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SIAM: A model for service implementation analysis applied to the impact of telegraphy in Macaronesian ports

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Abstract

Several factors have been considered to explain the success and pre-eminence of some ports over others, such as geography, telecommunications, taxation or the availability of local goods for trade. This is especially significant in the final period of the nineteenth century and the first years of the twentieth century, which corresponds to the rise of steam navigation and the laying of the world network of submarine telegraph cables. This article presents a model (the Service Implementation Analysis Model or SIAM) that aims to analyse the influence of communications technology within historical models of sea trade. To evaluate this model, the authors propose using a scheme based on technology acceptance models, which perform a cost–benefit comparison, and adding an ex post analysis, so that this study can explain further reasons for the incorporation of these solutions. This analysis is complemented by a series of evaluation factors, which form a feedback system to incorporate scientific advances, regulatory changes, the geostrategic context, and social acceptance or rejection. Using these feedback factors, it is possible to study how the economic model is modified as a function of technological factors within the co-evolution of science and society as inseparable elements. This model has been applied to explain the divergence in the evolution of maritime trade among Macaronesian archipelagos before the Great War. However, it can be directly

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extrapolated to other cases of historical analysis in which technological evolution played a significant role.

Keywords
Macaronesia, maritime trade, technology acceptance model, telegraphy, wireless telegraphy

Introduction

There is a growing trend for scholars from different fields to believe that the convergence of studies in the humanities, social sciences and technology can create new areas and methods of study and analysis.[1] For example, Geels and Schot proposed that society and technology exist together as a socio-technological system and cannot be conceived or operate separately, and that changes in the socio-technological system must be considered jointly within socio-economic transition processes.[2] This theory of socio-technological co-evolution assumes that society and technology exist as an interactive system and not in isolation, as they complement and harmonize with each other. Therefore, transitions in the global system are due to systemic innovations that produce fundamental changes in socio-technological systems based on multiple causal relationships and their co-evolution.[3]

These transitions may be due to the evolutionary processes of the dominant technology, but sometimes sudden changes occur, resulting in the substitution of one technology for another and, at times, even causing radical changes in society. From the point of view of island societies in the nineteenth century, these transitions can be classified into three categories: (1) the evolution of sailing ships in the maritime trade through the introduction of new sailing equipment and the use of copper-plated hulls; (2) the introduction of steam navigation; and (3) the arrival of the telegraph, and later of radiotelegraphy, since it

1. Bomi Song, Daekook Kang, Byungun Yoon and Yongtae Park, 'Development of Two-Layered Service Evolution Map: Structure and Development Process', in IEEE International Conference on Industrial Engineering and Engineering Management, Macao, China, 7–10 December 2010.
2. Frank W. Geels and Johan Schot, 'Typology of Sociotechnical Transition Pathways', *Research Policy*, 36, No. 3 (2007), 399–417. See also Sang-Wook Kim and Jae-Lim Jung, 'A System Simulation for Investigation of IT and Society Co-evolution Dynamics and Its Policy Implications', *Korean System Dynamics Review*, 9, No. 1 (2008), 171–97 and, more recently, Keeeun Lee, Sunhye Kim and Byungun Yoon , 'A Systematic Idea Generation Approach for Developing a New Technology: Application of a Socio-technical Transition System', *Technological Forecasting and Social Change*, 176 (2022), Article 121431.
3. Jochen Markard, Rob Raven and Bernhard Truffer, 'Sustainability Transitions: An Emerging Field of Research and Its Prospects', *Research Policy*, 41, No. 6 (2012), 955–67. See also Jan Rotmans, René Kemp and Marjolein van Asselt, 'More Evolution Than Revolution: Transition Management in Public Policy', *Foresight*, 3, No. 1 (2001), 15–31.

brought about a radical change in island societies, with effects that went far beyond maritime transport.

The co-evolution theory is necessarily based on a feedback view, which starts from empirical evidence of the flow of the technological trajectory and the external influences on it. Song et al. (2016) proposed a method to analyse the evolution of technology through an evolutionary map of the service provided by these technical advances, measured through social trends.[4] Taking these ideas to historical analysis, we can evaluate the effect of technology flow through a methodology based on collecting data from the a priori forecast that was made of its potential costs and benefits, including information on the social trends that affect it, categorized, for example, by social, technological, economic, environmental and political factors.[5] Examples of possible indicators would be changes in the demographic structure, living standards, welfare, consumption conditions or the labour market. On the other hand, increases in risk factors, whether for the health of users, possible social polarization or vulnerability due to changes in the political or strategic situation, should also be assessed. These factors must then be enhanced by the technological flow itself, or by geopolitical or regulatory environment changes. Therefore, studying the interrelationship between social, economic, political and technological factors is an essential tool both for ex post historical analysis and for forecasting the impact of the future development of new technology.

This article proposes a model based on these premises: the Service Implementation Analysis Model or SIAM. It is based on previous studies that evaluate the divergence in the evolution of maritime traffic in the various Macaronesian archipelagos through a situation economy model. This model considers geographical or political factors as conditioning factors in addition to the available transport or telecommunications infrastructure. It has been assumed that the acceptance of the technology prediction schemes can also be modified to model the mentioned factors and justify their negative or positive impact.

However, the evolution of technology and its effect on societal change cannot be understood as static or even linear. On the other hand, to make this explanation more reliable, it is necessary to add an element of recursion, involving the effect of evolutionary factors on technology. This recursion includes the appearance of new solutions or the improvement of existing ones; the creation of specific regulations or international agreements that encourage or sanction their use; the interest of the society that supports their use; and, finally, other internal political or geostrategic factors that depend on this technological evolution. These last factors are crucial because possessing a privileged position that allows the use of a resource can attract the interest of other powers to maintain its exploitation or try to prevent its use.

4. Bomi Song, Changyong Lee, Byungun Yoon and Yongtae Park, 'Diagnosing Service Quality Using Customer Reviews: An Index Approach Based on Sentiment and Gap Analyses', *Service Business*, 10, No. 4 (2016), 775–98.
5. L. Lee, 'An Analysis of Research Trend in the Field of Remanufacturing Using Network Analysis and Text Mining' (Unpublished Master's dissertation, Soongsil University, Korea, 2018).

An exhaustive study of the effects of technology on the evolution of the economy of the Macaronesian archipelagos in a particular period, marked by the expansion of Atlantic maritime trade, has been carried out for model justification. The technological factor was shown to be decisive in explaining some territories' relative success or failure when compared to others. This analysis is based on the conditions that led to the first submarine telegraph cables and their different nature, depending on whether they were of strategic or simply commercial interest. The evolution of geopolitical conditions and later the appearance of new technologies such as wireless radiotelegraphy or telephone networks forced a change in the pre-eminence between these territories, where the Canary Islands in general, and Las Palmas in particular, reached a dominant market position until the crisis caused by the outbreak of the Great War and the consequent decrease in maritime traffic that affected all of these territories.

