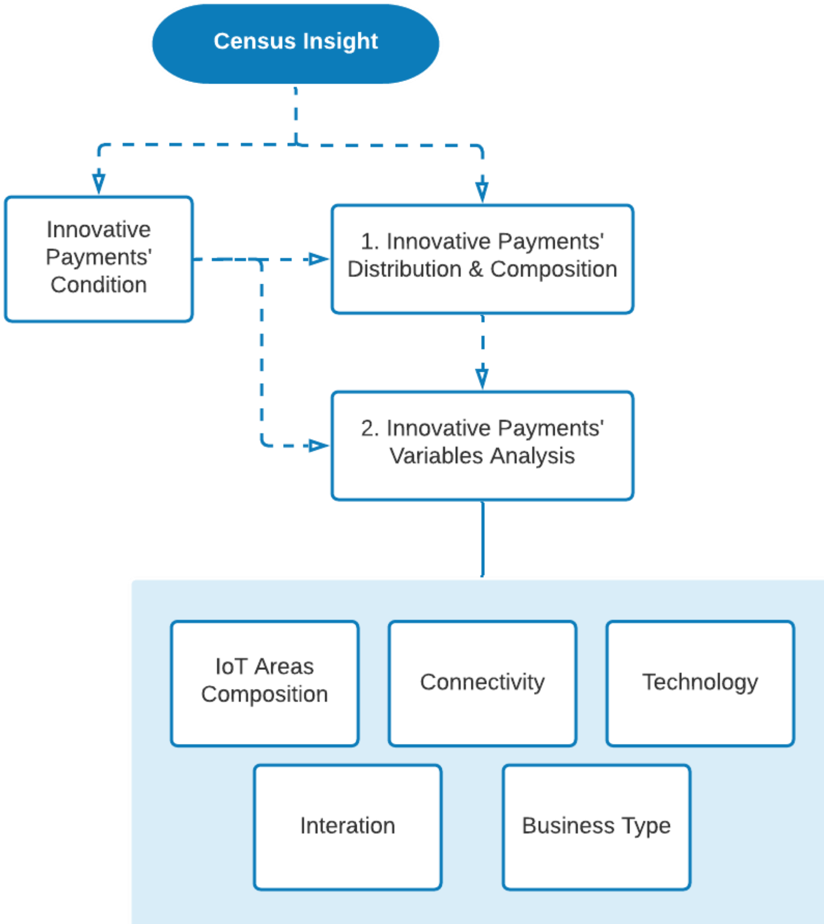


Figure 36: Workflow Empirical Analysis

The sources considered during the Empirical Analysis are:

- The Census Analysis.
- Reports and Market Analysis' which include the tendencies and descriptions of the general technology implemented, as well as those that focus precisely on the conduction of payment through such technologies.
- Websites of the products and services studied in the Census.

The Empirical Analysis was performed entirely on Microsoft Excel. It should be taken into consideration that the Census Analysis became static on the date 20/03/2021. Therefore, any change on the companies or products analyzed would not be taken into consideration.

3. Empirical Analysis

Now that the Methodology implemented has been clearly explained, is time to gather the information collected and present the findings of such research. First, a description of the selected characteristics for every category of Innovative Payments shall be provided in order to establish a comparison between each other. Then, the most relevant categories shall be analyzed individually to determine the effect of each subcategory through the same characteristics previously presented.

Moreover, two particular considerations need to be mentioned:

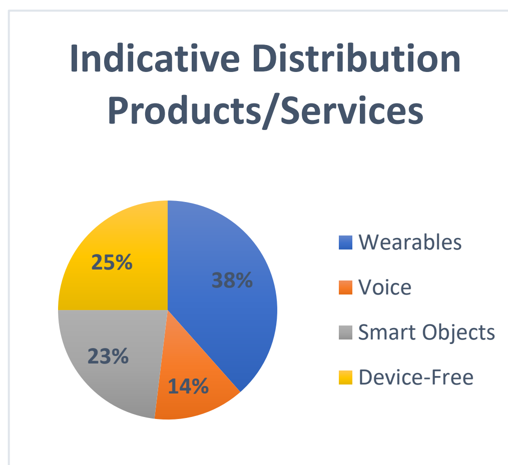
- The representations will be made by considering the indicative distribution of Innovative Payments, that is, the number of identified products/services within each payment category instead of the total number of products/services. The reason for such consideration is that each product or service can be included in more than one payment category.
- The current situation will be first presented by considering only those products/services that were noted as "Currently Available" within the variable "Condition". Then, an insight towards future development of each payment category will be made by considering also those products/services that were noted as "On Development". Furthermore, when relevant, a mention of those products that are currently "Unavailable" will be made.

3.1 Innovative Payments' Distribution, Composition & Condition

Before starting the analysis is important to introduce the number of "Currently Available" (CA) products and services as well as those integrating "On Development" (OD) products and services (see Table 20). From this point forward, such values will be used to compute the percentual integration of each variable within each category.

Innovative Payments	Indicative Distribution of Products/Services (CA)	Indicative Distribution of Products/Services (CA + OD)
Wearable	60	70
Voice	21	25
Smart Objects	36	51
Device-Free	39	53
Total	156	199

Table 20:Indicative Distribution of Innovative Payments Products/Services - Source: Census



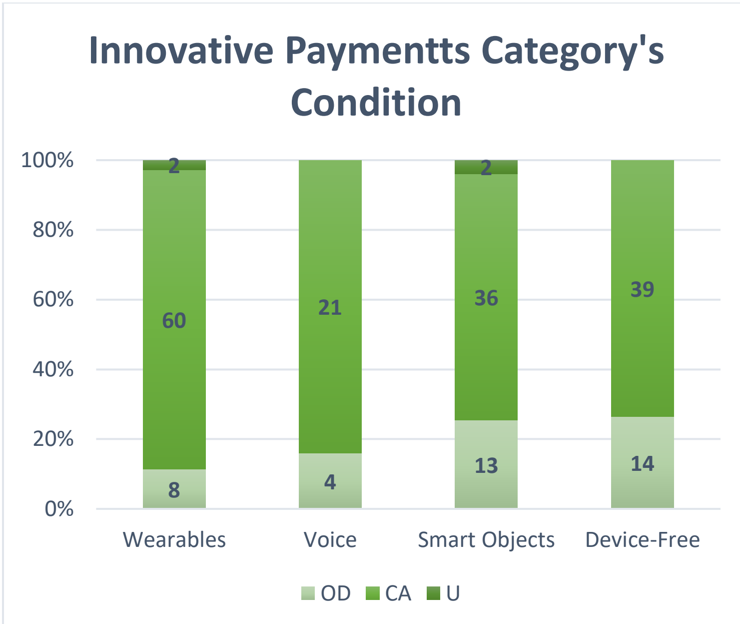
Graph 1: Indicative Distribution of Innovative Payments Products/Services – Source: Census

Now that the total number of products/services that integrate each Innovative Payments' category has been presented, it seems almost illogical not to discuss its distribution. Right from the start we can see the dominance Wearable Payments over the rest of the categories. This should come as a surprise as Voice Assistants have been the most diffused IoT devices, reaching 4.2 billion devices in 2020 (Voicebot.ai, Business Wire, 2020). This would account for 3.3 billion devices more than the number of diffused Wearables (Cisco Systems, 2019). Such difference explains itself by remembering that Voice Payments are conducted by a few service providers. As a matter of fact, the most famous virtual assistants (Siri, Alexa and Google) are the ones that not only offer the most services but are presented in the vast majority of those 4.2 billion devices. In order to avoid double counting, unless the services offer required the payment process to be conducted over a different service provider, it was not considered on the analysis. This diminished the number of Voice Payments which is why it is considered as the lower portion of Innovative Payments. Differently, Device-Free Payments are developed by a great number of service's providers which increases the offer of products and services even though they may be harder to encounter on a day-to-day basis.

In the future, as shown on Graph 2, we could expect to see an increase of Device-Free and Smart Objects Payments' products/services. Again, the theory of the increase in the number of service providers over both categories could explain such increment, while at the same time providing a justification for the lack in rates of development over Wearables and Voice Payments. Having said this and taking into consideration that the percentage distribution may change, it is still not expected to be enough for the dominance of the categories to be affected on the short term. There are several reasons for this phenomenon:

- Even though the development of Wearable Payments is the lowest of all Innovative Payment's categories in terms of percentage over its own category, the fact that it is also the category with the greatest number of products means that it will still be introducing a significant number of new products/services.
- On the contrary to Wearable Payments, Voice Payments are already positioned last in terms of distribution and even though their internal development may account for a greater percentage than Wearables, it is still not enough to increase the size of the category with respect to the others.

- Because Device-Free Payments and Smart Object Payments are so closely related in terms of size, the slightly advantage of Device-Free Payments in growth reassures its dominance over Smart Objects and keeps it on its original position.



Graph 2: Innovative Payments Category's Condition - Source: Census

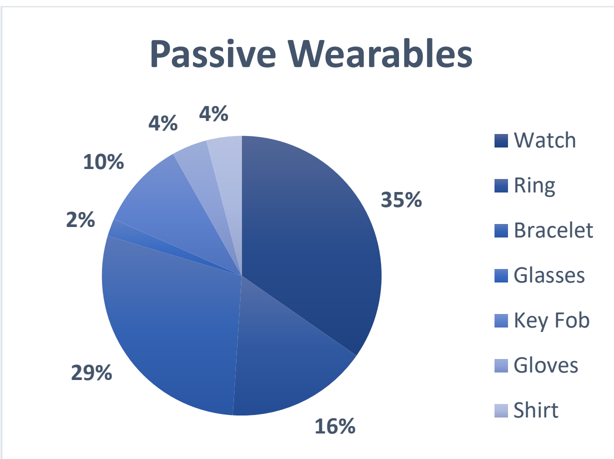
To understand the composition of Innovative Payments each category will be further analyzed according to their subcategories in a decreasing order of distribution.

3.1.1 Wearable Payments

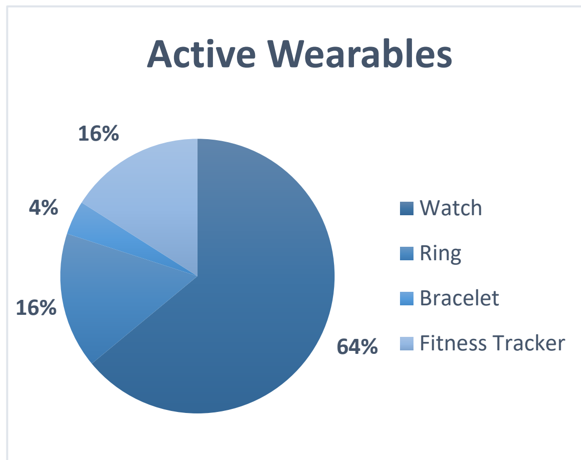
The categories for Wearable Payments are currently dominated by Passive Wearables on a 55 to 45 percentage base. This comes as a surprise, as one would expect Active Wearables to take the lead. During the Census, several articles informed about technological advancements that could have great implications for Passive Wearables. In particular, the development of stretchable NFC for clothing (Clark, 2019a), a waterproof NFC sweat sensor (Clark, 2019b), or even the introduction of smart fabric which does not use NFC antennas at all (Clark, 2017). The mentioned innovations could allow for the development of even the most unthinkable Passive Wearables. This theory is a possible explanation for the insertion of NFC chips on strange places, such as pieces of clothing or even on nails.

By looking at Graph 3 and 4 we may notice that in both subcategories the dominant products are watches followed by bracelets, which in the case of Active Wearables is tied to rings. The explanation for such tied might be that smart bracelets or fitness trackers provide the same functionalities, in the same form, as a smart watch. This is not the case for smart rings, which provide some of the same functionalities but in a different form. A clear example is Ring by Logbar, which uses motion sensors on the finger to interpret the desired command and then executes it (Logbar, 2015). Such differences might attract the consumer who is looking for an alternative form of wearable. This might also explain why smart bracelets fall so far behind smart watches or even fitness trackers. Looking back at Passive Wearables, the distance between bracelets and rings might be explained by the fact that the unavailability of smart functions makes the bracelet more appealing to consumers than the ring by itself.

An interesting remark is that clothing may not be an attractive choice for consumers when looking for a payment-enabled wearable. This comes to mind after noticing that they do not only account for the lower portion of Passive Wearables, but they were also introduced several years ago, with the oldest article dating as far as 2014 (Clark, 2014).

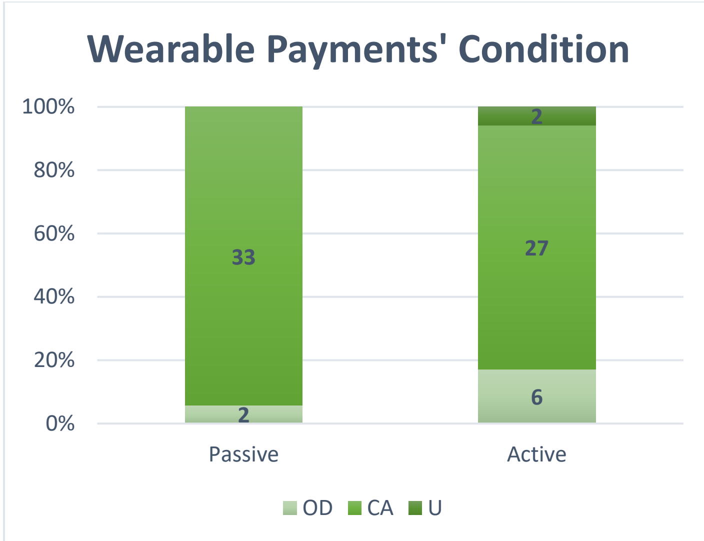


Graph 4: Passive Wearables' Composition - Source Census



Graph 3: Active Wearables' Composition - Source: Census

From all the Passive Wearables' products/services analyzed, 94 percent were "Currently Available", leaving only 6 percent "On Development" (see Graph 5), which is disperse among different products. This leads us to believe that, in the future, we might expect for their current composition trend to continue as is, with the incorporation of a few new type of payment-enabled products such as Nails (Phillips, 2020). The case is not the same for Active Wearables' products/services. Only 77 percent were found to be "Currently Available", while 17 percent where "On Development" and 6 percent "Unavailable" (see Graph 5). It is interesting to notice that the portion of smart bracelets and rings that are "On Development" is the same, but the "Unavailable" category is integrated just by smart rings. This suggests a greater effort of Active Wearable's developers to promote products differently from smart watches, with a higher interest in the development of smart rings. In the future, there might be a greater dominance of the smart ring, but such difference is still uncertain and would clearly depend on changes in consumers' preferences.

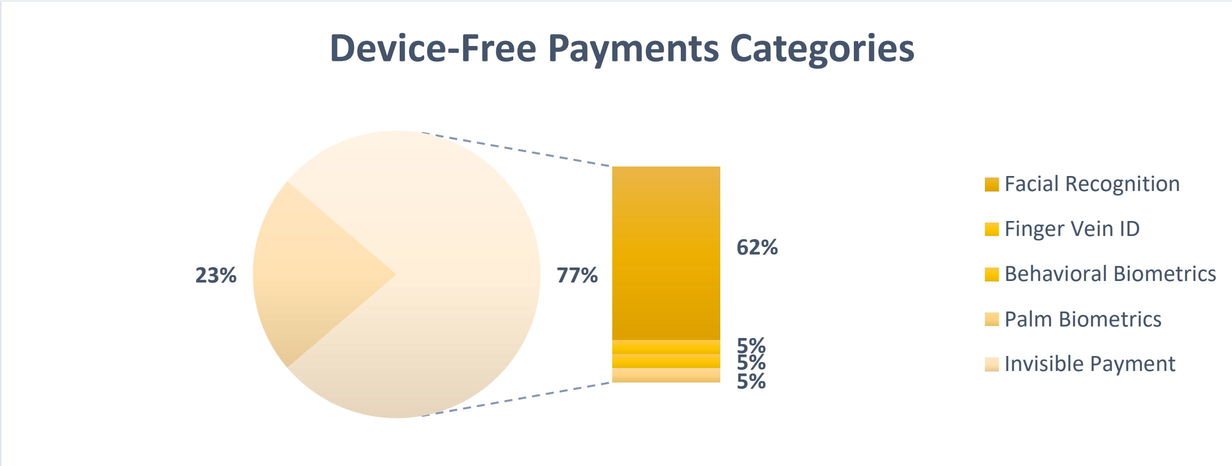


Graph 5: Wearable Payments' Condition - Source: Census

3.1.2 Device-Free Payments

As shown on Graph 6, Biometrics' products/services surpass Invisible Payments by more than three times its size. This indicates a stronger development of Biometric Payments which might be explained by two conditions. Either the intricacies of constructing an Invisible Payment environment prove to be more complex than they appear and are therefore, still in need for development, or consumers interpret Biometrics as a more secure measure of control which provides them with more confidence on their use, consequently fomenting their faster development. Whichever the actual reason, the fact is that biometrics are becoming faster than ever part of our day-to-day lives.

Facial Recognition seems to be the most common type of biometric implemented for Device-Free Payments. A possible explanation for this phenomenon is that Facial Recognition is the most developed type of biometric (excluding fingerprint recognition) while the other types of biometrics are new not only to the payment environment but to other applications as well. Despite of this, Behavioral, Finger Vein and Palm Biometrics are starting to be highly diffused by banks and retailers.

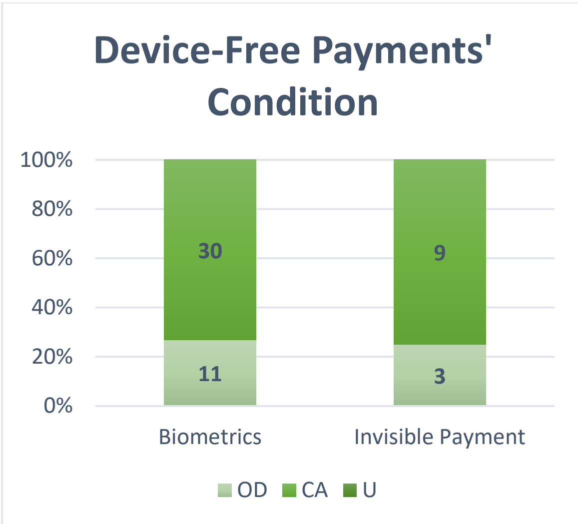


Graph 6: Device-Free Payments Categories Composition - Source: Census

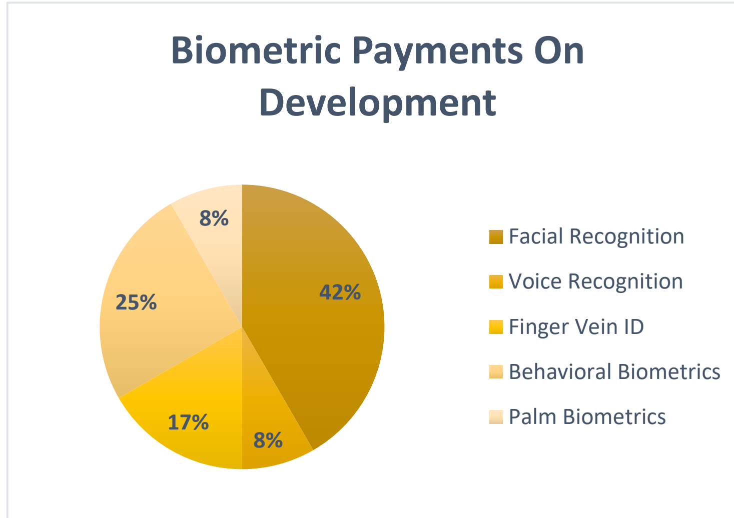
Considering that the percentual relation between "On Development" and "Currently Available" for Biometrics and Invisible Payments are quite similar (see Graph 8), in the future, we could expect the relation between Device-Free Payments categories to remain constant.