This article is organized as follows. First, it describes the evolution of maritime trade during the period in the Atlantic archipelagos of Iberian sovereignty (Cape Verde, Madeira, the Azores and the Canary Islands) through a situational economy model that considers technological evolution as one of the fundamental parameters. Subsequently, the modelling of these technological factors is studied using the SIAM, and then the evolution of the implementation of communications services (telegraphy, radiotelegraphy and telephony) is reviewed considering this model. Finally, after discussing the results, some conclusions are drawn and future work on this line of research is proposed.

Evolution of trade in the Macaronesian archipelagos

Most of the existing studies on submarine cables prior to the First World War are written from a national point of view[6] or in the context of the great powers' struggles to ensure their circles of influence.[7] The laying of these cables in the nineteenth century suffered from a series of technological limitations, which reduced the maximum length of a link, thereby making it necessary to have intermediate points of connection; the global network of submarine cables, although dominated by the great powers, could therefore only be built using the territories of third countries as mooring points. The inherently transnational nature of the submarine cable network thus created new links between

6. For this period of Portuguese archipelago cables, see Ana Paula Silva, 'Portugal and the Building of Atlantic Telegraph Networks', *Journal of History of Science and Technology*, 2(2005), 21–48; Ana Paula Silva, 'A introduzão das telecomunicações eléctricas em Portugal: 1855–1939' (Unpublished PhD thesis, NOVA University Lisbon, 2007). In the Spanish case, see Luis Enrique Otero Carvajal, 'Las telecomunicaciones en la España contemporánea, 1855–2000', *Cuadernos de Historia Contemporánea*, 29 (2007), 119–52; R. Pérez Jiménez, 'Los orígenes de las telecomunicaciones en Canarias (1880–1936)' (Unpublished PhD thesis, University of La Laguna, 2020).
7. Daniel R. Headrick, *The Invisible Weapon: Telecommunications and International Politics, 1851–1945* (Oxford, 1991), 103–29. See also R. J. Cain, 'Telegraph Cables in the British Empire, 1850–1900' (Unpublished PhD thesis, Duke University, 1971), 189; P. M. Kennedy, 'Imperial Cable Communications and Strategy, 1870–1914', *English Historical Review*, 86, No. 341 (1971), 728–52.

European nations, shaping their national and international strategies, and leading to the creation of the first permanent international institutions.[8] Likewise, the relationship between the countries at the core of this process and others that could be called peripheral, including Spain and Portugal, connected countries with very different political and economic statuses. This brought tensions and ambiguities to light regarding the balance of gains and losses for each network builder.

In the 1850s, when the British telegraph cable network began to be established, Portugal became a necessary actor for the mooring of cables and the establishment of repeater stations to channel telegraph traffic between the United Kingdom and its Mediterranean possessions (Gibraltar, Malta and Egypt), and other continents. For this purpose, use was made of its metropolitan territories (on the Iberian Peninsula and the archipelagos of Madeira and the Azores) and its African colonies: Cape Verde, Sao Tome and Principe, Guinea, Angola and Mozambique. Britain used the Portuguese dominions as a central part of its 'telegraph empire' by appealing to the old alliance between the two countries and its financial capacity, which Portugal needed to implement modernization policies.[9] The backbone of this network was the so-called 'Atlantic strategic triangle': Lisbon, Cape Verde and the Azores.[10] Added to this was the traditional Portuguese distrust of placing its capacity to connect with the rest of Europe exclusively in the hands of its Hispanic neighbour, especially in an era characterized in Spain by political instability.[11]

On the other hand, regarding the case of the Canary Islands, its telegraphic connection with the rest of the world was initially planned as part of a great project to link the Iberian Peninsula with the Antillean dominions that constituted the last remnants of the Spanish colonial empire. Only the realization of the technical and economic incapacity of Spain in the last third of the nineteenth century opened the door to a project of its own for the Canary Islands, with French financial support, given France's interest in controlling a cable to Dakar, but always counting on the necessary British technical support.[12] It was therefore predominantly a commercial cable, which did not have the advantages of being within the backbone networks of the British Empire, such as

8. Félix Fernández-Shaw, 'La Unión Internacional de Telecomunicaciones (UIT): Pasado, presente y futuro', *Revista de Política Internacional*, 125 (1973), 91–118.
9. George Canning stated that 'Portugal has been, is and always will be the best support for Great Britain on the European continent' in his *Report Written by the Portuguese Ambassador in London*; quoted in Ana Paula Silva, 'Shaping the Portuguese Empire in the 20th Century: The Telegraph and the Radio', *Icon*, 7 (2001), 118. The British interest was, above all, to secure multiple alternative links between Britain, India, South Africa and Australia. Historical Archive of the Portuguese Foundation of Communications, Lisbon, Concession Contracts, Archive No. 3.7.1/Pr 9. 42/M2, Document 39, 'Submarine Cables (1869–1971)'.
10. Silva, 'Portugal'.
11. Daniel R. Headrick and Pascal Griset, 'Submarine Telegraph Cables: Business and Politics, 1838–1939', *Business History Review*, 75, No. 3 (2001), 543–78.
12. Ángel Bahamonde Magro, Gaspar Martínez Lorente and Luis Enrique Otero Carvajal, *Las comunicaciones en la construcción del estado contemporáneo en España, 1700–1936* (Madrid, 1993).

having immediate access to cable ships in case any repairs were needed – ships that British companies owned almost exclusively.[13]

Once these cables were laid, and with the development of steam navigation, which forced ships to make more frequent stops, the ports of these archipelagos became open alternatives for traffic linking South American countries or the Cape of Good Hope routes with European ports – mainly British. Suárez Bosa and Cabrera Armas have compared the evolution of port traffic in the Macaronesian archipelagos in the period of 1850–1914.[14] This period was a time when British dominance imposed de facto freedom of the seas, creating what has come to be called the 'first globalization'. It was based, among other factors, on the power of the Royal Navy to maintain a network of coaling stations on the main maritime routes.[15] The evolution of the lines calling at these archipelagos shows a divergence, ranging from the apparent hegemony of Sao Vicente in 1875 to the predominance of the Canary Island ports, especially La Luz, in 1913. In fact, in that year, out of 24 main routes, only one passed through the port of Santa Cruz de Tenerife; another passed through Funchal, 7 passed through Sao Vicente, and 12 through the Port of La Luz.[16] To explain this different evolution, Suárez Bosa and Cabrera Armas based on a model initially proposed by González Vieitez and Bergasa Perdomo,[17] which studies this evolution by focusing on three parameters (see Figure 1):

- The situational economy concept that a concatenation of factors – that is, geographical position and the regulatory and labour framework – would give institutions' stability and legal security.
- The transportation infrastructure, including the availability of ports, their refuelling and repair capacity, and their communication with the island's hinterland, which would allow goods to be exported. This makes it necessary to consider the main ports and road networks, as well as small ports, davits for cabotage and infrastructures to support navigation (lighthouses, traffic lights, watchtowers and warehouses).
- Communication infrastructures, which are the main subject of this work.

13. Operated mainly by the Electric Telegraph Company. In 1904, for example, there were 28 British cable ships for five French, two American, two Danish, one German, one Japanese, one Italian and one Chinese. See Kennedy, 'Imperial Cable Communications'.
14. Miguel Suárez Bosa and Luis Cabrera Armas, 'Los puertos francos y las economías insulares atlánticas', in 7th Iberian Congress of African Studies, Lisbon, Portugal, 9–11 September 2010. See also Miguel Suárez Bosa and Luis Cabrera Armas, 'La competencia en los servicios portuarios entre Cabo Verde y Canarias (1850–1914)', *Anuario de Estudios Atlánticos*, 58 (2012), 363–414.
15. Roland Wenzlhuemer, *Connecting the Nineteenth-Century World: The Telegraph and Globalization* (Cambridge, 2013).
16. Adam W. Kirkaldy, 'British Shipping: Its History, Organization and Importance', *Economic Journal*, 25 No. 98 (1915), 220–22.
17. Antonio González Vieitez and Oscar Bergasa Perdomo, *Desarrollo y subdesarrollo de la economía de Canarias* (Las Palmas de Gran Canaria, 1995).

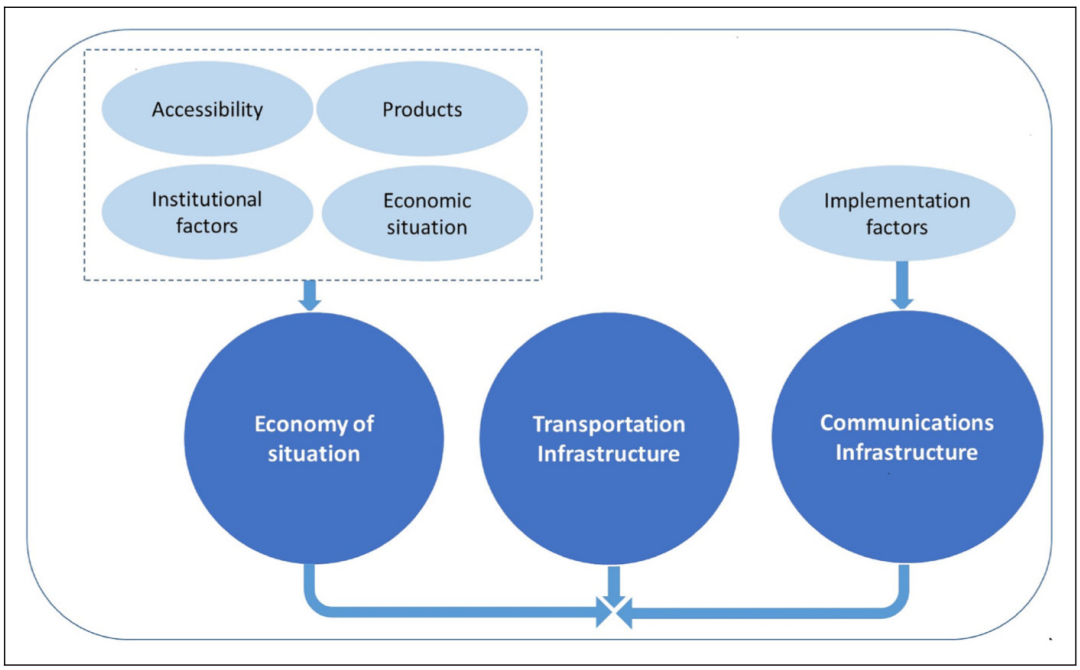

Figure 1. The situation income model.
Source. Based on Miguel Suárez Bosa and Luis Cabrera Armas, 'La competencia en los servicios portuarios entre Cabo Verde y Canarias (1850–1914)', *Anuario de Estudios Atlánticos*, 58 (2012), 363–414.

Although an essential factor in the development of the Atlantic islands throughout history, geographical location is not enough to explain the development or regression of some archipelagos compared to others. To illustrate this fact, the situation income model relates this development to several socio-economic aspects: (1) accessibility due to the opening of markets brought about by steam navigation and the reduction in costs by using larger ships; (2) comparative advantage, since the type of exports – fruit – gave the Canary Islands and Madeira an advantage over Cape Verde due to their closer proximity to European markets; (3) a favourable economic situation, which allowed a sustained demand from European countries, and was caused by the long period of peace at the end of the nineteenth century and beginning of the twentieth century; and (4) a series of institutional aspects, especially the so-called 'transaction cost', which included not only transport, production, wage and labour market costs, but also information, bureaucratic and management costs. These are reflected in the taxes on the entry and exit of goods by sea, and coal and water supply. The advantage of agglomeration economies, in which good communications are essential, was also considered.[18]

If the study is limited to the situation economy model, the traffic was favourable for the Canary Islands due to the exemption of taxes on imports and the coal supply, unlike in the Portuguese archipelagos. The Portuguese administrations maintained a high level of

18. This refers to the spatial concentration of economic activity – standard services that reduce production costs.

taxation since they allowed the coal companies to form monopolies (or duopolies at some points). At the same time, port competition was much more significant in the Canary Islands, and there was a free-trade regulatory framework. Another unfavourable factor for Cape Verde was that the cost of transporting fuel from Great Britain was higher, given the greater distance to be covered, and the prices of other services such as water were also higher, due to their greater scarcity in those islands. This allows Suárez Bosa and Cabrera Armas to emphasize that in the case of Cape Verde, 'its [initial] triumph was the result of submarine telegraphy'.[19]

From the mid 1880s, a new facility began to operate on the island of Gran Canaria – Puerto de La Luz – and, together with the improvements at Santa Cruz de Tenerife harbour, this was the main factor that enhanced sea trade in these islands. From this moment on, the Canary Islands began to prevail over their commercial rivals, as shown in Figure 2, which compares the tonnage of ships that berthed in the main ports of the various archipelagos. In all cases, there was a turning point in growth around 1884, when the cable-connection effects were entirely in force, such that, by 1887, the traffic of the Canary ports surpassed that of the Portuguese islands.