Regarding particularly Biometric Payments, the development of Facial Recognition is slowing down. Even though it will remain dominant, the aggregated development of every other type of biometric accounts for a 58 percent over the total "On Development" services (see Graph 7). This means that soon, biometric services will be more disperse in type. After Facial Recognition, such dispersion will be mostly incorporated by Behavioral Biometrics, which according to the information gathered through the Census, is being implemented mostly on financial institutions, specifically banks. Finger Vein ID is the option that follows, being tested by retailers, pubs or even dinners. Finally, with a tied percentual development we have Palm and Voice Recognition, which are both being tested by retailers.

An interesting advancement will be the incorporation of Voice Recognition by Virtual Assistants. If the development of the technology allows for its incorporation on standard smart devices, it has the potential to rapidly become the most widely diffuse biometric payment.



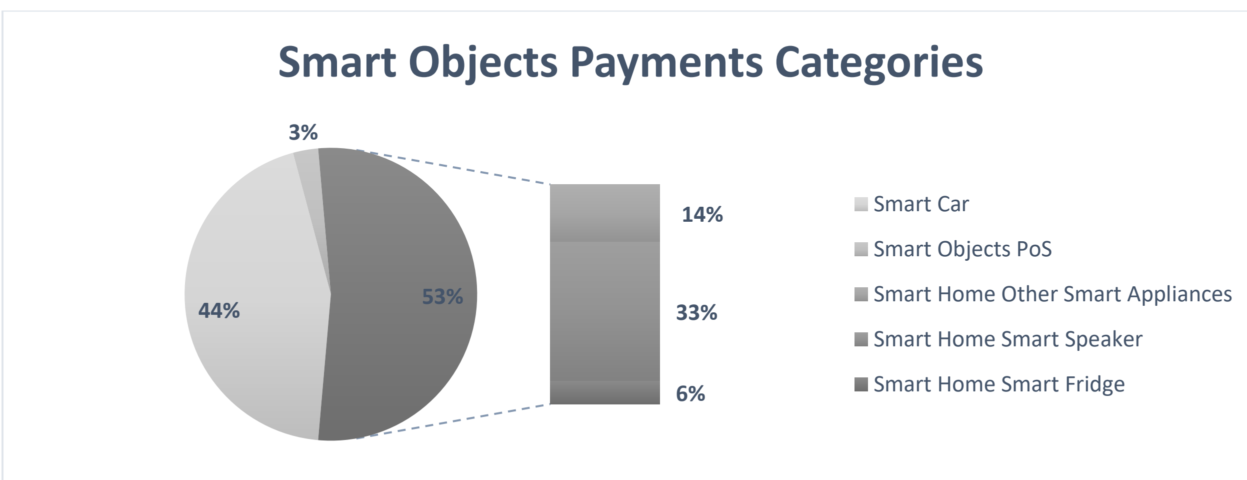
Graph 8: Device-Free Payments' Condition - Source: Census



Graph 7: Biometric Payments on development distribution - Source: Census

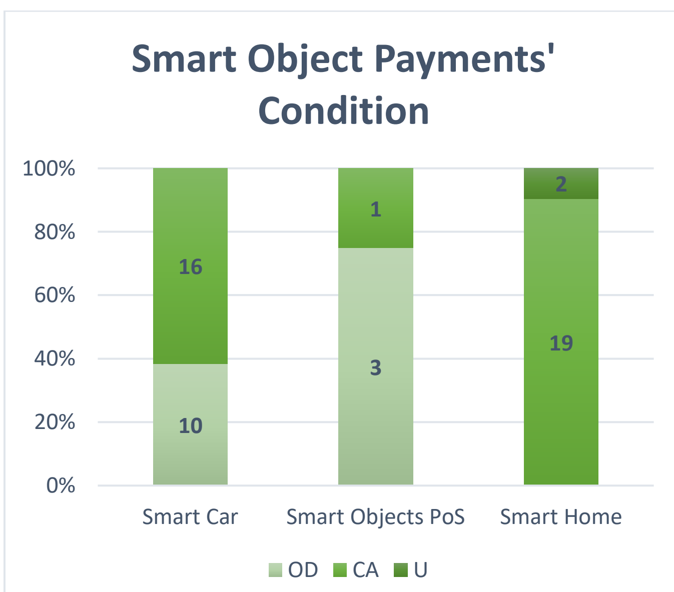
3.1.3 Smart Objects Payments

The Smart Objects Payments categories is currently being dominated by "Smart Homes" with 53 percent, followed by "Smart Car" with 44 percent and finally "Smart Objects PoS" with 3 percent (see Graph 9). The distribution is a clear representation of the pre-existence of the smart products on each category. With smart speakers and smart appliances being the oldest available products, it seems only natural that "Smart Homes" take the biggest part of the Smart Objects Payments' composition. In the same way it seems natural that "Smart Objects PoS" takes the lowest part such composition, as it was already mentioned on the Literature, it is a very innovative category where there are still a lot of improvements to be made.



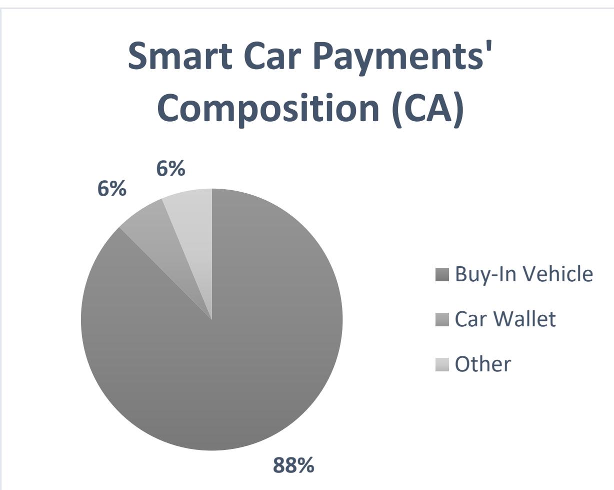
Graph 9: Smart Objects Payments Categories Composition - Source: Census

After looking at Graph 10, it can be safely assumed that the composition within the Smart Objects Payments will not remain the same. The percentage distribution given to Smart Home Payments will decrease for lack of new development. Furthermore, the category has been shown to present "Unavailable" products, which specifically refer to Amazon's Dash Buttons and AT&T dash-like buttons. This may be considered an impediment for service providers that create payment-enabled appliances, as consumers either do not possess the need to be able to order replenishments as they please by hitting a single button, or simply satisfy such need through other means. If the latter (which seems more likely) is to be the truth then, service providers may lack a motivation to further develop smart appliances. This is not the case for Smart Car or Smart Objects PoS Payments, which are clearly seeing fast advancements. Smart Cars Infotainment services have had the largest increase on subscribers of all the categories, more than doubling its number from their previous value of 0.19 million in 2017 to 0.55 million by 2020 (Statista, 2018). Considering the given data, it seems only natural that the category will continue to see unprecedented growth. Moreover, as 40 percent of the found products/services are still "On Development", it can be safely assumed that Smart Car Payments will soon be the greatest integration of the Smart Objects Payments' composition. An even more impressive development is shown by Smart Objects PoS which will expand itself by incorporating Smart Mirrors. Once again, the innovativeness of such category is made itself clear, as 75 percent of such category is still "On Development". Considering the context we are currently living in, it is not farfetched to estimate a continuous increase of Smart Objects PoS, as the implementation of the products within such category do not only provided greater customer satisfaction, but also reduce human interaction at PoS which helps to control the spread of infectious diseases.

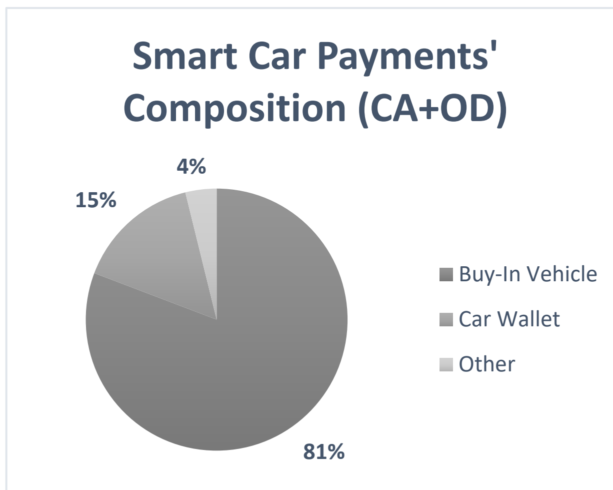


Graph 10: Smart Object Payments' Composition - Source: Census

A special remark needs to be made according to Smart Car's composition. For being on itself a smart product, the category was subdivided by the type of payment that was conducted. It is interesting to see that almost the entire Smart Car's payment services are located within the "Buy-In Vehicle" spectrum (see Graph 12), that is, Infotainment. Although it shall not remain like this for long. As Smart Cars start to become more autonomous, the category of "Car Wallet" (which corresponds to payments conducted through a wallet implemented by the vehicle) will begin to take a bigger part (see Graph 11). Finally, the "Other" category corresponds to types of payments that are neither done inside the vehicle or through a car wallet. There was only one type of service found that could not be incorporated within the other categories, that is Amazon's Key-in Car, which uses the smart car as a point of delivery drop (Hawkins, 2018). The article that mentions such service was written in 2018, which makes it a large enough period of time to say that either consumers did not want to use such service, or it might still need some enhancements to work accurately. Either way, it is still worth having on the analysis as it makes for an interesting outlier to consider. Besides, once autonomous vehicles are fully developed, their use will only be limited to their connections, which would make the re-implementing of this type of service an interesting consideration.



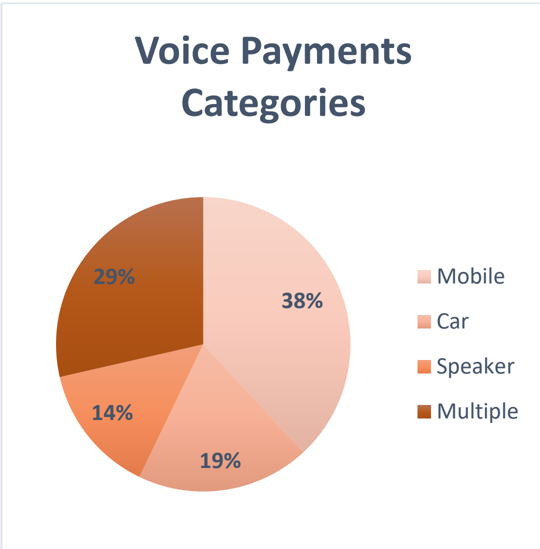
Graph 12: Smart Car Payments' Composition (CA) - Source: Census



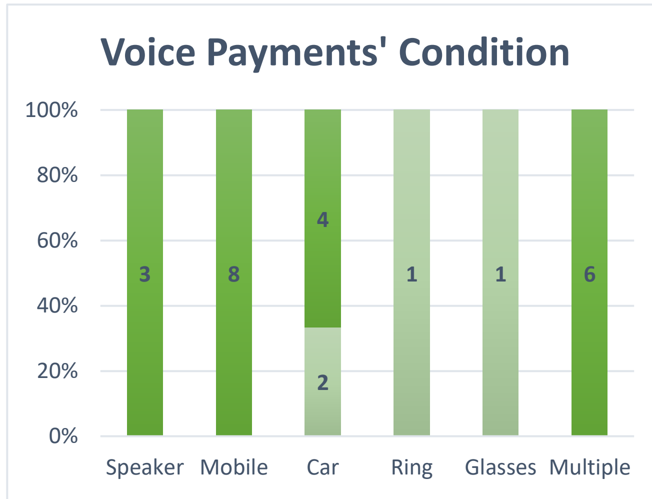
Graph 11: Smart Car Payments' Composition (CA + OD) - Source: Census

3.1.4 Voice Payments

As it is to be expected, Voice Payments are mostly integrated by virtual assistants being used on smartphones followed by those which are enabled in multiple smart objects (such as Alexa which is enable in every mentioned product) (See Graph 14). Interestingly, Smart Cars Payments by voice have surpass those made through Smart Speakers. This is a further demonstration of the already established development of Infotainment services within the Smart Cars environment. Furthermore, Graph 13 presents an increment of the products/services presented in such category. This, as well as the introduction of two new products, are evidence that the future of Voice Payments stands apart from regular devices we are currently accustomed to.



Graph 14: Voice Payments Categories - Source: Census



Graph 13: Voice Payments' Condition - Source: Census

During the Census, each category was decomposed into subcategories that noted the virtual assistant which performed the payment action. From the subdivision, two remarks struck the most. First, Amazon's Alexa is present in every category of Voice Payments, which makes it the most diffused virtual assistant from which to perform the payment process. Second, Alphabet's Google is the one that presented the greatest advancements by beginning to incorporate voice recognition into its functions. The article noted the adaptation of such capabilities for the use of smart speakers but, with a successful test run, they could be incorporated in every category within Voice Payments (Clark, 2020b).

3.2 Innovative Payments' Variables

3.2.1 IoT Areas Composition by Innovative Payments

As identified during the thesis, five IoT areas correspond to payment-enable environments (see Table 21). Through this analysis it was expected to find connections between the areas that may have identifiable consequences presented within the characteristics.

IoT Areas				
Smart Home	Smart Car	Smart Retail	Wearables	Smart City

Table 21: IoT Areas - Source: Literature & Census

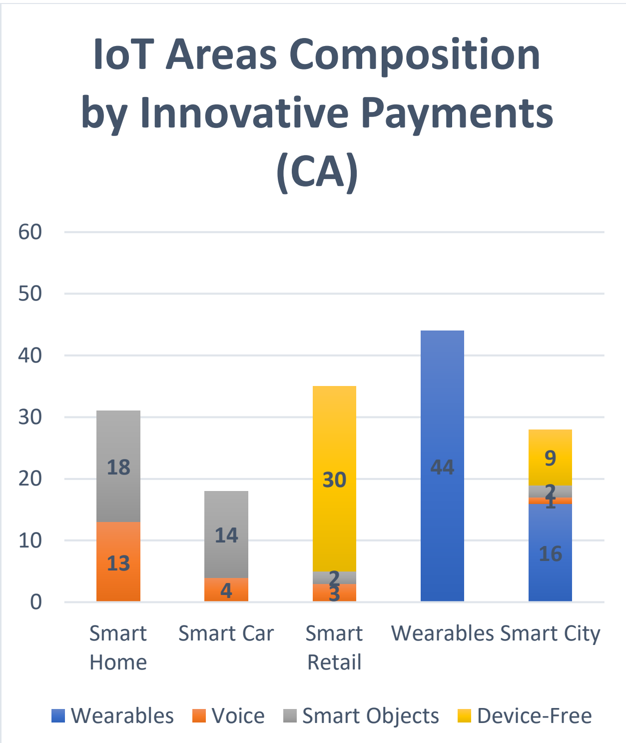
In accordance with the previous distribution, the Wearable IoT area is the one presenting the greater number of payment-enabled products/services while being closely followed by the Smart Retail area, which is mostly integrated by Device-Free products/services (See Graph 16). A possible explanation of this tight race between the two categories could be given by looking at the Smart City area. Recalling what it was said in the Methodology, Smart City is mostly integrated by developments of banks or public transport agencies. This would mean that developments within such area would have an easier access to funding either through the financial or governmental sector. Although easier access to financing and government contracts provides a good enough reason for payment providers to developed themselves within the Wearables or Device-Free payments environment, it also means that such categories would benefit from a faster growth. As it is known, the greater the financing of an industry, the faster is its development.

Differently from the previous categories, Smart Objects and Voice Payments are distribute within the areas of IoT, being its major components on the Smart Home and Smart Car areas. A possible explanation for this situation is the profiting from the networking different smart connections might provide. Every-day objects are more and more being turn into smart objects by either automating its functions or being integrated with a virtual assistant. This provides the consumer with an increase number of opportunities to fulfil its needs wherever he/she may go, independently of the object he/she is in contact with. All of this is valid provided that the object is able to carry the action of payment and deliver the desire product or service wherever the consumer wants it.

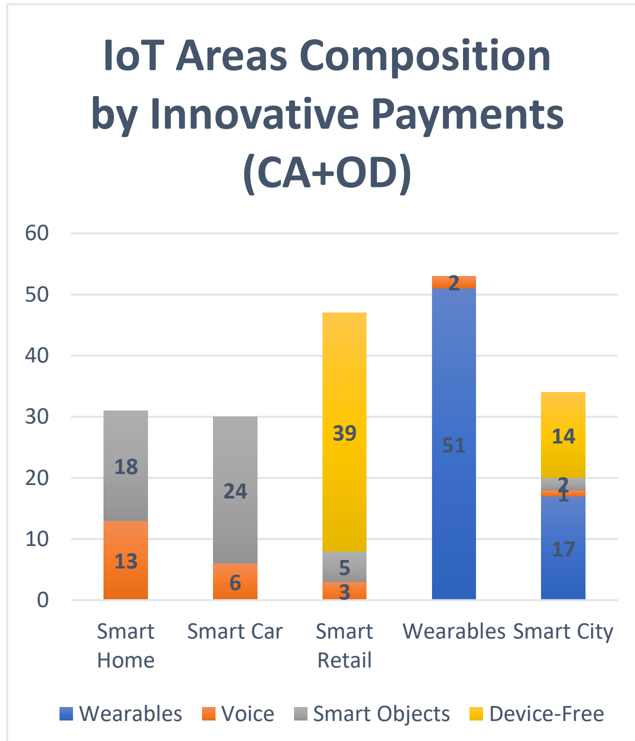
As it can be seen by comparing Graphs 15 and 16, the composition of the IoT Areas will remain quite similar. Still a few remarks can be made:

- The Wearable Payments present their largest growth among the Wearables IoT category, which suggest that the development of new wearable products is prioritize over the interaction that the products may have within other objects in the city.
- The incorporation of Voice Payments within the Wearables IoT Area provides an extensive reach of its areas of application. This may produce greater interaction among smart products which might ultimately create more payment-related opportunities.
- The Smart Car IoT Area is the one presenting the most growth, almost duplicating its size. Such growth is driven mostly by the developments of Smart Objects Payments, accounting also for a smaller increase of Voice Payments.