The growth of the two main Canary Islands ports went in parallel, and the higher volume of Las Palmas should not be attributed exclusively to the construction of the new port of refuge of La Luz since Tenerife had comparable infrastructures. Conversely, the explanation for this should rely more on the conditions of exploitation of maritime operations than the mere availability of infrastructures. The substitution effect of the Portuguese ports had already been foreseen by one of the great factotums of the Canary Islands policy during the borbonic Restoration – Feliciano Pérez Zamora – who justified the need to make the telegraphic connection, among other arguments, because of its favourable consequences for the commercial position of the Canary Islands based on maritime traffic: 'to communicate with their shipowners and consignees' but 'not finding this telegraph in the Canary Islands, they have to depart from their more common, more ordinary course, and they all go to the island of La Madera'.[20]

However, was this evolution due exclusively to the telegraph cable? It would be tempting to reduce the problem in this way, but it seems clear that it was not. The growing strength of agricultural exports from the Canary Islands, especially from 1890 onwards, would turn this archipelago into not just a simple staging post, but also a target for merchant fleets, especially those from Britain. Therefore, it is necessary to go a step further in the previous model, developing the 'communications infrastructure' construct through a series of factors that intervened in each technological solution's implementation, evolution and social acceptance. This construct can be approached from the perspective of mere economic profitability and through its capacity to transform society or nature, its potential to improve the society image itself, and the collective satisfaction provided by its use. These parameters can be as decisive as the financial benefits when considering using technology or discarding it as obsolete. Their conjunction has been studied in recent years to analyse the potential impact of a given technology and its acceptance by possible users.

19. Suarez Bosa, M., Cabrera Armas, L. ';La competencia de los servicios portuarios'
20. Spanish Parliament, *Diario de Sesiones del Congreso*, 39 (17 July 1879), 694.

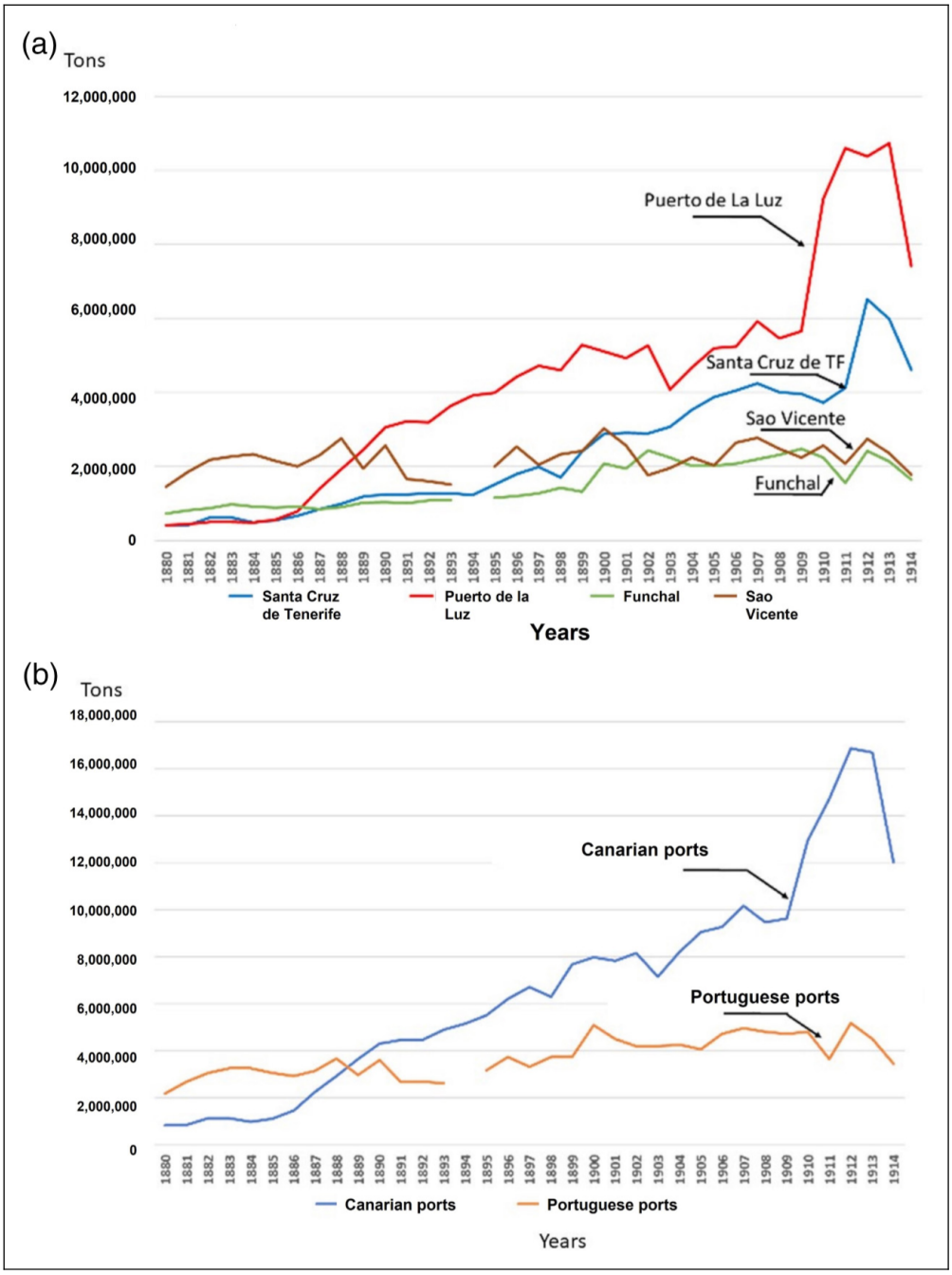

Figure 2. (a)The tonnage of ship traffic calling in the ports of the Canary Islands (Santa Cruz de Tenerife and Puerto de La Luz), Madeira (Funchal) and Cape Verde (Sao Vicente), 1880–1914, disaggregated by destination. (b) The tonnage of ship traffic calling in the ports of the Canary Islands (Santa Cruz de Tenerife and Puerto de La Luz), Madeira (Funchal) and Cape Verde (Sao Vicente), 1880–1914, directly comparing the Portuguese archipelagos and the Canary Islands. **Source.** Based on Miguel Suárez Bosa and Luis Cabrera Armas, 'La competencia en los servicios portuarios entre Cabo Verde y Canarias (1850–1914)', Anuario de Estudios Atlánticos, 58 (2012), 363–414.