- The development of Smart Mirrors for Smart Object Payments expanded the influence of such category over the Smart Retail IoT Area, allowing it to become the second most influential category over the area.
- The static behavior of the Smart Home IoT Area leads to believe that service providers are focusing elsewhere to build their payment-enable products.



Graph 16: IoT Areas Composition by Innovative Payments (CA) - Source: Census



Graph 15: IoT Areas Composition by Innovative Payments (CA+OD) - Source: Census

Regarding the integration of each IoT Area through Innovative Payments subcategories, it became apparent that every subcategory was positioned on within the area one could most likely expect. For this reason, no particular graph is being shown during the analysis, although they have been included in the Appendix.

3.2.2 Innovative Payments' Connectivity

As it was presented in the Methodology, only three connectivity areas will be considered (see Table 22). This characteristic provides an insight on how smart products interact with one another. Through such interaction the cost component of the products is heavily affected. It is the objective of this analysis to determine the current and future networks that will provide such interaction within IoT payment-enabled products.

Connectivity		
Unlicensed	LPWA	Cellular

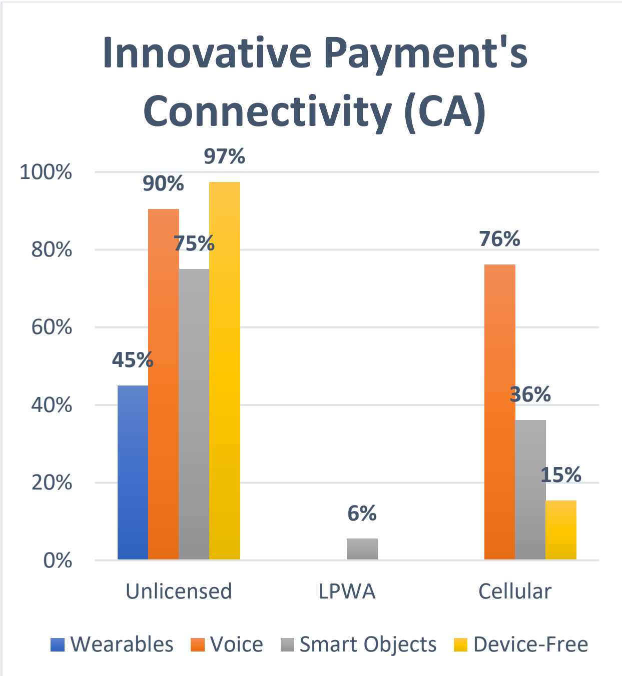
Table 22: Connectivity Types - Source: Literature & Census

Surprisingly, the connections used by Innovative Payments are mostly Unlicensed (See Graph 17), meaning not exclusive to a particular company (for example: Wi-Fi, Bluetooth, Zigbee, Z-Wave or other). At this point, a clarification needs to be made, as the use of an unlicensed connection does not mean for it to be unprotected and within everyone's reach, just that is not contractually exclusive to the company's products. Although Unlicensed connections are not as expensive as Cellular, there is still cost saving potential by profiting of LPWA connections which are almost unused by current smart products/services supporting payment capabilities. One explanation for the current situation is that LPWA are being used only in areas where the connection is constantly needed and there is a considerable distance between the smart objects (for example, smart agriculture). Most of the currently payment-enabled products use wi-fi access for the convenience of being on a wi-fi enabled area. It is not impossible to consider that once LPWA become widely distributed, more and more smart products will begin to incorporate it as the connection of choice. Consequently, the cost of using such products would decline and their accessibility should increase.

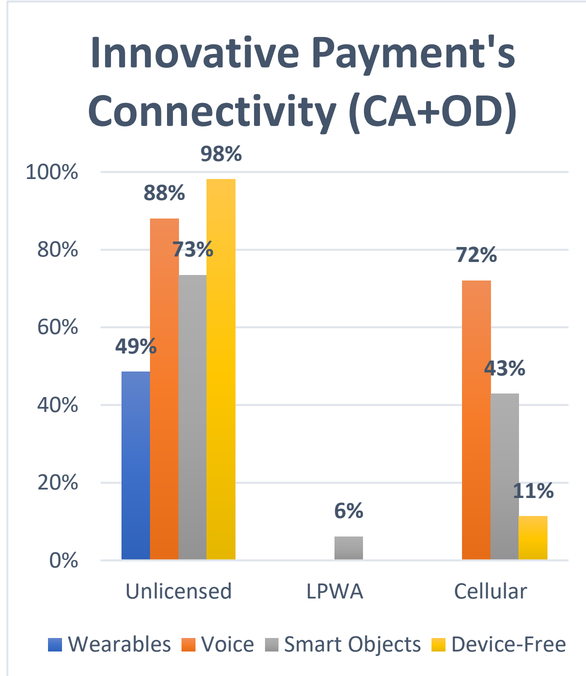
A similar situation is given by Cellular connectivity, which is mostly present on Voice or Smart Object payment-enabled products that already integrate such connectivity from a manufacturing basis. Because it is already available and greatly diffused within the mentioned categories, payment service providers take advantage of such availability by enabling their services through such connection. Once more, if LPWA connections were available on the smart product, and widely distributed over the areas on which the product is used, this could lower the service's cost and therefore, increase the use of such services.

A clarification needs to be made regarding Wearable Payments. Because it was decided not to consider NFC connections in any connectivity category, so as to differentiate the Connectivity variable from the Technology variable, all Passive Wearables were not considered to have an actual Connectivity. This is the main reason why Graph 18 only shows 45 percent of Wearable Payment products/services.

Regarding the incorporation of "On Development" products/services, there is not much change to be expected when it comes to the distribution of Innovative Payments' Connectivity. The only noticeable difference is a sizable increment on the use of cellular connectivity in the Smart Objects category, which presumably corresponds to the expected increase in Smart Car Payment products/services.



Graph 18: Innovative Payment's Connectivity (CA) - Source: Census



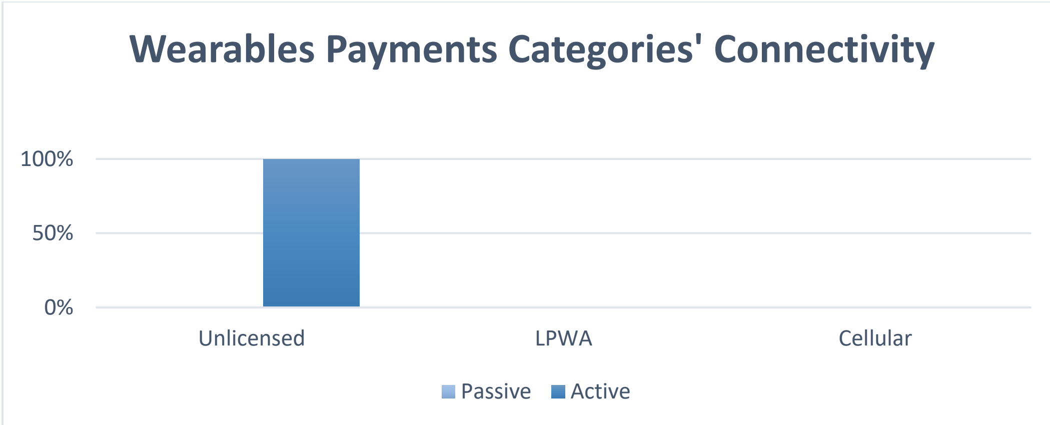
Graph 17: Innovative Payment's Connectivity (CA+OD) - Source: Census

To further analyzed the connectivity variable, each subcategory of Innovative Payments will be examined individually.

It is important to remark that the future distributions of connections will not be presented on each individual category as there were not significant changes that could provide further insights from the ones already mentioned. This means that in the near future, the connectivity through which Innovative Payments subcategories will perform the payment process will remain distributed almost identical as what it was found to be now. Nevertheless, the graphs detailing such distributions are still included on the Appendix.

<u>Wearables Payments</u>

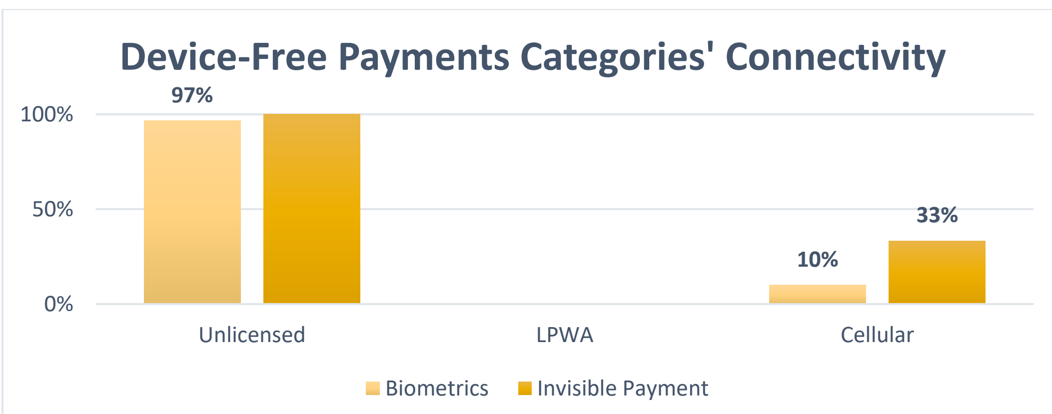
All the 27 currently available products/services that belong to the Active Wearables category, use Unlicensed connections (see Graph 19). Although it should be noted that some are able to use the cellular connection of a mobile device. This type of connection was still considered to be unlicensed as the wearable device was just leveraging on the connectivity capabilities of a secondary device.



Graph 19: Wearable Payments Categories' Connectivity – Source: Census

<u>Device-Free Payments</u>

As shown in Graph 20, Biometrics and Invisible Payments implement both Unlicensed and Cellular connectivity. Even though in both categories Unlicensed is the preferable connection, there seems to be a greater tendency for Invisible Payments to include Cellular connections. The reason for this resides on the often need for an in-app login when entering a self-service store. Because biometrics are on itself the mean of payment, they do not present such need and therefore, require less smartphone interaction, which leads to lower need of Cellular connectivity.

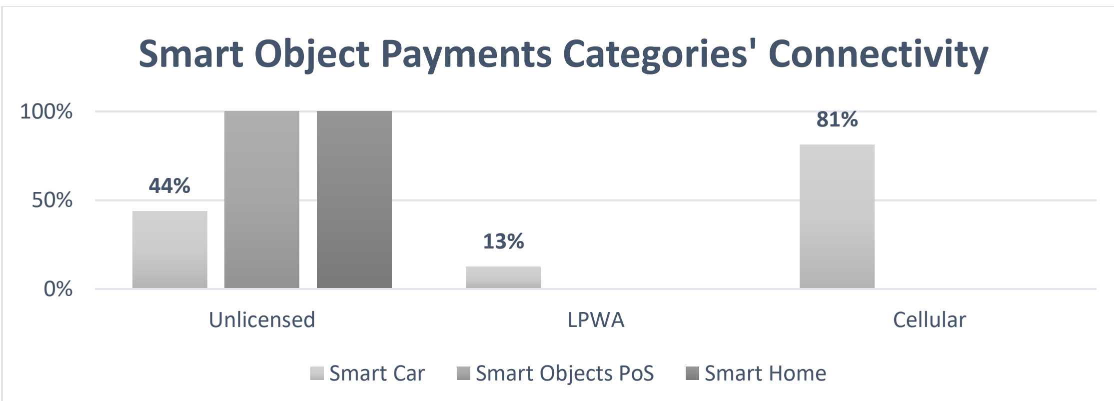


Graph 20: Device-Free Payment Categories' Connectivity - Source: Census

<u>Smart Objects Payments</u>

The Smart Car payments implements all three types of connectivity with a preference for cellular connections which are seen in 81 percent of the 16 products/services. Differently, Smart Objects PoS and Smart Home categories only use unlicensed connections. For payments conducted within the Smart Home category this seems completely logical, since we can safely assume that every home that acquires a smart product has wi-fi already set up. Instead, for payments conducted within the Smart Objects PoS category, it is only logical that the cost of enabling a Cellular connectivity for an entire shop during opening hours would make this option unreliable. It is interesting though, that the given reasons would not invalidate the consideration of a LPWA connection. Although the justification of why LPWA is not being considered is still unclear, we can safely assume that at the very least, it is not being chosen.

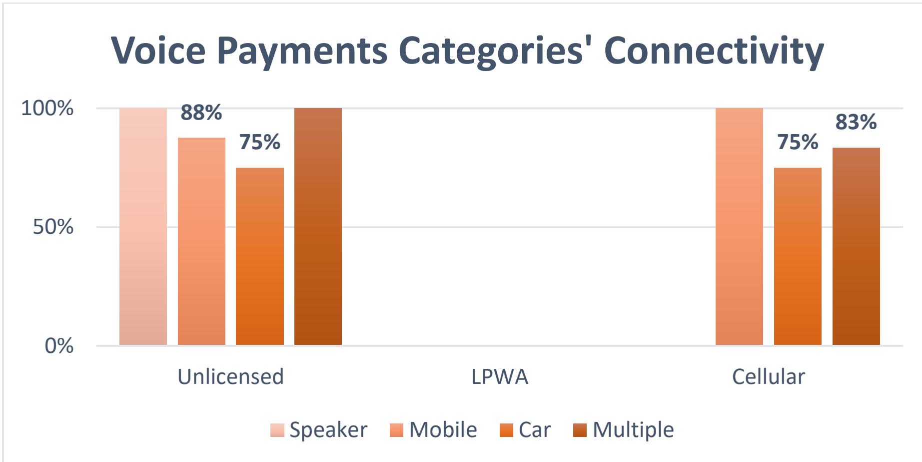
It is worth mentioning that the Smart Car subcategory is the only one of the entire Innovative Payments spectrum that uses LPWA connections, which was identified on the Literature as the option that predominates for IoT networks (Yang, et al., 2017). By analyzing the companies that implement these connections we realize that they are either auto manufacturers or technology companies which specialize on assisted parking. This is consistent with the research as it contemplates operations over large areas that required constant connections. It would be interesting to see if further development within Smart Cars imposes the use of such connectivity option over other types of IoT objects.



Graph 21: Smart Object Payment Categories' Connectivity - Source: Census

<u>Voice Payments</u>

As it is to be expected, voice payments made through Speakers use entirely Unlicensed connections (see Graph 22). That is not the case for those made via smartphones (Mobile category), which leverages entirely of Cellular connections while also incorporating in 88 percent of products/services Unlicensed connections. Strangely enough, voice payment made through connected vehicles implement both type of connections in the same proportions. One explanation for this phenomenon might be the interconnections between cars and smartphones, as some applications that are developed for the smart car are also in need for the use of a smartphone, which would require access to wi-fi or Bluetooth. Differently, the most innovative applications for smart cars, like payment for fuel through the vehicle, are enabled by the cellular connection within the vehicle. Therefore, depending on the application we are considering and its interaction with different objects, the connectivity implemented may differ. As the tendency for smart vehicles to develop its autonomy strengthens, we could expect Cellular connections within voice payments enabled by smart cars to rise.



Graph 22: Voice Payments Categories' Connectivity - Source: Census

3.2.3 Innovative Payments' Technology

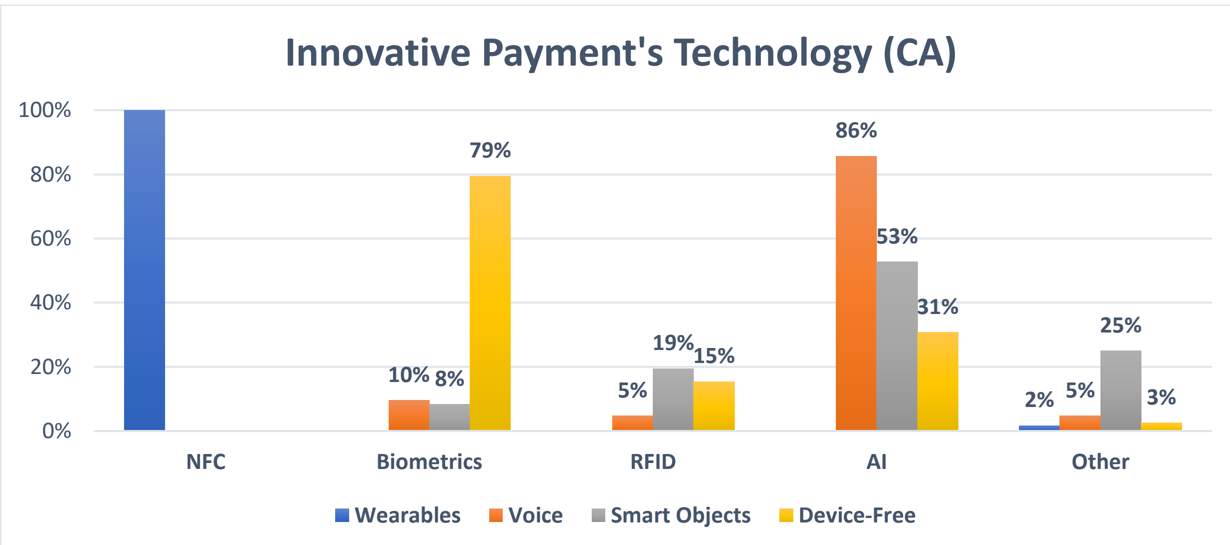
In accordance with the information retrieved from the Literature and that gathered through the Census, five categories for the Technology variable will be presented (see Table 23). It is important to remember that it was noted the technology which ultimately assisted on the performance of the payment process. In particular, the category "Other" integrates complementary technologies such as Bluetooth and Wi-fi. The analysis of this variables aims to identify the dependent technology for each Innovative Payment category, as well as the relation between the use of more than one technology.

Technology				
NFC	Biometrics	RFID	AI	Other

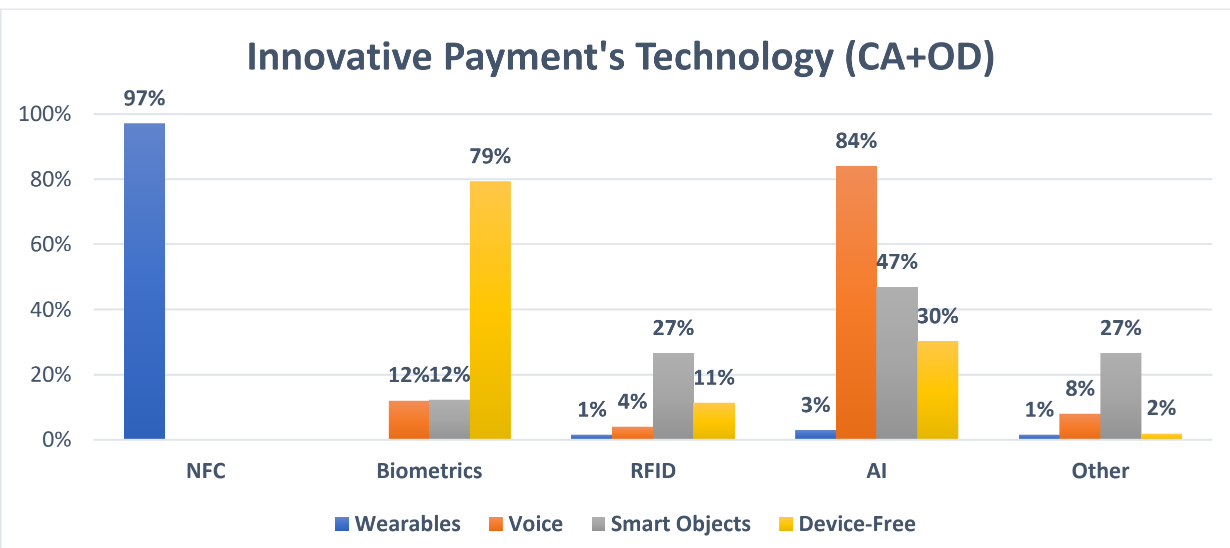
Table 23: Technology Types - Source: Literature & Census

As it was expected on the categories Wearables, Device-Free and Voice, their respective technologies (NFC, Biometrics, AI) predominated (see Graph 23). It is interesting to see that most of the categories rely on several technologies to perform the action of payment. This is proof of the increased networking between smart products. In particular, the implementation of Voice Payments through the assistance of RFID sensors on Smart Cars, or, through Biometrics in Smart Appliances are clear examples of such situation. Needless to say, the same example could be provided by looking at Smart Objects Payments and analyzing the influence of AI when assisting to perform the action of payment. Such compatibility allows for payment services to be present in more and more smart products.

When comparing the current situation with the addition of “On Development” products and services, the aspect that strikes the most is the use of Wearable Payments over technologies that differ from regular NFC (see Graph 21). The most relevant examples are: the Moscow Public Transport office by implementing the use of RFID within wearables to allow passengers pay for their ticket (Phillips, 2021), and Amazon’s new wearables through which the consumer can access Alexa, allowing AI to become the technology of payment (Amazon, 2019a; Amazon, 2019b). Both traits expand the current capabilities of wearables allowing them to fulfil the payment process in ways that differ from traditional means.



Graph 23: Innovative Payment's Technology (CA) - Source: Census

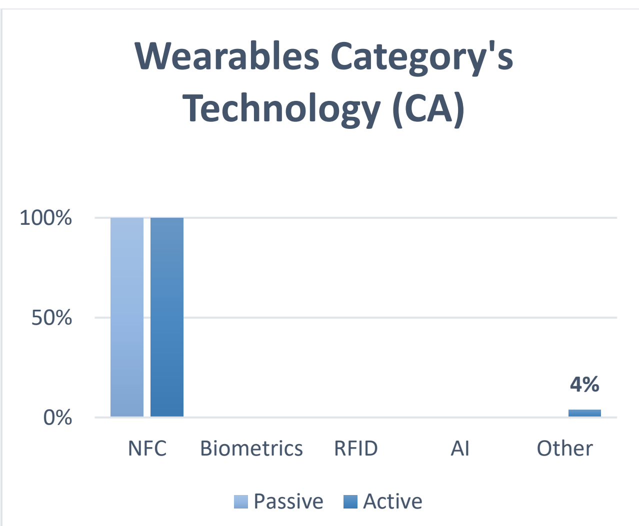


Graph 24: Innovative Payment's Technology (CA+OD) - Source: Census

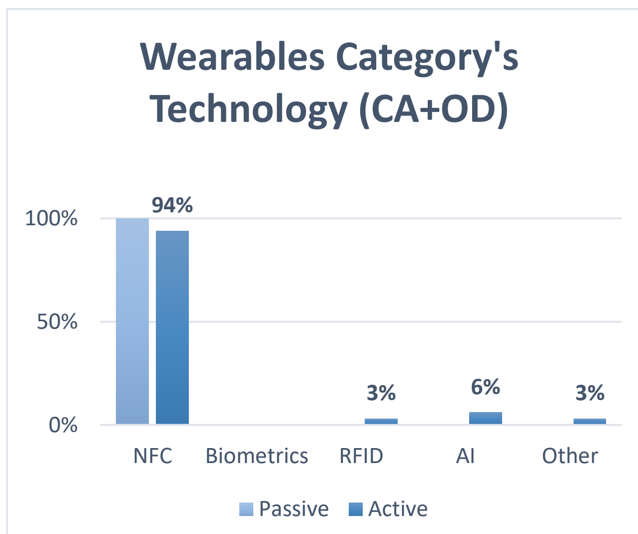
It would be interesting to take a closer look at every Innovative Payment subcategory to understand further changes within one another.

Wearable Payments

The analysis over wearable payments allows to identify the previously mentioned new types of technology as part of the Active Wearables category. Although this is not the only noticeable consideration to be made, as the percentage of NFC use in Active Wearables diminishes. This means that the new technologies are not expected to act in addition of the current execution of the payment process by NFC, but it aims to replace such option and incorporate other technology instead. Having said this, there are two reasons why it would be highly unlikely for a new technology to replace NFC as the choice of preference. First, consumers have already shown their acceptance on the use of current wearable products to conduct payments, while there is still not enough information about the incorporation of AI systems within wearables and their use towards the same function. Second, systems which leverage on current wearable technology (for example, public transport) are being developed faster than ever before, which may not be easily adaptable towards the inclusion of other technologies. The mentioned reasons are more than enough to assure the continuance dominance of NFC within Wearable Payments.



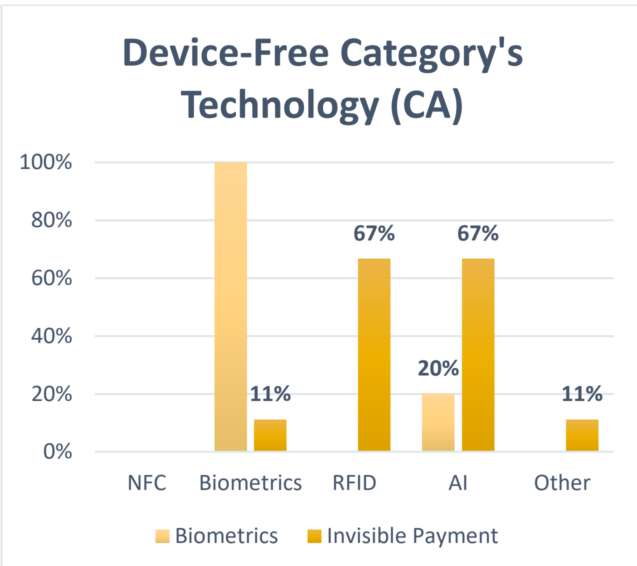
Graph 26: Wearables Category's Technology (CA) - Source: Census



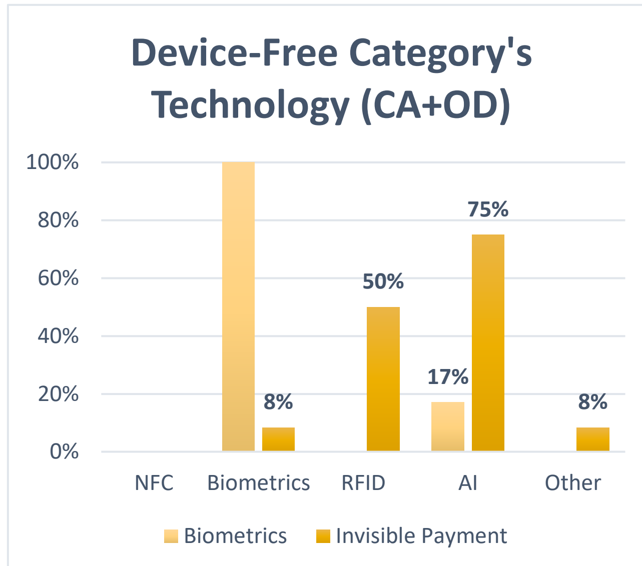
Graph 25: Wearables Category's Technology (CA+OD) - Source: Census

Device-Free Payments

Differently from other Innovative Payments categories, the intricacies of how Invisible Payments perform the payment action do not seem so clear at first hand. By looking at Graph 27 and Graph 28, we notice that they offer a slight change on their technology of preference by selecting AI-enabled services. This does not come as a surprise but might suggest a greater trust of AI's tracking capabilities. The alternative to a sole AI-enabled Invisible Payments' store is that which tracks the taken product by the use of RFID technologies. If AI are sufficiently capable of distinguishing one customer from another and keep track of every taken product by their own means, that would render the use of RFID redundant. This might be good news for consumers, as the requirements to build an Invisible Payments' store would diminish, which ideally makes it more accessible for implementation of new service providers.



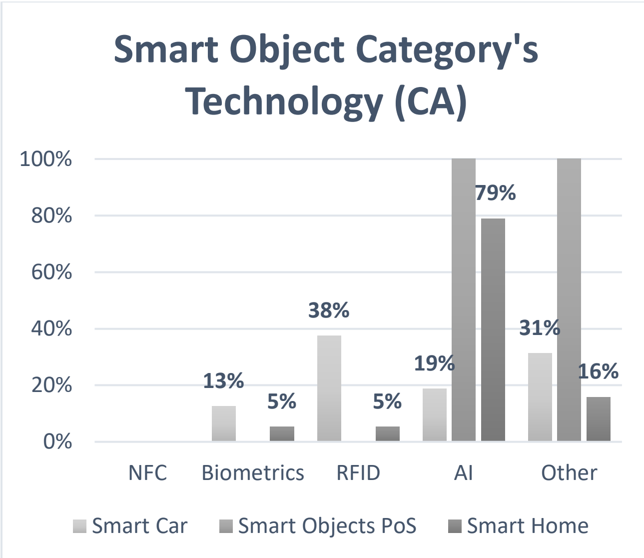
Graph 28: Device-Free Category's Technology (CA) - Source: Census



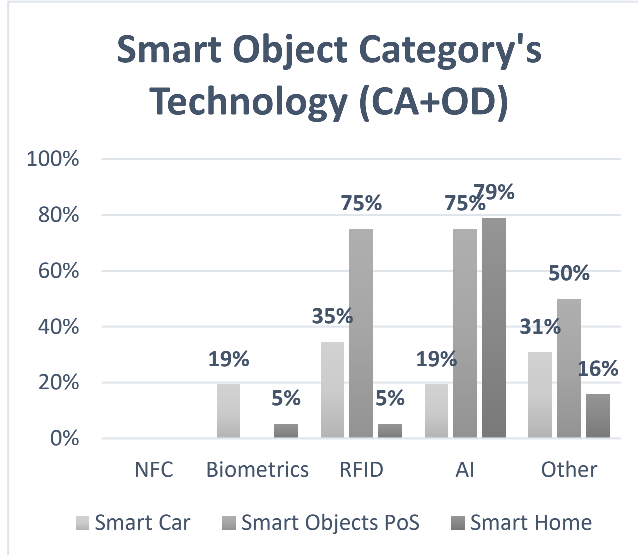
Graph 27: Device-Free Category's Technology (CA+OD) - Source: Census

<u>Smart Objects Payments</u>

Smart Objects Payments present the largest technological variations. By comparing Graphs 29 and 30, we notice an increase on Smart Car's use of Biometrics, while a decrease of their use of RFID. This suggests a further development of infotainment services (noted as "Buy-in Vehicle" in the Smart Car's composition) over the rest of the categories. In particular, services which do not focus on parking assistance, as it has been shown that those usually integrate RFID technology. Furthermore, there are noticeable changes for the Smart Objects PoS category. Those variations are the result of the appearance of Smart Mirrors and new models of Smart Carts, all of which incorporate RFID technology.



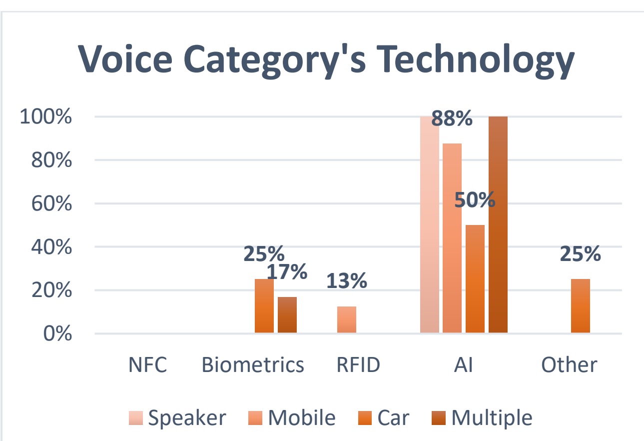
Graph 30: Smart Object Category's Technology (CA) – Source: Census



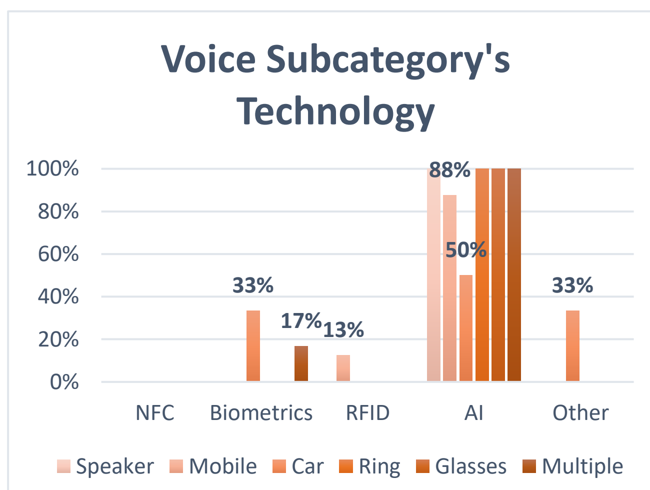
Graph 29: Smart Object Category's Technology (CA+OD) - Source: Census

<u>Voice Payments</u>

The percentage distribution over the technologies used within the Voice Payments categories remains exactly the same with the exception of the voice payments conducted by car, which increase their connections both in the “Biometrics” and “Other” types of technologies. One explanation for this might be the need to incorporate simpler verification methods. We should take into consideration that this category accounts for payments that are conducted by voice while inside the vehicle, which would more often than not mean while driving. The incorporation of biometrics as a mean of verification may simplify the purchasing process, which increases user satisfaction and consequently the use of such payment service.



Graph 32: Voice Payments Category's Technology (CA) – Source: Census



Graph 31: Voice Payments Category's Technology (CA+OD) – Source: Census

3.2.3 Innovative Payments' Interaction

The type of interaction is an interesting variable to be considered as it allows to clearly visualize the percentage of completely autonomous payments to be made within a category. It is the first time in history where machines are able to engage in the payment process among one another and without the requirement of any human intervention. This type of development should be particularly studied as it is still unclear the amount of purchasing power that we should give to smart products.

It is important to remember that, for simplification, the categories where label "Human-to-Machine" (H2M) if a person was participant at any moment of the purchasing process, or "Machine-to-Machine" (M2M) if the process was completely autonomous (See Table 24).

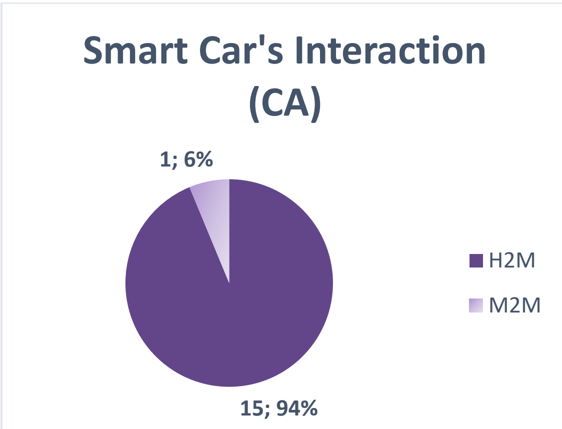
Interaction	
H2M	M2M

Table 24: Interaction Type - Source: Census

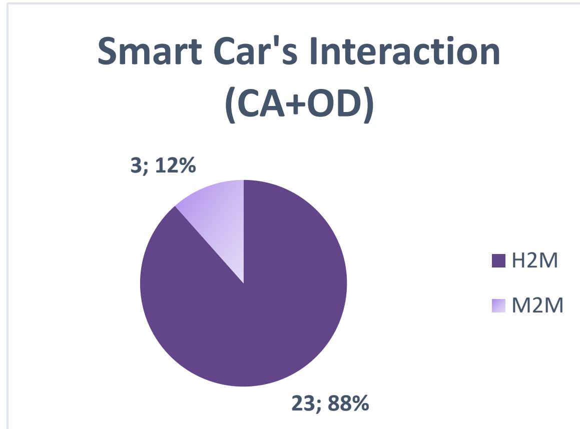
Even though every category was initially considered for this type of analysis, the only subcategory that presented M2M payments within Smart Objects Payments, specifically "Smart Car". For this reason, the rest of the analysis shall concern only such subcategory.

The innovativeness of M2M interactions is once again evident, not for its lack of appearance in every other subcategory but, as seen in Graphs 33 and 34, its size overall the Smart Car's subcategory is minimum. As it was described in the Literature, a machine requires a digital ID to interact with another machine. At the same time, it requires access to payment credentials store within itself, which would mean that it requires access to a digital wallet. By the logics of this reasoning, it is only natural that we would find this type of service within the "Car Wallet" composition of Smart Car's Payments. However, it is interesting to notice that not all available services within the "Car Wallet" composition provide a Machine-to-Machine Interaction. In fact, a Car eWallet system developed by IBM is noted as a "digital assistant in the car that allows secure and convenient payments even on the go" (Del Castillo, 2017). This implies that car wallets might have been first introduced to assist the driver but are now being developed to assists the vehicle itself.

Through the Census, it was noted that M2M services are mainly being provided by Automotive companies, with the exception of the startup Car IQ which, according to its classification on Yahoo Finance (2021), is not just considered an Automotive but a FinTech as well. Furthermore, Car IQ provides the only available service, as those provided by Daimler Trucks and Jaguar Land Rover are still on development. This shows even though incumbents are striving to take advantage of the technology, startups may develop faster, which ultimately implies that they shall decide the limitations and applications of the technology.