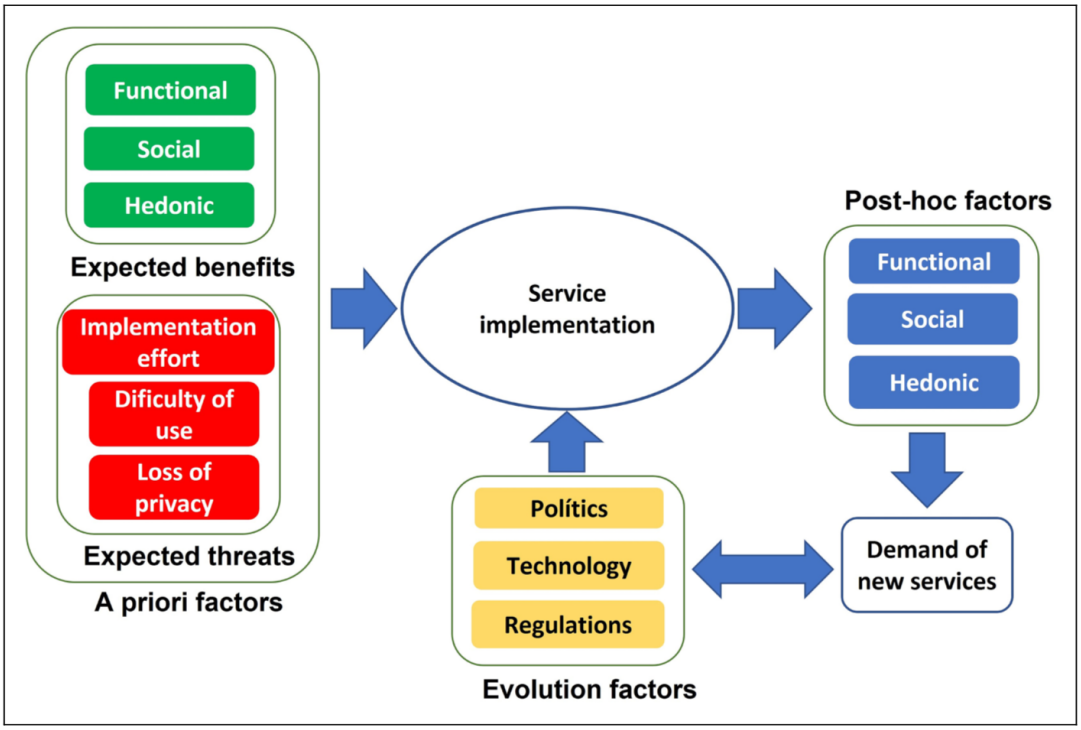

Figure 3. The SIAM.

Modelling of technological factors

Technology acceptance models are widely used to assess new developments or tools.[21] They are based on two previous models – the theory of reasoned action and the theory of planned behaviour – which are grounded on individual behaviours and relate the concepts of attitude, intention and behaviour.[22] A first technology acceptance model was proposed, which studied the intention to adopt or reject an information system based on its usefulness and ease of use.[23] Later, new variables were incorporated, such as social influence and cognitive processes, the adjustment of the technology to the expected function or the

21. For an overview of technology acceptance models, see Lidia Aguiar Castillo, Julio Rufo Torres, Petra de Saa Pérez and Rafael Pérez Jiménez, 'How to Encourage Recycling Behaviour? The Case of WasteApp: A Gamified Mobile Application', *Sustainability*, 10, No. 5 (2018), 1544–63. See also Lidia Aguiar-Castillo, 'Contribución al estudio del impacto de la gamificación en el sector turístico: Promoción de comportamientos pro-ambientales' (Unpublished PhD thesis, University of Las Palmas de Gran Canaria, 2020).
22. Martin Fishbein and Icek Ajzen, 'Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research', *Philosophy and Rhetoric*, 10, No. 2 (1977), 177–188; Icek Ajzen, 'From Intentions to Actions: A Theory of Planned Behavior', in Julius Kuhl and Jürgen Beckmann, eds., *Action Control: From Cognition to Behavior* (Heidelberg, 1985), 11–39.
23. Fred D. Davis, 'Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology', *MIS Quarterly*, 13, No. 3 (1989), 319–40.

materialization of benefits, and the so-called anchoring or adjustment factors.[24] These include aspects such as the degree to which society believes it will develop new tasks with the adopted technology, the degree of the perceived threat of the technology, and the degree of entertainment expected from the consequence of its use. Therefore, it is a model that compares the effort required to perform a task using traditional systems and the effort required using the new technology under study.

On this basis, models have been configured that analyse the intention to use different technologies according to the cost–benefit binomial based on organizational processes. In this way, it is established that usage intention is influenced by the perceptions of the benefits that can be perceived by society (functional, social and hedonic) on the one hand, and, on the other, by the costs involved in their use (effort, difficulty of use and loss of privacy). In addition, these models identify a series of variables that motivate, facilitate and promote use (technological skills and predisposition, trust, altruism, availability, access to technology and the socio-economic environment). The technology acceptance model has been adapted to assess intention to use technology, focusing on the cost–benefit trade-off underlying these models, where perceived functionality is detailed as an essential factor for technology acceptance, in addition to the social and hedonic aspects that appear fundamental. These models establish empirically verifiable hypotheses that explore the cause–consequence relationships of expected benefits, expected threats and technology characteristics with society's reaction to the evaluated technology.

This model has been widely referred in the scientific literature, which makes it possible not only to analyse the factors that a priori can lead to a technology being accepted by customers, but also to reflect a posteriori on the conditioning factors that led to its implementation, based on the history of its use. These models based on the cost–benefit binomial can be also applied to the analysis of the role of technology in history, which can be seen as a straightforward organizational process.[25] The model presented here – the SIAM – is more complex since it includes feedback effects due to technological evolution and other geopolitical factors (see Figure 3).

Three types of perceived benefits can be identified: (1) functional, which include tools that give the user the possibility of obtaining more resources or a greater return on their investments; (2) social, which refer to relationships with other individuals, their social visibility, and how these tools help to establish links with people who have the same interests; and (3) hedonic, which prioritize the feelings of pleasure, fun, or personal or group satisfaction that the user perceives when using an innovation. Concerning the perceived costs of intending to use a technology, they are referred to as its implementation

24. Viswanath Venkatesh, 'Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model', *Information Systems Research*, 11, No. 4 (2000), 342–65; Viswanath Venkatesh and Fred D. Davis, 'A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies', *Management Science*, 46, No. 2 (2000), 186–204.
25. For a description of this approach for the cell telephone market, see B. Alberts, 'Technology Appropriation Revisited: Mediation Theory as a New Philosophy of Technology for Information Systems Research' (Unpublished PhD thesis, Twente University, 2012).

difficulties and the costs involved in its adoption, which include the effort required, the difficulty of use, and the loss of privacy that it may entail for the user – for example, when delivering a telegram that is subject to censorship.

Once the technology has been implemented, the results are studied; these constitute a new set of a posteriori factors with the same structure of benefits and shortcomings, which serve as an incentive to demand new services. These, in turn, will serve as requirements for the evolution of these new tools, such as technology, the creation of a national or international regulatory framework, or political and strategic aspects that promote or limit their implementation.

This model can be used to analyse the process of the adoption and evolution of a technological tool. We can now look at a specific case – the telegraph connection in the different archipelagos of Macaronesia in the last quarter of the nineteenth century – to evaluate the impact of the main factor (communications infrastructure) on the situation income model.

Application of the SIAM to the implementation of the telegraph connection in the Macaronesian archipelagos

To study the described model's applicability to the implementation process of the telegraph connection in the Atlantic archipelagos (Spanish and Portuguese) and therefore its effect on the evolution of maritime traffic in the studied period, it is necessary to describe the a priori and a posteriori factors in each case.