Graph 34: Smart Car's Interaction (CA) - Source: Census



Graph 33: Smart Car's Interaction (CA+OD) - Source: Census

3.2.4 Innovative Payments' Business Type

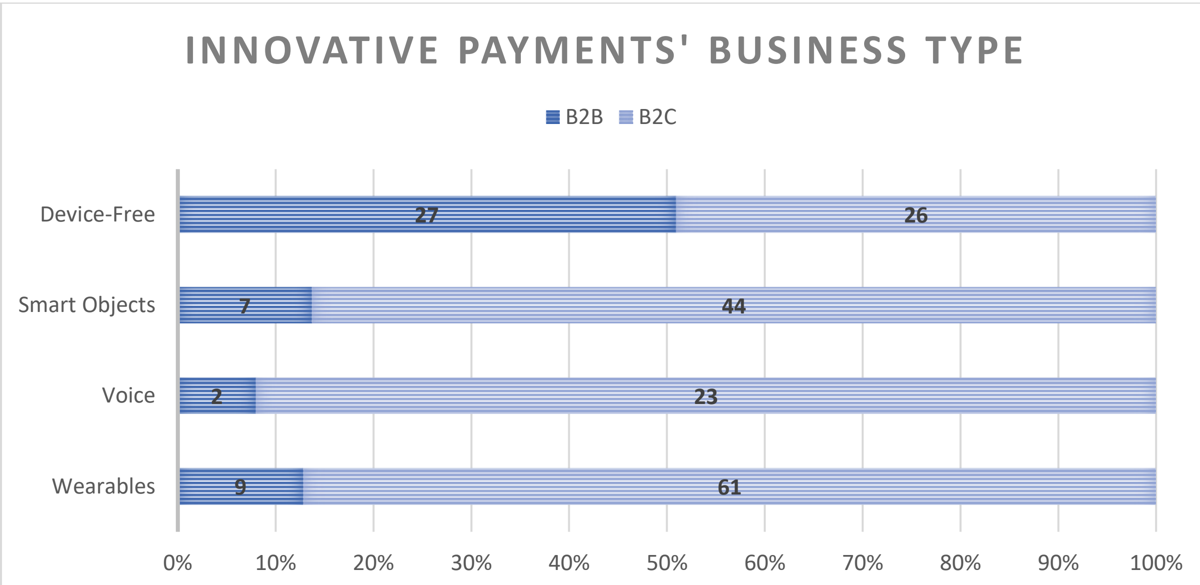
The Business Type variables is used to further understand the differences among Innovative Payment's categories, looking for additional information towards its development and the type of interactions that each company working within the payment environment might have. For simplifications sake, the variable has been divided into two possible values, Business-to-Customer (B2C) and Business-to-Business (B2B).

Business Type	
B2C	B2B

Table 25: Business Type - Source: Census

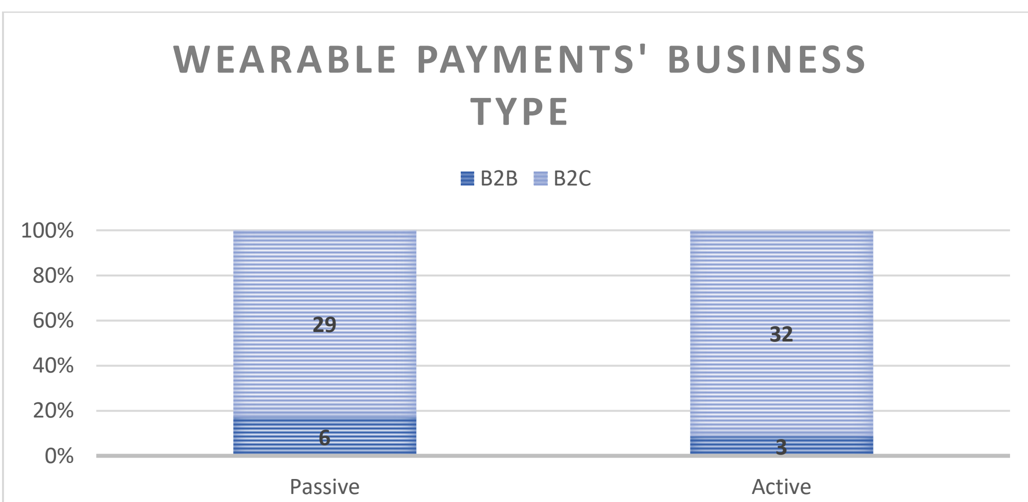
By looking at Graph 35 it is clear that the business orientation within the Device-Free Payments category differs from that present in the other types of Innovative Payments. The distribution signals that there is an almost equal development of the companies whose business is inclined to build device-free payment environments and those whose business is to offer the customer such service. An explanation for this phenomenon could be that the know-how required to build such system is extremely specific and completely different from the one required to run it. If this were to be the case, it seems logical that in order to provide such type of service to customers, retailers would need to make partnerships with specialized technology-oriented firms in order for them to develop such system.

The situation is completely different for the other categories of Innovative Payments. One explanation for such difference is that because Smart Objects, Voice and Wearable Payments are much more object oriented, there is no need for a third party to build an accessory part of the system, if any at all. Having said this, partnerships are still needed in order to expand the capabilities of smart products. It is for this reason that we should always find a combination of the two business types, instead of a complete dominance of one over the other.



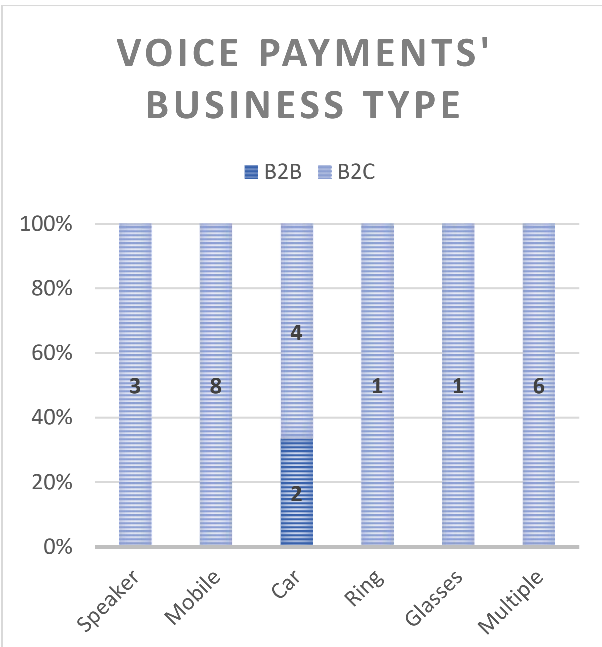
Graph 35: Innovative Payments Business Type - Source: Census

By analyzing Wearable Payments individually, we notice that Passive Wearables account for a greater percentage of B2B companies than Active Wearables (see Graph 36). This is a reasonable distribution, as more than 25 percent of the researched firms that developed Passive Wearables are located on the fashion industry, which suggest that they would require to form a partnership with technology firms whose service would be to provide the technological expertise required for the Passive Wearable to perform the action of payment.

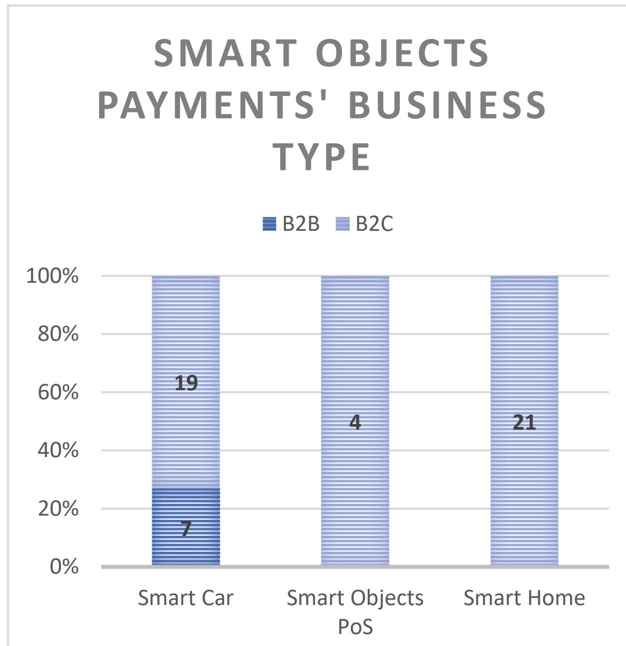


Graph 36: Wearable Payments' Business Type - Source: Census

In both categories, Voice and Smart Objects Payments, the only B2B companies are present within the "Car" and "Smart Car" categories respectively (see Graphs 37 and 38). This helps to partly validate the previously mentioned theory where the companies that develop the smart products within the mentioned categories do not require external assessment for the object to perform the payment process. Smart Cars differ from other categories because of the unprecedented growth they are currently going through, which do not only enable innovative services, but different technologies through which to process payment services. The implementation of such technologies and services may require external assistance, which would explain the incorporation of B2B enterprises within such category.

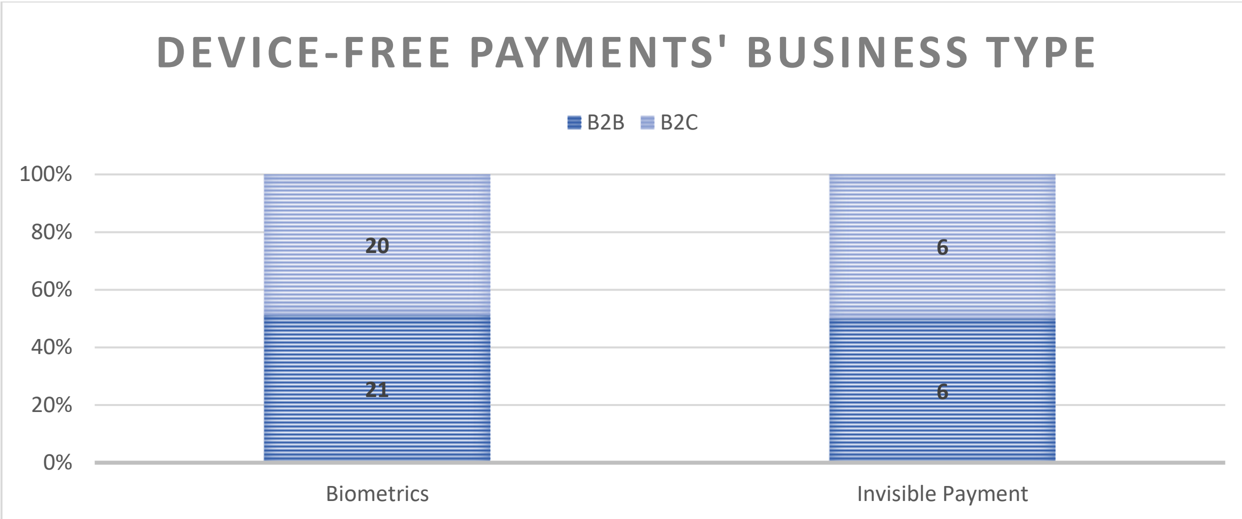


Graph 38: Voice Payments' Business Type – Source: Census



Graph 37: Smart Objects Payments' Business Type - Source: Census

Finally, Device-Free Payments categories seem to be equally distributed in terms of business type (see Graph 39). This distribution serves as further confirmation of the theory announced for payments within smart cars. Recalling what it was said on the "Technology" analysis, smart cars are increasingly incorporating biometrics as their payment-enabling technology, which might once again demonstrate that the incorporation of new technologies requires the assessment of external specialized companies.



Graph 39: Device-Free Payments' Business Type - Source: Census

4. Conclusions

During this chapter, the main findings will be presented on the same style as the development of the Empirical Analysis, meaning that first an overall conclusion will be delivered for Innovative Payments and then a deeper focus on each of its categories will be considered. At the end of the results a section will be dedicated to suggestions for further research on the subject.

Before presenting the results, it is important to highlight the main limitations of the analysis. First, the available information for Innovative Payments is scarce. The lack of data relating the use of smart products to conduct payments makes it difficult to dissociate the payment service from the product on itself. Second, most of the smart products that have been analyzed had only been implemented in small areas and are still in need of testing around different environments. Both mentioned aspects are valid reasons to consider that the same category of innovative payment could developed differently either by technology or connections, depending on the area it is implemented. As it was mentioned on the Literature, the evolution of new forms of payment depend upon each region's socio-demographic factors, as well as user's perception towards new payment instruments characteristics (transaction speed, cost, safety, and user-friendliness) (Van Der Cruijsen & Plooij, 2015). Third, the products/services analyzed could not be tested because of the presence of extensive entry barriers (either for availability or the requirement to purchase the object). The testing of such innovative services could provide insights on user experience which would be much more determinant for their future development than those gathered by technical characteristics. Finally, in spite most products/services are relatively new (where the articles that mentioned them were from 2018 forward), some of those that were incorporate in the analysis were mentioned in articles that dated as back as 2014. Although this does not invalidate the analysis done, a more accurate description of current smart products' payment related characteristics could be provided by conducting a future search which restricts the incorporation of products that have been released after a certain period.

4.1 Key Findings

4.1.1 Innovative Payments

The overall results for Innovative Payments have been summarized on the table below.

Variables\Innovative Payments	Wearables	Device-Free	Smart Objects	Voice
Current Composition	38%	25%	23%	14%
OD Variation	-3%	+2%	+2%	-1%

IoT Area of Dominance	Wearables	Smart Retail	Smart Car	Smart Home
Connectivity of Preference	Unlicensed	Unlicensed	Unlicensed	Unlicensed
Dominant Technology	NFC	Biometrics	AI	AI
Incorporates M2M Paym.	No	No	Yes	No
Dominant Business Type	B2C	B2B	B2C	B2C

Table 26: Innovative Payments Summarized Results - Source: Census

Considering the findings detailed during the Empirical Analysis, we may divide the categories of Innovative Payments into two groups.

On one side, we have Wearables and Device-Free Payments, which are characterized by having the greatest number of service providers. They are being developed in two IoT Areas, one of which is Smart Cities. The access to such area provides a greater interaction with governmental agencies as well as with banks. This not only helps such service providers to have easier access to funding which consequently stimulates faster growth, but it also helps them to leverage on the fundamental characteristics that payment systems need. Those, which were mentioned during the Literature, are: the facilitation of transaction occurrence and the reduce of transaction costs. The first, stimulates consumers by reducing their lack of familiarity and thus, their learning costs. After all, if regular users encounter such systems on their day-to-day life (for example, while taking the public transport), they will be easier accustomed to the system at hand which will increase their trust for its use around retailers. The second, allows for greater implementation of the systems in different environments. When transaction costs are reduced, the entire payment system benefits, as consumers are more incline to use such payment system. Furthermore, the main increment in IoT Areas came from both Wearables and Smart Retail for Wearables and Device-Free Payments respectively (as shown on Table 23). This proofs that the main developments within both categories is to increase the number of services being provided instead of leveraging on the types of services that an increment of the Smart City area could provide. Moreover, when analyzing the type of connectivity as well as well as the type of technology implemented, it was found that both areas have a preference for Unlicensed connections while using almost a single type of technology to enable the payment process. At this point, a clarification needs to be made, as Device-Free Payments present several types of enabling-technologies, but if we considered the systems implemented within such category, we can realize that each system is mostly supported by a single type of smart product that for its complexity may require the use of more than one type of technology. These singularities in terms of connectivity and technology are signals of the prioritization of a single-type product/service over the need of extensive networking. This might seem strange, as it is being analyzed as part of the IoT system which it was mentioned to be an ecosystem of interconnectivity, but we should notice that it does not negate the connections with the system on which it is involved, it just tells us that the focus is on improving the single product/service over such connections. Finally, by looking at the business type variable, we notice that Device-Free Payments' complexity urged for the partnership between technology experts and payment service providers. This translates into an increase of B2B firms over the regular B2C a smart products' payment provider is expected to have. This is not the case for Wearable Payments, which is much more dominated by B2C companies as the focus relies on the product and not the partnerships.

On the other side, we have Smart Objects and Voice Payments which have the least number of service providers. As it has been showed, both categories are dispersed among the IoT Areas, which suggest a higher interest of networking between products/services. In this case, a further development of the products is not being prioritize. Instead, the capabilities of such products are being expanded by their interaction with objects outside their regular environment. Although, there is one exception that has been greatly enhanced in recent time, that is Smart Cars, further distinctions of such product will be noted later on within the Smart Objects' conclusions. Moving back to Smart Objects and Voice Payments general characteristics, it should be mentioned that the development of new products (AI-enabled glasses or rings, and smart mirrors) enabled their insertion, or expansion, into different IoT Areas. By continuously increasing the type of smart products available, so does the networking capabilities of such system. This leverages on one of the fundamental principles of payment systems described on the Literature, Network Scalability. With a greater network available the payment options are exponentially increased, either by buying a movie ticket directly from the vehicle while going to the movies or buying a cup of coffee by placing orders through your glasses while going to work. Ultimately, this creates a whole new set of payment opportunities from which consumers could leverage. Moreover, these two groups saw a balance connectivity, not just incorporating Unlicensed connections, but integrating Cellular and in few cases LPWA. These is further proof of the profiting of connections between different smart products. A greater network requires constant availability of connectivity options. The same example could be made by looking at the results achieved from the technology variable. As both categories incorporate almost every type of payment-enabling technology, which suggest the use of the different objects within each category to ultimate conduct the payment process. Finally, the business type variable signals a focus oriented towards products instead of business partnerships. At first it may seem a contradiction towards the information just presented, but if we consider that there are just a few service providers then we notice that a focus towards the development of different products was to be expected, which would implicate a B2C domination.

The last remark to be made revolves around fully autonomous M2M payments. This type of payment was only present on the Smart Objects category, with a very small percentage (6 percent) over the entire products/services within the category. Even though it might be too early to begin an accurate assessment of such payments there are a few points worth mentioning. First, the fact that the other categories did not show any type of product capable of conducting the payment process by itself is unsurprising. By looking at the subcategories within Innovative Payments and the divisions within the subcategories, we notice that this type of payment is present only within Smart Cars, specifically within its "Car Wallet section". This tell us that in order for a machine to conduct payments on its own, it is a requirement for it to have access to a digital wallet. This condition is fulfilled by only a few smart products of those that have been analyzed. Between those products we find wearables and smartphones. Even though both products can access a digital wallet, they are always in contact with a person to conduct the payment action. Given this situation, it seems unlikely that they will be able to achieve fully autonomous M2M payments. Although, we must not disregard the possibilities of a future intelligent virtual assistant which might be capable of performing such action. As wearables recently incorporated AI systems within them, this theory might include the development of such payment type within the wearable category.