A priori factors

This group comprises two sets of elements: expected benefits and expected threats. These are different in each case, although they also present some points of similarity. Evidently, in all cases, the apparent functional benefit was the connection between island territories and the continent, and therefore the rest of the world. From the state's point of view, this implied a more significant structuring of its territory and a better strategic projection in the event of a conflict forcing the need for its defence. From the point of view of local societies, the telegraph was associated with maritime trade and a greater capacity to attract ship traffic, and therefore higher customs duties and the possibilities of exporting local products when ships did not have a connection on the high seas.[26] It also implied social benefits such as access to news services, leading to the emergence of a modern press, or legally allowing island administrations to receive the *Gaceta* or *Diario do Governo* much more quickly than the 'quarantine' of which contemporaries spoke.[27] This connection was also expected to facilitate access to other services such as notices to navigators, public safety or contact with displaced persons, in addition to

26. Roland Wenzlhuemer, 'Telecommunication and Globalization in the Nineteenth Century', *Historical Social Research/Historische Sozialforschung*, 35, No. 1 (2010), 7–18.

27. This term is even included in official documents, such as the *Boletín Oficial de la Provincia de Canarias*, 146 (7 December 1883).

strengthening the self-esteem of local societies through access to 'modernity' and their sense of belonging to their mother state.[28]

However, in the case of the Portuguese archipelagos (initially Madeira and Cape Verde, and later the Azores), this purely local or national need was subsumed by global strategic aspects and British interests. From the beginning, these networks were seen as part of the imperial communications network, allowing access from the metropolis to India or the African possessions of the Empire through territories that, without being part of it, were considered reliable allies.[29] This meant that not only was its laying carried out at the expense of the British government, but there were also some additional benefits, such as the protection of the Royal Navy over these lines in case of conflict, and priority access to the repair ships of the English Telegraph Company, which held, in practice, a monopoly over the capacity to recover damaged cables. This was not negligible in a period when cable technology was unreliable and knowledge of the seabed was almost anecdotal, which led to a string of failures and service interruptions (more than 20 in the case of the cable from the Canary Islands to Cadiz in the period 1883–1908).[30]

If only these factors were applied, it is clear that, in the case of the Canary Islands, these functional benefits would be less than the effort required for its implementation since it was an expensive service to install and maintain, and vulnerable to possible interruptions for strategic or military reasons – even those external to the archipelago – and also due to labour conflicts. In addition, in the case of the Canary Islands, internal political difficulties arose from conflicts over the definition of possible mooring points. The fundamentally commercial nature of this cable (and therefore it not being subject to a subsidy from the British government) and the commitments required for its laying resulted in very high tariffs. In practice, this limited its use to large companies that were mainly linked to port interests, or agricultural exporters and the administration. The high tariffs reduced the supposed hedonic benefits to almost zero since its use by private individuals was also subject to censorship, and it provided limited national and international news in the incipient insular press in the form of a few lines grouped under the heading 'Telegraph News' – and this was only thanks to a state subsidy. In both cases, the cable also meant an increase in foreign dependence, which was direct in the Portuguese case but also high in the case of the Canary Islands due to the absence of Spanish companies that could maintain or repair the cable, or supply equipment, technology or even trained personnel for its telegraph network. This foreign

28. This consideration can be seen in the parliamentary debates reflected in the Spanish Parliament, *Diario de Sesiones del Congreso*, 39 (17 July 1879), 694; 128 (17 March 1880), 2414; 143 (15 April 1880), 2934.
29. The so-called 'Atlantic strategic triangle' (Lisbon, Cape Verde and the Azores) formed a fundamental part of the network in the initial period. The construction of this node was, from the beginning, not only a technical undertaking but, above all, a political, economic and financial negotiation. See D. de Cogan, 'British Empire Cable Communications (1851–1930): The Azores Connection', *Arquipélago: Revista da Universidade dos Açores* (1988), 165–93.
30. P. Miguel Vigil, 'El fondo del mar entre la Península y Canarias deducido de los trabajos de telegrafía submarina', *Memorias de la Real Sociedad Española de Historia Natural*, 4, (1906), 6–56.

dependence produced many problems when the Canary Islands–Peninsula network was finally incorporated into the national postal service (Correos y Telégrafos).

A differential factor between the two cases can be derived from the possibility of developing an internal communications network that potentially enhanced the territory's economic development and the living conditions of its inhabitants, or improved its strategic defence. In the case of the Canary Islands, and simultaneously with the telegraphic connection to the Peninsula, an inter-island network was implemented and, at least in the larger islands, a series of lines covering the primary agricultural production areas (the valleys of La Orotava, Arucas, Gáldar and Santa María de Guía). In the case of Cape Verde, only one cable was laid between Sao Vicente and the island of Santiago in 1884, and only as part of a line to the Gambia territory. There were no internal networks in Madeira either, and only the Azores had an inter-island network development model similar to that of the Canary Islands from 1893 onwards.[31]

A posteriori factors

Once the different lines had been laid, they had a series of beneficial effects on the archipelagos, which are classified as functional, social and hedonic. At the same time, a series of shortcomings were revealed that stimulated the creation of new lines and even new technological solutions.

Among the functional benefits, the most striking was that obtained from the changes in the commercial navigation model, resulting from the possibility now offered to charterers to connect with ships during their port calls – although not yet during their navigation on the high seas. This allowed captains or shipowners to dynamically reassign routes according to possible commercial opportunities and change their cargo according to the demand at the destination. The reallocated routes immediately took advantage of the Canary ports, whose economic environment offered a greater variety of local products and had a more favourable tax regime than the Portuguese archipelagos.

A second immediate effect was the increase in the interest of other powers in having mooring points in these archipelagos to serve as intermediate stations and improve the quality of their communications. In peacetime, this made it possible to attract investments to lay new lines and avoid the effects of breakdowns by acting as secondary links in the event of outages, and reduced their vulnerability to possible attacks by other powers.[32] However, in wartime, it could turn these archipelagos into military targets of the first order, even if they belonged to neutral powers. Also, in cases of conflict, the availability of these telegraphic lines meant an improvement in the islands' security conditions in terms of their strategic defence capabilities by allowing them to request reinforcements

31. José Vilela, *Datas e factos do cabo submarino em Portugal (1855–2015)* (Lisbon, 2015), 24.
32. On such considerations, see Elizabeth Bruton, '"The Cable Wars": Military and State Surveillance of the British Telegraph Cable Network during World War One', in Andreas Marklund and Mogens Rüdiger, eds., *Historicizing Infrastructure* (Aalborg, 2017), 180–205; George Johnson, *The All Red Line: The Annals and Aims of the Pacific Cable Project* (Ottawa, 1903).

in real time.[33] At the same time, the different garrison units could be coordinated in the case of an invasion, avoiding having to distribute them to protect all the coasts and facilitating a comprehensive defence.[34]

On a social level, as already mentioned, although these lines provided an expensive service that prevented their use by the whole population, they allowed for the creation of the first modern press in the archipelagos, with the inclusion of current news (and therefore of propaganda associated with the powers in cases of conflict).[35] These infrastructures were the basis for a genuine, albeit limited, increase in the standard of living of the populations, which was associated with the economic change brought about by the increase in trade and export crops – fruit in the case of the Canary Islands and wine in the case of Madeira.[36] It also led to the emergence of companies and workshops to maintain this equipment.

However, telegraphy was not without technical and administrative limitations. First, although a significant step had been taken in supporting maritime trade, a ship was still inaccessible as soon as it was out of the visual range of the signals that could be made to it from land. Thus, a shipowner still did not have control over a boat while sailing but could direct it from his base or a port of call to the best destination to optimize its freight with a simple telegram.[37] Furthermore, it was difficult to coordinate battle fleets on the high seas, at either the strategic or the tactical levels, since the speed of the ships, the greater distance at which they had to form their battle lines, and the smoke from their smokestacks made communication with flags, as in Nelson's time, impossible in practice.

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33. An example is an action on Cocos Island in the Great War. See 'Official History of Australia in the War of 1914–1918, Volume IX – The Royal Australian Navy, 1914–1918' (9th ed., 1941), *Australian War Memorial*, https://www.awm.gov.au/collection/RCDIG1069926. An earlier example of the importance of wire-cutting operations to deprive the enemy of information is the Cienfuegos operation in the Spanish–American War in Cuba. See John Pelzer, 'Spanish–American War: Raid on Cienfuegos', *Historynet*, 21 August 2006, https://www.historynet.com/spanish-american-war-raid-on-cienfuegos.htm. There is also the Fashoda incident. See Kennedy, 'Imperial Cable Communications'.
34. See the involvement of telecommunications systems in the defence of the Canary Islands during the 1898 conflict. José Manuel Castellano Gil and José Manuel Clar Fernández, *Los planes de defensa del archipiélago canario en el siglo XIX* (Santa Cruz de Tenerife, 2009), 118; Pérez Jiménez, 'Los orígenes'.
35. As an example, it increased the number of telegrams sent to the Canary Islands during the Great War. Yanes attributes this to the newsworthiness of the conflict and the propagandistic zeal of the parties in the so-called 'paper war'. Julio Yanes, 'La Primera Guerra Mundial en Canarias: Vida cotidiana, opinión pública y reacción social', *XXI Coloquio de Historia Canario-Americana* Las Palmas de Gran Canaria, Spain (2014), 98. For propaganda in the Great War, see https://encyclopedia.1914-1918-online.net/pdf/1914-1918-Online-propaganda_at_home_and_abroad-2017-06-07-V1.1.pdf (accessed 1 October. 2022).
36. It is the case of Madeira from 1878 onwards. The situation of the latter archipelago has been studied in Yrjö Kaukiainen, 'Shrinking the World: Improvements in the Speed of Information Transmission, c. 1820–1870', *European Review of Economic History*, 5, No. 1 (2001), 1–28.
37. Wenzlhuemer, 'Telecommunication'.

Even on the ground, army units on the move were limited to follow, or to install, telegraph lines, making their movements predictable and traceable.

Finally, communications systems based on fixed lines were expensive to lay and maintain, subject to frequent breakdowns, and vulnerable to being cut or interrupted, not only by military conflicts but also by labour claims.[38] In addition, they left areas of the archipelagos uncovered as they were considered to be of low commercial or strategic profitability – both less populated islands and areas within the main islands. These 'islands in islands' created social inequalities, and they were perceived as lacking opportunity for economic development, as shown by the intensity with which these telecommunication services were demanded.[39] All of these shortcomings contributed to the generation of a demand for new technological, political and regulatory solutions to avoid, or at least alleviate, these problems.

Evolution factors

We will now consider the evolution factors, which are grouped into three main categories: political (including regulatory aspects), technological and social. For both Iberian nations, the fin-de-siècle period was traumatic when they had to face their limitations and learn their true capabilities. In the Portuguese case, the British ultimatum of 1890 brought them face-to-face with the true nature of their alliance with the British Empire, assuming a subordinate position and urging the need to open their foreign policy to other potential interests. From the telecommunications point of view, this opening of policy took the form of a closer link with the Spanish terrestrial telegraph network, and offering permission to lay cables, using its archipelagos as mooring points, to other European powers. This distrust (from the British view) led to the Portuguese archipelagos being progressively sidelined by the British government, reducing the need to maintain and repair the lines that connected them. Now, they were looking exclusively for mooring points of imperial sovereignty in their networks of strategic interest, as part of their policy known as 'all red lines'.[40]

The Spanish case was even more drastic, as the loss of the Antillean colonies created a security crisis in which the defence of the Canary Islands became an absolute priority.

38. Between the end of February and early March 1918, the Canary Islands remained isolated from the rest of the world except for the radiotelegraphic connection, due to the telegraph staff having a labour conflict. See *El Imparcial* (Tenerife), 27 February 1918; *Diario de Las Palmas*, 2 March 1918.
39. In Cape Verde, for example, telegraph coverage did not go beyond the port of Sao Vicente and the island of Santiago. In the case of the Canary Islands, the islands of Fuerteventura, La Gomera and El Hierro were not connected to the world telegraph network until 1908. See Vilela, *Datas*; Pérez Jiménez, 'Los orígenes'.
40. French, German or American cable moorings are found more frequently in the Lusitanian archipelagos, especially the Azores. Conversely, the Eastern Telegraph Company and its subsidiaries laid cables such as the Falmouth–Gibraltar (direct) during the following years, which strove to reduce British dependence on the Portuguese colonies and islands. See Silva, 'Portugal'; Mary Evelyn Townsend, *The Rise and Fall of Germany's Colonial Empire* (New York, 1966), 84, 184–5, 190–1; De Cogan, 'British Empire Cable Communications'.

Spanish interests became increasingly focused on the Balearic–Gibraltar–Canary Islands axis, including new interests in Morocco. These new priorities meant that the poor condition of the telecommunications networks linking the Canary Islands to the Iberian Peninsula, and their vulnerability, became a significant problem. It also opened the door to new lines, even with the participation of other powers, and the consideration of other technological solutions. In this frame, the role of the first specific communications act in Spain in 1907 should be highlighted, which provided a stable framework for developing new services. On the other hand, this growing strategic importance and the German presence in these lines made the Canary Islands a potential target in the event of conflict, and resulted in communications cuts during the Great War.[41]

In terms of technical advances, the technology that made it possible to connect the Atlantic islands with the continent soon began to show its shortcomings. First, the cables were not very robust and suffered numerous breaks. This was in addition to the fact that their range was limited, so thicker cables with better traction had to be made, which required the use of cable ships of greater capacity and with more complex laying equipment, and therefore of more significant gross displacement and cost. These new realities further reinforced the competitive advantage of the United Kingdom, which had both the technical and economic capacity to charter and maintain these vessels, and almost exclusive access to the insulating material (gutta-percha) used at the time.