4.1.2 Wearable Payments

The overall results for Wearable Payments have been summarized on the table below.

Variables\Wearables	Active	Passive
Current Composition	45%	55%
OD Variation	+5%	-5%
IoT Area of Dominance	Wearables	Wearables
Connectivity of Preference	Unlicensed	None
Dominant Technology	NFC	NFC
Incorporates M2M Paym.	No	No
Dominant Business Type	B2C	B2C

Table 27: Wearable Payments Summarized Results - Source: Census

The wearables results provided an insight towards where the product is heading. Several advancements on the NFC technology fomented the incorporation of such device into strange places (such as nails). Although not every type of wearable is destined for success. Along the many type of Passive Wearables that have been developed, clothing items do not seem to have much acceptance. They were the oldest products introduced into the Census while occupying one of the lowest values in terms of wearable compositions. This is a clear indication of unacceptance by the market. Still, the current situation remains an increase on the number of Passive over Active Wearables. But this does not seem to be the case for long. The number of Active Wearables that are "On Development" surpass those of Passive Wearables. This is thanks to the insertion of new types of wearables such as smart glasses or smart rings. In fact, the tendency for the development of smart rings is on the rise. After smart watches, it has been found to be the second largest portion of Active Wearables composition. Although this case is not reciprocated by Passive Wearables, which include regular rings on a third spot right after bracelets. This suggests that the different functionalities contemplated between a smart ring and a smart watch may motivate consumers to view them as an alternative choice. Furthermore, service providers seem to be convinced of such situation that continue to increase the development of such products instead of producing more smart watches or bracelets.

Regarding the connectivity of wearables, they presented entirely Unlicensed connections. This was to be expected, as they take advantage of the connections present within their environment. Without a modification of the environment, changes within the single object will not be viable. The same concept relates towards their selected technology. Even though wearables are currently incorporating the use of alternative technologies, such as AI, their environment is already developing systems that leverage on their use of NFC antennas. Such developments would make nearly impossible to modify the predominant technology.

Considering the business type, it was logical to see a dominance of B2C businesses. This is because most firms working within this category are already targeting the end of line that are customers. Although it must be taken into consideration that fashion-oriented firms which sell Passive Wearables, do need to alliance themselves with technology or financial firms to enhance their products with the necessary requirements to conduct the action of payment.

4.1.3 Device-Free Payments

The overall results for Device-Free Payments have been summarized on the table below.

Variables\Device-Free	Biometrics	Invisible Payments
Current Composition	77%	23%
OD Variation	+5%	-5%

IoT Area of Dominance	Smart Retail	Smart Retail
Connectivity of Preference	Unlicensed	Unlicensed
Dominant Technology	Biometrics	AI + RFID
Incorporates M2M Paym.	No	No
Dominant Business Type	B2B	B2B + B2C

Table 28: Device-Free Payments Summarized Results - Source: Census

The category that predominated within Device-Free Payments was Biometrics. Several reasons can explain such behavior, for example the straight relation between biometrics and security. As we all know, before incorporating biometrics as a mean of payment confirmation it was mainly used on a few devices as a means of alternative password measure, with the most common example being the facial authentication to enable PC or smartphone access. On the Literature, it was already mentioned a connection between perceived payment security, trust, and electronics payments' use (Kim, et al., 2010). Considering such connection, it is possible that consumers are already well predispose to the use of biometrics as a mean of payment. This is not the case for Invisible Payments, which are completely innovative and incorporate technologies which consumers do not see, even less fully understand. The ease in consumers acceptance for biometrics combined with the complex development of Invisible Payments environments are reasons enough to justify the presented results.

An interesting remark must be made on the types of biometrics. As it was mentioned, the most developed type of biometric is Facial Recognition, which is why it was expected to be the predominant payment-enabling technology. Although this situation is not expected to change for quite some time, its dominance among the biometrics' composition is diminishing. Thanks to technological advancements, new types of biometrics are taking a bigger role. Behavioral Biometrics are being incorporating more than ever by Banks, while Finger Vein ID is being tested by different types of retailers, pubs or even dinners. But that is not all, the future development of Voice Recognition may be the greatest advancements towards biometrics yet to be made. This is because its incorporation on smart objects may allow for an unprecedent growth in the use biometric payments. As it has already been showed, Voice Assistants have been the most diffused IoT devices, reaching 4.2 billion devices in 2020 (Voicebot.ai, Business Wire, 2020). Although it should be noted that this is merely speculative and in need of further review.

Device-Free Payments have been showed to incorporate both Unlicensed and Cellular connectivity. Although the cellular incorporation is mostly thanks to Invisible Payments, which usually required a smartphone in order to link the consumer with its payment credentials and allow him/her to enter the premises. A similar situation is given through their payment-enabling technology, which in the case of Invisible Payments is distributed mostly between RFID and AI. Depending on how the whole environment is set up, either one technology or the other might be implemented, and in some cases even both (PYMNTS, 2020). The two characteristics suggest that there is not a fully established way of constructing an Invisible Payments' environment. Without a clear guideline on how this type of stores are constructed, it is not easy to determine the repercussions that technological decisions may have on costs. For now, and in accordance with the connectivity characteristics described in the Literature, we can guarantee that the selected connections are accounting for a higher expense than what is possible. This may be an indication that there is still further development for Invisible Payments' stores to be made.

The previous theory is also supported by the analysis made on the Business Type variable. It was found that both Biometrics and Invisible Payments were produced within the same proportions by B2C and B2B companies. This suggests that in order to build such payment services the assistance of different types of companies, in particular technology-oriented ones, is required.

4.1.4 Smart Objects Payments

The overall results for Smart Objects Payments have been summarized on the table below.

Variables\Smart Objects	Smart Car	Smart Objects PoS	Smart Home
Current Composition	44%	3%	53%
OD Variation	+9%	+5%	-14%
IoT Area of Dominance	Smart Car	Smart Retail	Smart Home
Connectivity of Preference	Cellular	Unlicensed	Unlicensed
Dominant Technology	AI + Other	AI	RFID
Incorporates M2M Paym.	Yes	No	No
Dominant Business Type	B2C	B2C	B2C

Table 29: Smart Objects Payments Summarized Results - Source: Census

The Smart Objects Payments categories presented the greatest change. Currently available products established Smart Home as the category of dominance, but this situation will not remain for long. The smart products that integrate the Smart Home category seem to have reach a growth impediment, as neither of the found products or services could be classified as "On Development". Furthermore, several innovative products capable of enlarging the subcategory of Smart Appliances such as Amazon's dash button have been discontinued. The situation is completely different for Smart Car and Smart Objects PoS as both categories have seen unprecedent growth. Such is the case that the distribution of Smart Objects

Payments will change, with Smart Car being on the new dominant position. Even though Smart Objects PoS will still be at the lower end of the composition, it is worth noticing that 75 percent of the category is "On Development". This assures its innovativeness and confirms that it is a category worth considering on any future analysis.

Looking more precisely at the advancements made within the Smart Car category, considerable growth has been seen from the "Buy In Vehicle" subcategory, in particular relating parking services. This makes sense, as the percentage of products/services that incorporated LPWA connectivity (mainly used for parking) is expected to rise. But that is not all, the Wallet subcategory has also presented considerable growth. In fact, this might be the most interesting subcategory, as within it resides the development of fully autonomous M2M payments. From the different products/services presented within the Smart Car category, we learn the capabilities that fully M2M payments may incorporate. Although the integration of regular smart services, such as paying for fuel or tolls while driving autonomously, are impressive characteristics, the incorporation of other types of services (for example Amazon's Key in Car, presented on the category "Other") is what leave the possibility for further enhancements still open. This allows me to conclude that the development of smart cars is far from over. In the future, we should give special consideration to those services from which we can benefit while not even present in within the vehicle, as this might be the greatest use for M2M payments.

4.1.5 Voice Payments

The overall results for Voice Payments have been summarized on the table below. Notice that because the table considers "Currently Available" conditions, some products have their variables noted as with an "E" superscript which signals it is an estimated result as the product is not yet available.

Variables\Voice	Mobile	Car	Speaker	Multiple	Ring	Glasses
Current Composition	38%	19%	14%	29%	0%	0%
OD Variation	-6%	+5%	-2%	-5%	+4%	+4%
IoT Area of Dominance	Smart Home	Smart Car	Smart Home	Smart Home	Wearables	Wearables
Connectivity of Preference	Cellular	Cellular + Unlicensed	Unlicensed	Unlicensed	Unlicensed^{E}	Unlicensed^{E}
Dominant Technology	AI	AI	AI	AI	AI^{E}	AI^{E}
Incorporates M2M Paym.	No	No	No	No	No^{E}	No^{E}

Dominant Business Type	B2C	B2C	B2C	B2C	B2C	B2C

Table 30: Voice Payments Summarized Results - Source: Census

Voice Payments can already be distinguished as one of the most diverse Innovative Payment's category, and with the development of new AI-integrated smart products (such as rings or glasses), it is only expected to keep expanding. Payments made through smart cars by voice have already surpass those made through smart speakers, which signals a considerable growth from the side of the former (in accordance with what it was previously mentioned for the Smart Car category in Smart Objects Payments). Such growth may be a reason why smart cars are increasing its use of biometrics as a payment-enabling technology. With the development of more Infotainment services that are commanded by voice, biometric confirmation comes helpful not only regarding the security of the payment system, but also that of the driver which can simply finish the transaction by looking to its rearview mirror. As it is to be expected, such technological advancements required an expert hand in order for them to be implement. For this reason, it is not surprising that the "Car" incorporates B2B firms. Although, this is not the case for the other categories. Once again, this leads us to believe that Voice Payments are mainly integrated by product-oriented agencies, which are not inclined to required technological assistance.

Regarding Voice Payments' connectivity, it was noticed that they leveraged not only on the connections provided by the environment where its enabling product is located, but also of though generated by the product itself, as it is the case for Cellular connections in cars and smartphones. This suggest that even a change in the environment would not completely modify the connection of preference. Having said this, it would be interesting to see if changing the available connection of a certain environment would incite service providers to select a different option.

4.2 Final Remarks

After presenting the conclusions of every category, it is imperative to consider the system as a whole and note the most prominent findings:

- The categories of Wearable Payments and Device-Free Payments can be defined as product/service oriented while Smart Object Payments and Voice Payments are considered network oriented. This means that the former leverage on a single type of product or service instead of profiting of access to the whole IoT network as would the latter.
- Wearable Payments were seen to be the one of the most mature services which, in the past, had leveraged on NFC advancement to expand Passive Wearables. Now, they seem to be decreasing

and giving space to the development of new smart technologies which might include AI as a technology of choice.

- Biometric payments are expanding their technology's capabilities while also incorporating new sectors to developed (bars, dinners, banks, etc.). This suggests a greater trust over such technology, which might motivate consumers experience new types of payment methods.
- The development of voice biometrics might imply the incorporation of this type of technology within Voice Payments which would be an interesting advancement to look forward.
- Smart Home payments seem to have reach a growth impediment as there is no further development being made and innovative products have been discontinued.
- Smart Objects PoS payments is developing fast and should be considered as a central point for future analysis as it might provide unprecedent connections between objects and retailers.
- Smart Car payments did not only see one of the largest growths, but it was also the only category that incorporated fully autonomous M2M payments. It was found to be the only smart product besides wearables or smartphones that could perform such kind of payments because of the required access to a digital wallet, although it is not disregarded that virtual assistants may, in the future, have a limited access to a wallet and therefore, be able to perform such type of payments.
- Even though LPWA was noted on the Literature as the connectivity of preference by IoT systems, it has been shown that it is the least type of connection selected. This is an interesting finding that suggest Innovative Payments still have further improvements available.

After recollecting the main findings, it is time to answer the central questions made during the Methodology:

1. *Which type of Innovative Payment predominating in the current market? Will it remain the same in the near future?*
    a. Currently Wearable Payments are predominating although they are expected to show a decline in the future. This does not mean that the compositions of Innovative Payments will change, but we should be prepared for further shifts as the most innovative categories and subcategories (Device-Free Payments or Smart Objects PoS Payments) further develop.
2. *According to the classifications, are we able to identify a limit for the "smart-things" that can integrate payment applications?*

   a. There is no actual "limit" as it has been shown that with technological advancements unthinkable devices can even be set to conduct the action of payment. Having said this, we need to notice that Wearables and Device-Free Payments seem to be most restrictive categories than Voice Payments and Smart Objects Payments which may incorporate a greater number of products.

3. *Which are the main characteristics of innovative payments with respect to those of IoT devices? Are the currently used characteristics the best available in the market or is there any room for improvement?*
   a. Innovative Payments still have room for improvement. The most noticeable example is the lack of use of LPWA connections. With future development we should expect to see greater use of such connections as they are a fundamental part of the cost of each machine.

4.3 Further Research

A first point of further research might be the analysis of the development of fully autonomous M2M payments within IoT products. By looking at the progress of digital wallets as well as digital identities, one may begin to understand the characteristics that the objects which conduct such type of payment possess. Furthermore, if we can understand the benefits that a connected object can provide, as well as the task it can achieve on its own, we will be able to foresee where this type of payment might be heading. For this type of analysis, it might be interesting to take a closer look at Smart Industries, where smart machineries are already being connected to IoT networks and might begin soon ordering the suppliers required within the supply chain.

A second point is made through the description of Device-Free Payments. Once Voice Recognition has been fully developed and is established as a regular mean of payment, it would be interesting to analyze its use through virtual assistants as well as smart objects. Both categories can highly benefit from the comfort and security this type of technology could provide.

A third point is made through Smart Objects Payments analysis regarding Smart Objects PoS. Once the subcategory has introduced a greater number of products or expanded the reach of the ones presented during this thesis, it should be further analyzed in order to consider the relation between smart objects and retailers, and how it differences from the one of consumers and smart objects. Finally, it can provide interesting insight towards consumers payment method of choice or its store preference according to payment methods availability.

References

ABI Research, 2020. *ABI Research.* [Online]
Available at: https://www.abiresearch.com/press/smartwatches-new-vertical-applications-and-increasing-contactless-adoption-will-drive-payment-enabled-wearables-market-us72-billion-2024/
[Accessed 10 10 2020].

Aldossari, M. Q. & Sidorova, A., 2018. Consumer Acceptance of Internet of Things (IoT): Smart Home Context. *Journal of Computer Information Systems,* pp. 1-11.

Alsén, D., Patel, M. & Shangkuan, J., 2018. The Future of Connectivity: Enabling the Internet of Things. *The Internet of Things: How to Capture the Value of IoT,* pp. 91-99.

Al-Sumaiti, A. S., Ahmed, M. H. & Salama, M. M. A., 2014. *Smart Home Activities: A Literature Review,* s.l.: Taylor & Fancis Group.

Amazon, 2019a. *Amazon.* [Online]
Available at: https://www.amazon.com/Echo-Loop/dp/B07JPK4XJ6
[Accessed 06 July 2020].

Amazon, 2019b. *Amazon.* [Online]
Available at: https://www.amazon.com/All-new-Echo-Frames/dp/B083C58VDP/ref=p13n_ds_purchase_sim_1p_dp_desktop_1?pd_rd_w=JlVRo&pf_rd_p=aa96da76-5f67-44bb-853b-5d14d66e2ec7&pf_rd_r=C0T5GBP326EVEZTCBPA7&pd_rd_r=2c0a4236-96db-4556-8fcd-146886bf893d&pd_rd_wg=XrOKy&pd_rd_i=B
[Accessed 06 July 2020].

Anan, L., Mahajan, D. & Nadeau, M.-C., 2019. *Are Convenience And Rewards Leading To A Digital Flashpoint?,* San Francisco: McKinsey Digital Payments Survey.

Antelop Solutions, 2019. *nfcw.com.* [Online]
Available at: https://members.nfcw.com/94116/antelop-solutions-nfc-payments-strong-customer-authentication-digital-onboarding/
[Accessed 2 June 2020].

AP., 2019. *Projected shipments of connected cars between 2019 and 2023 (in million units). Statista..* [Online]
Available at: https://www.statista.com/statistics/743400/estimated-connected-car-shipments-globally/
[Accessed 10 March 2021].

Balta-Ozkan, N., Davidson, R., Bicket, M. & Whitmarsh, L., 2013. Social Barriers To The Adoption of Smart Homes. *Energy Policy,* Volume 63, pp. 363-374.

Bauer, H., Scherf, G., Von Der Tann, V. & Klinkhammer, L., 2018. Six Ways CEOs Can Promote Cybersecurity In The IoT Age. *The Internet of Things: How to Capture The Value of IoT,* pp. 100-107.

Ba, W., Mendelson, H. & Zhu, M., 2020. *Sales Policies for a Virtual Assistant,* Standford: Standford University.

Bhagyashri, K., Manikanta, S. & Suresh, V., 2013. Principle Elements and Framework of Internet of Things. *International Journal of Engineering And Science,* 3(5), pp. 24-29.

Boel, P., 2019. Payment Systems - History and Challenges. *Sveriges Riskbank Economic Review,* pp. 51-63.

Borowski-Beszta, M. & Polasik, M., 2020. Wearable devices: new quality in sports and finance. *Journal of Physical Education and Sport,* 20(2), pp. 1077-1084.

Bruno, P. et al., 2020. *How Payments Can Adjust to the Coronavirus Pandemic-and Help the World Adapt,* s.l.: McKinsey & Company.

Burbach, L. et al., 2019. *"Hey, Siri", "Ok, Google", "Alexa". Acceptance-Relevant Factors of Virtual Voice-Assistants.* s.l., IEEE International Professional Communication Conference.

Callado Muñoz, F. J. & Utrero González, N., 2004. Towards Economic and Monetary Union: Chainging Trends in Payment Systems For New European Members. *Journal of Financial Transformation,* pp. 168-174.

Chung, H., Iorga, M., Jeffrey, V. & Lee, S., 2017. "Alexa, Can I Trsut You?". *Cybertrust,* pp. 100-104.

Cisco Systems, 2019. *Number of connected wearable devices worldwide from 2016 to 2022 (in millions) [Graph].* [Online]
Available at: https://www.statista.com/statistics/487291/global-connected-wearable-devices/
[Accessed 10 10 2020].

Clark, S., 2014. *NFCW.* [Online]
Available at: https://www.nfcw.com/2014/06/10/329610/dress-shirt-maker-offers-nfc-bonus/
[Accessed 1 June 2020].

Clark, S., 2017. *NFCW.* [Online]
Available at: https://www.nfcw.com/2017/11/01/355399/researchers-build-id-data-smart-clothing/
[Accessed 15 June 2020].

Clark, S., 2019a. *NFCW.* [Online]
Available at: https://www.nfcw.com/2019/09/03/364240/researchers-develop-stretchable-nfc-antennas-for-clothing/
[Accessed 13 June 2020].

Clark, S., 2019b. *NFCW.* [Online]
Available at: https://www.nfcw.com/2019/02/04/360315/researchers-unveil-waterproof-nfc-sweat-sensor/
[Accessed 13 June 2020].

Clark, S., 2020a. *NFCW.* [Online]
Available at: https://www.nfcw.com/2020/05/28/366703/google-pilots-voice-based-payments/
[Accessed 02 06 2020].

Clark, S., 2020b. *NFCW.* [Online]
Available at: https://www.nfcw.com/2020/05/28/366703/google-pilots-voice-based-payments/
[Accessed 2 June 2020].

Clodfelter, R., 2010. Biometric technology in retailing: Will consumers accept fingerprint authentication?. *Journal of Retailing and Consumer Services,* Volume 17, pp. 181-188.

Collins Concise English Dictionary, 2020. s.l.:HarperCollins Publishers.

Coumau, J.-B., Furuhashi, H. & Sarrazin, H., 2018. A Smart Home Is Where The Bot Is. *The Internet of Things: How To Capture The Value Of IoT,* pp. 73-77.

Dehghani, M. & Dangelico, R. M., 2017. *Smart wearable technologies: Current status and market orientation throguh a patent analysis,* Rome: IEEE Xplore.

Del Castillo, M., 2017. *Coindesk.* [Online]
Available at: https://www.coindesk.com/ibm-banks-automakers-blockchain-car-ewallet
[Accessed 1 July 2020].

Deloitte, 2019. *Revenues from consumer electronics sales worldwide in 2020, by category (in billion U.S. dollars). Statista.* [Online]
Available at: https://www.statista.com/statistics/1095850/global-consumer-electronics-revenues/
[Accessed 11 October 2020].

European Payments Council, 2019. *2019 Payment Threats and Fraud Trends Report,* Brussels: European Payments Council.

Farah, M. F. & Ramadan, Z. B., 2017. Disruptions versus more disruptions: How the Amazon dash button is altering consumer buying patterns. *Journal of Retailing and Consumer Services,* Issue 39, pp. 54-61.

Fidesmo, 2017. *Enabling the Future of Wearables,* s.l.: Fidesmo.

Finextra in association with Signicat, 2020. *Unlocking Revenue Through Digital Identity,* s.l.: Finextra Research.

Finextra, 2019a. *Finextra.* [Online]
Available at: https://www.finextra.com/newsarticle/33977/tinkoff-introduces-oleg-the-voice-assistant/payments
[Accessed 07 May 2020].

Finextra, 2019b. *Finextra.* [Online]
Available at: https://www.finextra.com/newsarticle/34093/citi-ventures-invests-in-car-iq/payments
[Accessed 07 May 2020].

Finextra, 2020. *The Future of Regulation,* s.l.: Finextra Research.

GlobeNewswire, Research and Markets, 2018. *Smart mirror market value worldwide in 2018 and 2023 (in billion U.S. dollars). Statista.* [Online]
Available at: https://www.statista.com/statistics/1016654/global-smart-mirror-market-value/
[Accessed 10 March 2021].

Grupta, S. et al., 2013. Arduino Based Smart Cart. *International Journal of Advanced Research in Computer Engineering & Technology,* 2(12), pp. 3083-3090.

Han, S. & Yang, H., 2018. Understanding adoption of intelligent personal assistants. *Industrial Management & Data Systems,* 118(3), pp. 618-636.

Hattula, C., Buchmann, M. & Moura, T. F., 2020. *The Acceptance of Amazon Go: An Analysis based on the Technology Acceptance Model and Cultural Dimensions.* Budapest, EMAC.

Hawkins, A. J., 2018a. *The Verge.* [Online]
Available at: https://www.theverge.com/2018/4/24/17261744/amazon-package-delivery-car-trunk-gm-volvo
[Accessed 6 July 2020].

Hawkins, A. J., 2018. *The Verge.* [Online]
Available at: https://www.theverge.com/2018/4/24/17261744/amazon-package-delivery-car-trunk-gm-volvo
[Accessed 29 June 2020].

HA, Y., 2020. The Effects of Shoppers' Motivation on Self-Service Technology Use Intention: Moderating Effects of the Presence of Employee. *Journal of Asian Finance, Economics and Business,* 7(9), pp. 489-497.

Hayden, R., 2014. Transforming Natonal Payments Systems. *McKinsey on Payments,* Issue 20, pp. 23-31.

Humphrey, D. B., 1995. *Payment Systems: Principles, Practice, and Improvements, Volumenes 23-260.* s.l.:World Bank Publications.

Hwangbo, H., Kim, Y. S. & Cha, K. J., 2017. *Use of the Smart Store for Persuasive Marketing and Immersive Customer Experiences: A Case Study of Korean Apparel Enterprise,* s.l.: Hindawi.

IC Insights, 2018. *Revenue of Internet of Things subsystems worldwide from 2012 to 2018 (in billion U.S. dollars) [Graph].* [Online]
Available at: https://www.statista.com/statistics/503466/iot-subsystems-revenue-worldwide/
[Accessed 10 10 2020].

Idris, M. et al., 2009. Car Park System: A Review of Smart Parking System and its Technology. *Information Technology Journal,* 8(2), pp. 101-113.

IHS, 2019. *Number of LPWAN connections by technology worldwide from 2017 to 2023 (in millions). Statista.* [Online]
Available at: https://www.statista.com/statistics/880822/lpwan-ic-market-share-by-technology/
[Accessed 10 October 2020].

Jamil, F. & Kim, D., 2019. *Payment Mechanism for Electronic Charging using Blockchain in,* Korea: IEMEK Symposium on Embedded Technology.

Jumio; PYMNTS.com, 2020. *Digital Identity Tracker,* s.l.: PYMNTS.com.

Kahn, F., n.d. *I-POST: Intelligent Point of Sale and Transaction System,* s.l.: IEEE.

Kim, C., Tao, W., Shin, N. & Kim, K.-S., 2010. An Empirical Study of Customers' Perceptions of Security and Trust in E-Payment Systems. *Electronic Commerce Research and Applications,* Volume 9, pp. 84-95.

Kim, J. & Park, E., 2019. Beyond coolness: Predicting the technology adoption of interactive wearables devices. *Journal of Retailing and Consumer Services,* Volume 49, pp. 114-119.

Kocianski, E., 2020. *How the COVID-19 Pandemic Will Accelerate Digital Financial Services,* s.l.: 11:FS.

Koo, H., Kim, S. & Nam, C., 2017. *Speaker Wars begins: Which applications will be the killer content for smart speaker?.* Kyoto, Econstor.

Kortuem, G., Kawsar, F., Fitton, D. & Sundramoorthy, V., 2010. *Smart Objects as Building Blocks for the Internet of Things,* s.l.: IEEE Computer Society.

Kumar Yadav, B. et al., 2020. *Smart Cart: A Distributed Framework,* Kolkata, India: IEEE International Conference for Convergence in Engineering.

Lee, V.-H.et al., 2020. Wearable payment: A deep learning-based dual-stage SEM-ANN analysis. *Expert Systems with Applications,* Volume 157, pp. 1-15.

Lee, Y. et al., 2020. Using Sonar for Liveness Detection to Protect Smart Speakers against Remote Attackes. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.,* 4(1).

Liao, Y. et al., 2019. Understanding the Role of Privacy and Trust in Intelligent Personal Assistant Adoption. In: N. Greene Taylor, C. Chirstian-Lam, M. H. Martin & B. Nardi, eds. *Information in Contemporary Society.* Washington: Springer, pp. 102-114.

Liu, Y. et al., 2016. *Magic Mirror: A Virtual Fashion Consultant,* Amsterdam: s.n.

Li, Y. & Hu, W., 2014. The Conceptual Design of "Smart Closet" Fashion Consultant Expert System. *International Journal of Business and Social Science,* 5(10), pp. 149-154.

Logbar, 2015. *Kickstarter.* [Online]
Available at: https://www.kickstarter.com/projects/1761670738/ring-shortcut-everything
[Accessed 30 May 2020].

Loup Ventures, 2019. *Smart speaker unit shipments from 2014 to 2025* (in millions). Statista..* [Online]
Available at: https://www.statista.com/statistics/1022809/worldwide-smart-speaker-unit-shipment/
[Accessed 11 March 2021].

Macmillan, R., 2017. *A Guide To Tokenization - The Essential Enabler For Expanding The World Of Commerce,* s.l.: SJB Research Ltd.

MarketsandMarkets, 2020. *Facial recognition market size worldwide in 2019 and 2024* (in billion U.S. dollars). Statista.* [Online]
Available at: https://www.statista.com/statistics/1153970/worldwide-facial-recognition-revenue/
[Accessed 14 March 2021].

MarketsandMarkets, 2020. *Global in-vehicle infotainment and services market size in 2019 and 2027 (in billion U.S. dollars). Statista..* [Online]
Available at: https://www.statista.com/statistics/737708/in-vehicle-infotainment-os-and-middleware-

market-size-worldwide/
[Accessed 10 March 2021].

MarketsandMarkets, 2020. *Size of the global connected car market between 2020 and 2025 (in billion U.S. dollars). Statista..* [Online]
Available at: https://www.statista.com/statistics/725025/connected-cars-global-market-size-projection/
[Accessed 10 March 2021].

Mastercard, 2020. *Mastercard Study Shows Consumers Globally Make the Move to Contactless Payments for Everyday Purchases, Seeking Touch-Free Payment Experiences.* [Online]
Available at: https://mastercardcontentexchange.com/newsroom/press-releases/2020/april/mastercard-study-shows-consumers-globally-make-the-move-to-contactless-payments-for-everyday-purchases-seeking-touch-free-payment-experiences/
[Accessed 20 August 2020].

McCole, P., Ramsey, E. & Williams, J., 2010. Trust Considerations on Attitudes Towards Online Purchasing: The Moderating Effect of Privacy and Security Concerns. *Journal of Business Research,* Volume 63, pp. 1018-1024.

McLean, G. & Osei-Frimpong, K., 2019. Hey Alexa... Examine the Variables Influencing the Use of Artificial Intelligent In-Home Voice Assistants. *Computers in Human Behavior,* Volume 99, pp. 28-37.

Millard, S., Haldane, A. & Saporta, V., 2007. *The Future of Payment Systems.* Ilustrated ed. s.l.:Routledge.

Miniauoui, S., Atalla, S. & Bin Hashim, K. F., 2019. *Introducing Innovative Item Management Process Towards Providing Smart Fridges.* Dubai, IEEE.

Mordor Intelligence , 2020. *Voice recognition market size worldwide in 2019 and 2025 (in billion U.S. dollars). Statista..* [Online]
Available at: https://www.statista.com/statistics/1133875/global-voice-recognition-market-size/
[Accessed 14 March 2021].

Mordor Intelligence, 2020. *Voice recognition market size worldwide in 2019 and 2025 (in billion U.S. dollars). Statista.* [Online]
Available at: https://www.statista.com/statistics/1133875/global-voice-recognition-market-size/
[Accessed 11 October 2020].

Nakajima, M., 2012. The Evolution of Payment Systems. *The European Financial Review,* pp. 8-11.

Nasonov, A., 2017. What's the future for biometrics in global payments?. *Biometric Technology Today*, September, pp. 5-7.

Niederkorn, M., Bruno, P., Istace, F. & Bansal, S., 2016. E- and M- commerce Payments Continue Rapid Growth. *Global Payments 2016: Strong Fundamentals Despite Uncertain Times,* pp. 32-36.

Niederkorn, M., Bruno, P., Istace, F. & Bansal, S., 2016. Modernizing Payments Infrastructure. *Global Payments 2016: Strong Fundamentals Despite Uncertain Times,* pp. 24-31.

North Yorkshire County Council, 2019. *Northyorks.* [Online]
Available at: https://www.northyorks.gov.uk/news/article/harrogate-first-town-uk-introduce-new-age-

smart-parking
[Accessed 07 May 2020].

Observatory of Digital Innovation, 2019. *Startup Intelligence: Internet of Things,* Milano: Politecnico di Milano.

Osservatorio Innovative Payments, 2020. *Innovative Payments: Collaborare paga,* Milano: Politecnico di Milano.

P20, 2020. *Payments in a Post-COVID-19 World,* s.l.: P20.

Park, E. & Cho, Y., 2017. Comprehensive Approaches to User Acceptance of Internet Things in a Smart Home Environment. *INTERNET OF THINGS JOURNAL,* 4(6), pp. 2342-2350.

Park, J., Nam, C. & Kim, H.-j., 2019. *Exploring the key services and players in the smart car market ,* s.l.: ELSEVIER.

Pasalic, D. et al., 2016. Vehicle Toll Payment System Based on Internet of Things Concept. *5th Mediterranean Conference on Embedded Computing,* pp. 485-488.

Patel, M., Shangkuan, J. & Thomas, C., 2018. What's new with the Internet of Things?. *The Internet of Things: How to Capture the Value of IoT,* pp. 14-21.

Payments, O. I., 2020. *Dagli Smart Objects alla Biometria: la rivoluzione del mondo dei pagamenti.* Milano: Politecnico di Milano.

Phillips, T., 2020. *NFCW.* [Online]
Available at: https://www.nfcw.com/2020/12/22/369792/dubai-beauty-parlour-introduces-smart-manicures-that-include-an-nfc-chip/
[Accessed 24 January 2021].

Phillips, T., 2021. *NFCW.* [Online]
Available at: https://www.nfcw.com/2021/01/22/370260/moscow-to-complete-contactless-ticketing-rollout-by-end-2021/
[Accessed 24 January 2021].

Ponemon Institute, 2020. *Privacy and Security in a Digital World,* s.l.: Ponemon Institute Research Report.

PYMNTS.com, 2020. *Inspiring Trust In The Digital Economy,* s.l.: PYMNTS.com.

PYMNTS, 2019. *PYMNTS.* [Online]
Available at: https://www.pymnts.com/news/artificial-intelligence/2019/boa-virtual-assistant-exceeds-10m-users-launches-new-features/
[Accessed 07 May 2020].

PYMNTS, 2020. *PYMNTS.* [Online]
Available at: https://www.pymnts.com/news/retail/2020/cashierless-tech-cutting-lines-reducing-theft/
[Accessed 25 June 2020].

Rothensee, M., 2008. User Acceptance of the Intelligent Fridge: Empirical Results from a Simulation. In: C. Floerkemeier, et al. eds. *The Internet of Things.* s.l.:Springer-Verlag Berlin Heidelberg, pp. 123-139.

Samsung, 2021. *samsung.com.* [Online]
Available at: https://www.samsung.com/us/explore/family-hub-refrigerator/apps/
[Accessed 10 03 2021].

Secure Technology Alliance Payments Council, 2017. *Implementation Considerations for Contactless Payment-Enabled Wearables,* Princeton: Secure Technology Alliance.

Singh, B., P, S. A. & Swarup Das, A., 2019. *Methodology for Building an Artificial Intelligent (AI) Virtual Assistant for Payment Processing.* s.l., IEEE Technology & Engineering Management Conference (TEMSCON).

Smart Payment Association, 2018. *Biometrics in Payment,* s.l.: Smart Payment Association.

Sohn, K. & Kwon, O., 2019. Technology Acceptance Theories and Factors Influencing Artificial Intelligence-Based Intelligent Products. *Telematics and Informatics,* Volume 47, pp. 1-14.

Statista, 2018. *Estimated amount of Infotainment Services subscriptions worldwide* from 2017 to 2023 by subsegment (in million) [Graph]. In Statista.* [Online]
Available at: https://www.statista.com/forecasts/885829/number-of-infotainment-services-subscriptions-worldwide
[Accessed 10 March 2021].

Statista, 2020a. *Number of Smart Homes forecast worldwide from 2017 to 2025 (in millions). Statista..* [Online]
Available at: https://www.statista.com/forecasts/887613/number-of-smart-homes-in-the-smart-home-market-worldwide
[Accessed 11 March 2021].

Statista, 2020b. *mart Home revenue forecast per segment worldwide from 2017 to 2025 (in million U.S. dollars). Statista..* [Online]
Available at: https://www.statista.com/forecasts/887687/smart-home-revenue-per-segment-worldwide
[Accessed 11 March 2021].

Statista, 2021. *Market size comparison for the global smart refrigerator market from 2018 to 2026 (in billion U.S. dollars). Statista.* [Online]
Available at: https://www.statista.com/statistics/1219723/smart-refrigerator-market-worldwide/
[Accessed 11 March 2021].

Statista, n.d. *Smart Appliances - Worldwide.* [Online]
Available at: https://www.statista.com/outlook/dmo/smart-home/smart-appliances/worldwide
[Accessed 10 March 2021].

Stragier, J., Hauttekeete, L. & De Marez, L., 2010. *Introducing Smart Grids in Residential Contexts: Consumers' Perception of Smart Household Appliances,* s.l.: IEEE.

Strategy Analytics, 2019. *Number of internet of things (IoT) connected devices worldwide in 2018, 2025 and 2030 (in billions) [Graph].* [Online]

Available at: https://www.statista.com/statistics/802690/worldwide-connected-devices-by-access-technology/
[Accessed 10 August 2020].

The Insight Partners, 2019. *Global biometric technologies market revenue from 2018 to 2027 (in billion U.S. dollars). Statista..* [Online]
Available at: https://www.statista.com/statistics/1048705/worldwide-biometrics-market-revenue/
[Accessed 14 March 2021].

Toft, M. B., Schuitema, G. & Thogersen, J., 2014. Responsible technology acceptance: Model development and application to consumer acceptance of Smart Grid technology. *Applied Energy,* pp. 392-400.

Tomic, N. & Todorovic, V., 2017. *The Future of Payments in the Internet of Things.* s.l., Sinteza.

Van Der Cruijsen, C. & Plooij, M., 2015. Changing Payment Patterns at Point-of-Sale: Their Drivers. *DNB Working Paper,* Volume 471, pp. 1-44.

Visa, 2017. *How Things Pay For Things,* s.l.: Visa.

Voicebot.ai, Business Wire, 2020. *Number of digital voice assistants in use worldwide from 2019 to 2024 (in billions)*.* [Online]
Available at: https://www.statista.com/statistics/973815/worldwide-digital-voice-assistant-in-use/
[Accessed 11 October 2020].

Voicebot.ai; Voices.com, 2019. *The State of Voice Assistants as a Marketing Channel,* s.l.: Voicebot.ai.

Voicebot.ai, 2020. *Smart Speaker Consumer Adoption Report,* s.l.: Voicebot.ai.

von Graevenitz, G. A., 2007. Biometric authentication in relation to payment systems and ATMs. *Datenschutz und Datensicherheit,* 31(9), pp. 681-683.

Wakefield Research, 2020. *The Visa Back to Business Study,* s.l.: Visa.

Walton, C., 2019. *forbes.com.* [Online]
Available at: https://www.forbes.com/sites/christopherwalton/2019/08/16/the-death-of-the-dash-button-is-nothing-but-bad-news-for-amazons-competition/?sh=773a304a1345
[Accessed 10 03 2021].

Wiggers, K., 2018. *Venture Beat.* [Online]
Available at: https://venturebeat.com/2018/10/17/twilios-autopilot-lets-developers-deploy-bots-across-text-message-and-ai-assistants/
[Accessed 29 June 2020].

Yahoo, 2021. *Yahoo Finance.* [Online]
Available at: https://finance.yahoo.com/company/cariq-2?h=eyJlIjoiY2FyaXEtMiIsIm4iOiJDYXIgSVEifQ==&.tsrc=fin-srch
[Accessed 25 March 2021].

Yang, H. & Lee, H., 2019. Understanding user behavior of virtual personal assistant devices. *Information Systems and e-Business Management,* Volume 17, pp. 65-87.

Yang, H., Yu, J., Zo, H. & Choi, M., 2016. User acceptance of wearable devices: An extended perspective of perceived value. *Telematics and Informatics,* Volume 33, pp. 256-269.

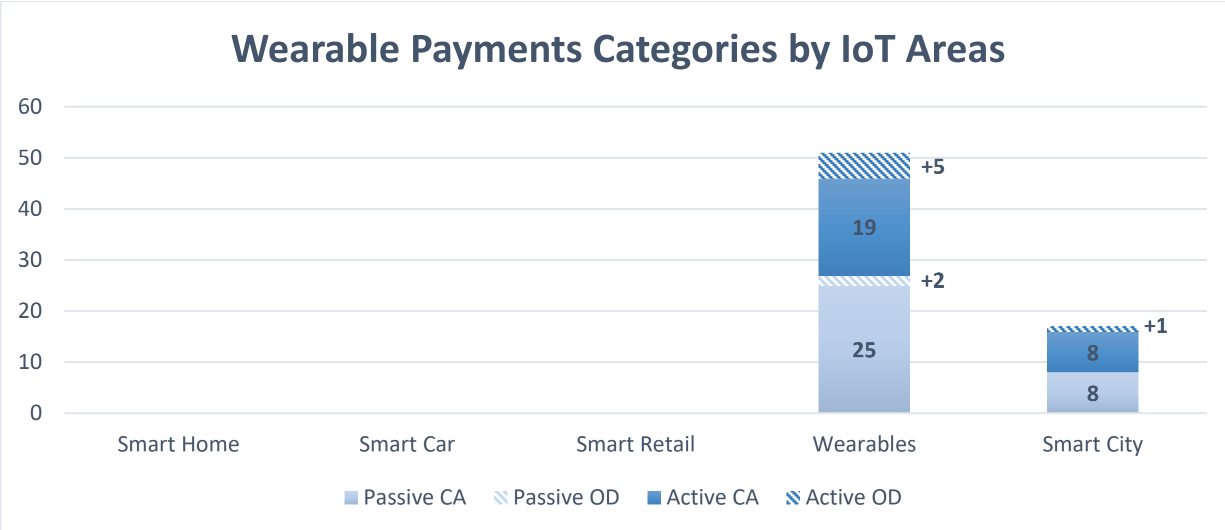
Yang, Y. et al., 2017. A survey on Security and Privacy Issues in Internet-of-Things. *Intenret of Things Journal,* 4(5), pp. 1250-1258.

Yewatkar, A. et al., 2016. *Smart Cart with Automatic Billing, Product Information, Product Recommendation Using RFID & Zigbee with Anti-Theft.* Lonavala, India, Procedia Computer Science.

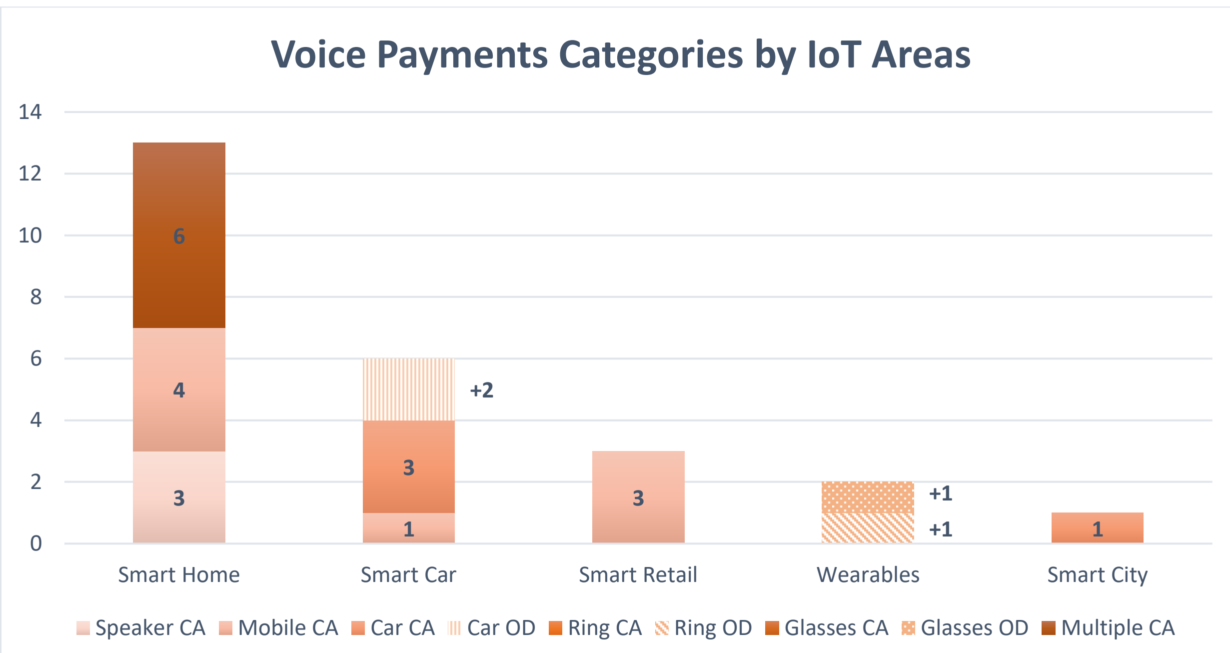
Zhang, K. W. & Kang, J. M., 2019. *Factors Affecting the Use of Facial-Recognition Payment: An Example of Chinese Consumers,* s.l.: IEEE.

Appendix

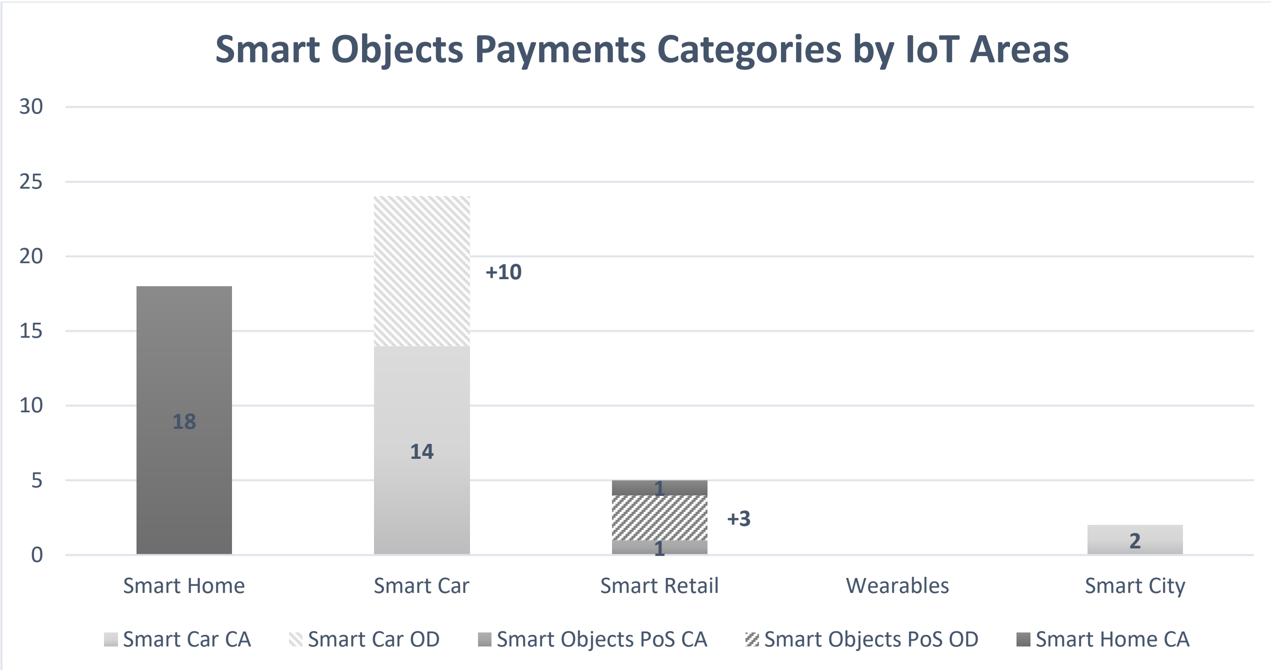
1. Innovative Payments Subcategories by IoT Areas



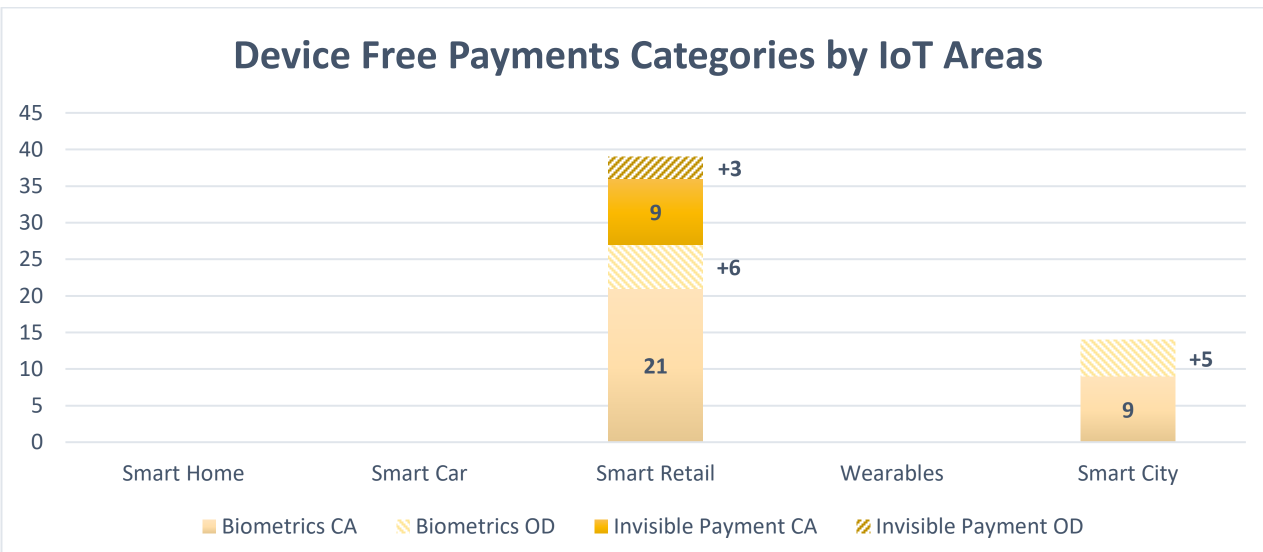
Graph 40: Wearable Payments Categories by IoT Areas - Source: Census



Graph 41: Voice Payments Categories by IoT Areas - Source: Census

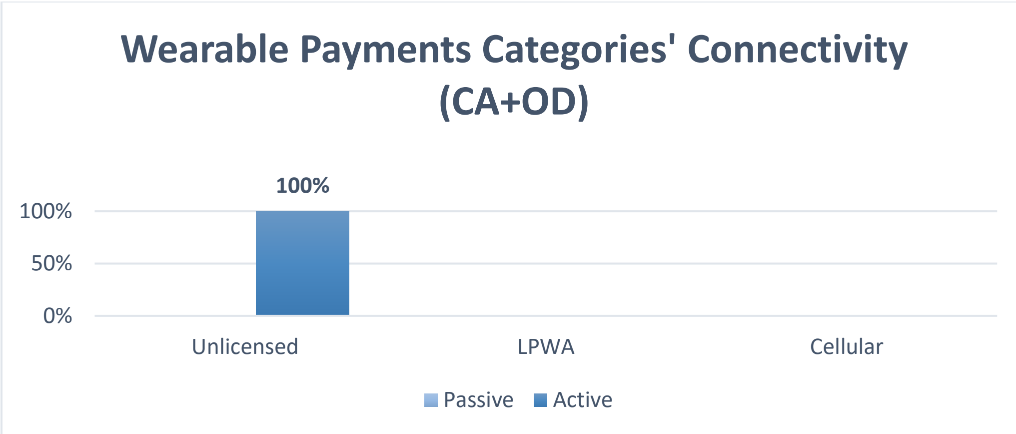


Graph 42: Smart Objects Payments Categories by IoT Areas - Source: Census

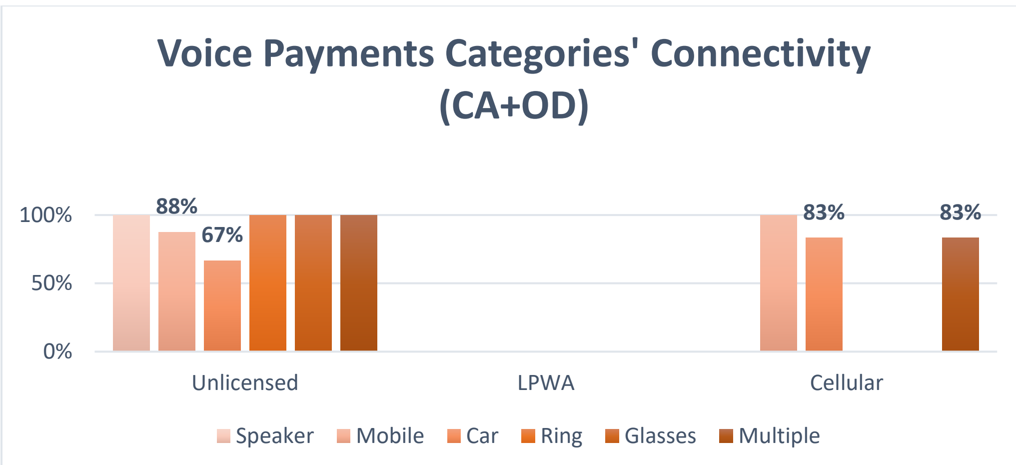


Graph 43: Device-Free Payments Categories by IoT Areas - Source: Census

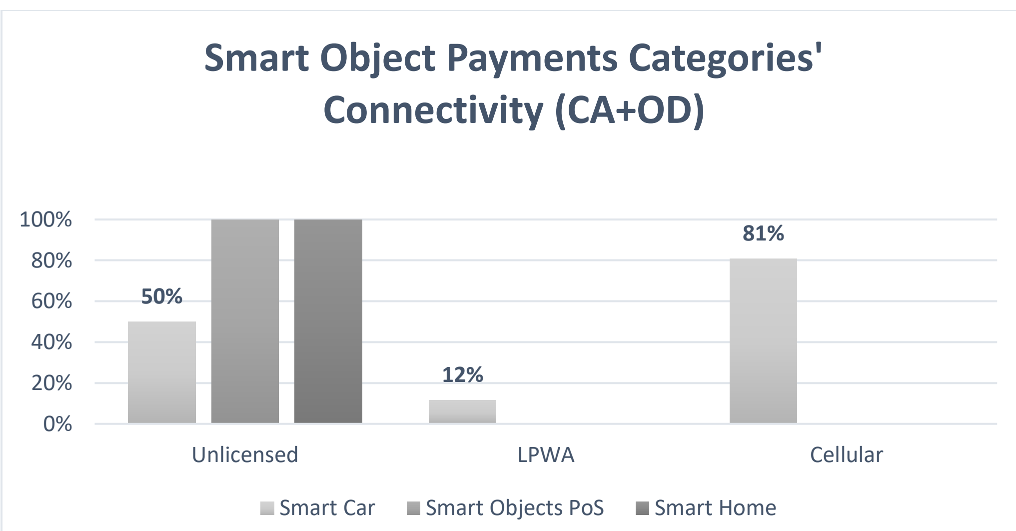
2. <u>Innovative Payments Subcategories by IoT Areas</u>



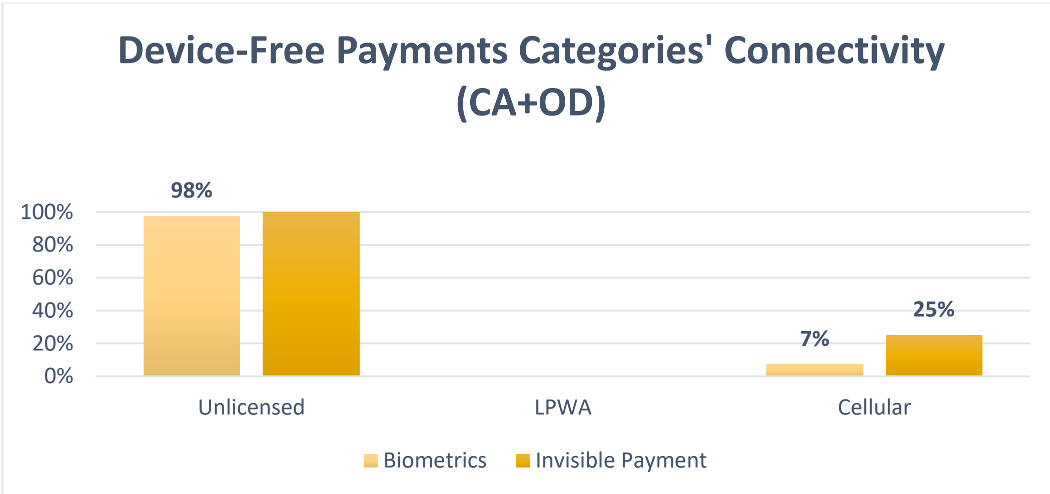
Graph 44: Wearable Payments Categories' Connectivity (CA+OD)- Source: Census



Graph 45: Voice Payments Categories' Connectivity (CA+OD) – Source: Census



Graph 46: Smart Object Payments Categories' Connectivity (CA+OD) - Source: Census



Graph 47: Device-Free Payments Categories' Connectivity (CA+OD) - Source: Census