Even so, the major drawback was still the inability to connect with ships at sea beyond the distance of visual contact. This is why the invention of wireless telegraphy systems at the beginning of the twentieth century gradually changed how navigation developed. It was a gradual development because this equipment was still expensive to acquire and maintain, and required the incorporation of skilled personnel into a crew. Few merchant ships could afford this, at least until the approval of the Security of Life at Sea protocols in 1914 (and the hazard of German U-boats in the First World War) made it compulsory.[42] The availability of long-range wireless telegraphy systems provided insular territories with an alternative means of

41. Britain entered the war on 3 August 1914 and, the next day, the Royal Navy cut the submarine cable linking Borkum (in the North Sea) to Tenerife, which could be considered a legitimate act of war, but it did the same with that from Tenerife to Monrovia, which linked two neutral countries. Javier Ponce, 'Neutral Waters? British Diplomacy of Force in the Canary Islands at the Start of the First World War', *Mariner's Mirror*, 106, No. 3 (2020), 292–306. Subsequently, the cable linking the Canary Islands and the mainland was cut in 1918 to prevent any possible assistance to the German submarine activity around the islands. Javier Ponce 'Canarias y la política exterior española en la Primera Guerra Mundial, 1914–1918: El protagonismo internacional de las islas como escenario de confrontación diplomática y estratégica' (Unpublished PhD thesis, University of Las Palmas de Gran Canaria), 2001. The Great War, in short, showed that the Canary Islands, with more precarious security than the Balearic Islands, was the main negative, passive and conservative target of Spanish foreign policy. Javier Ponce, 'España en la Primera Guerra Mundial: Política exterior, neutralidad y algunos apuntes sobre Canarias', *XXI Coloquio de Historia Canario-Americana* Las Palmas de Gran Canaria, Spain, (2014), 097, 1–8.

42. The Security of Life at Sea (SOLAS) protocol is available at: http://archive.org/details/textofconvention00inte/page/n5/mode/2up?view=theater (accessed 2 January 2022).

connection in cases of the accidental or intentional cutting of telegraph cables. These archipelagos could influence commercial navigation through 'on-board news' or as a rescue point when there were breakdowns or accidents.[43] With regard to wireless telegraphy, the Canary Islands enjoyed an enormous advantage since it had had operational radiotelegraphic stations since 1911, these being, along with those of Cadiz and Madrid, the first installed in Spain.[44] On the other hand, in Portugal, until the beginning of the Great War, only one station was operational in Cape Verde, working under British control and designed to connect the units of the Royal Navy stationed in the South Atlantic with the Admiralty, and therefore with relatively little commercial interest.[45]

An additional factor of great importance for inland connections was the growing presence of telephone networks from the beginning of the twentieth century. However, the telephone was not yet a viable alternative for connecting with the peninsular territories.[46] The late arrival of telegraphy in the archipelagos meant that its introduction coincided with the appearance of the telephone – in other places telegraphy had over 30 years of monopoly. Even at an early stage, the telephone had advantages, such as making an intermediary unnecessary since using a telephone was within reach of anyone and did not need knowledge of Morse code. In addition, telegraph messages were easier to censor or transcribe to third parties. This meant that postal administrations were, in principle, reluctant to expand the use of telephony, at least until they control it, which, in a regulatory framework that was not yet well defined, gave rise to almost permanent conflict.[47] It is for this reason that the telecommunications law of 1907 was so crucial, as it established a stable framework for both technologies to coexist. The telephone made it possible to improve the connection of farming areas with the loading points of coastal vessels or large export ports, since the condition of the inland roads (or rather their non-existence), due to the mountainous terrain of the islands, made it necessary to use

43. Wenzlhuemer, *Connecting*. See also Rafael Pérez Jiménez and Francisco del Pino Quintana Navarro, 'Conectando el Atlántico: La radiotelegrafía en Canarias durante el período de entreguerras', *Anuario de Estudios Atlánticos*, 65 (2018), 29–66.
44. Jesús Sánchez Miñana, 'Los primeros pasos de la radio en España: Guglielmo Marconi y Julio Cervera', in *XVII Simposium Nacional de la Unión Científica Internacional de Radio*, Alcalá de Henares, Spain, 11–13 September 2002. Available at: *https://forohistorico.coit.es/index.php/biblioteca/libros-electronicos/item/primeros-pasos-de-la-radio-en-espana-guglielmo-marconi-y-julio-cervera*
45. See 'A Telegrafia Sem Fios em Portugal', *História da Rádio em Portugal*, http://telefoniasemfios.blogspot.com/p/a-telegrafia-sem-fios-em-portugal.html (accessed 30 December 2021). During the First World War, a radio station was also installed in Madeira, in Quinta da Santana. It was sponsored by the British government to provide information to local newspapers and was closed at the end of the war.
46. The laying of submarine telephone cables over similar distances would not be a technological possibility until the 1950s. Mischa Schwartz and Jeremiah Hayes, 'A History of Transatlantic Cables', *IEEE Communications Magazine*, 46, No. 9 (2008), 42–8.
47. Ángel Calvo, 'El teléfono en España: Regulación sin regulador independiente, 1882–1975', *Revista de Historia Industrial*, 61 (2016), 141–82.

this alternative infrastructure for island trade.[48] This infrastructure was also an advantage for the Canary Islands since similar networks did not exist in other Atlantic archipelagos, such as Madeira, the Azores and Cape Verde, until after the First World War.[49]

From a social point of view, the Canary Islands enjoyed a period of commercial prosperity in the pre-war period, although this did not filter down equally to the different levels of island society. The economic advantages linked to the increased naval traffic and improved infrastructure (ports, logistics and communications) also led to the creation of island institutions, educational facilities and even a nascent tourist industry. This cycle, which was only interrupted by the outbreak of the Great War, was not paralleled in the Portuguese archipelagos.

Conclusions

This article has presented a model that aims to explain the influence of technology within situational economy models. A way of evaluating this construct has been proposed based on technology acceptance models, which make a cost–benefit comparison, but an ex post analysis has been added, so that the model allows an a posteriori explanation of the reasons to incorporate of these solutions. In addition, as the evolution of technology is not linear, it has been necessary to complement this analysis with a series of evolution factors, which form a feedback system and incorporate aspects such as scientific advances, regulatory changes, the geostrategic context, and the social acceptance or rejection of the technology. In this way, a complete study can be made of how the economic model was modified as technological factors were transformed, within the context of the co-evolution of science and society as two inseparable elements.

This model has been applied to explain the divergence in the evolution of maritime trade among Macaronesian archipelagos before the Great War. In those years, the Canary Islands, which initially had a small share in this traffic, achieved, at the beginning of the conflict, a dominant position. It does not seem that the geographical components (which remained unchanged) or trade regulations are sufficient to explain this change, which seems to have been due to the Canary Islands' capacity to offer added value to the ships that called there in the form of agricultural products for export. The model indicates that communications technology played a decisive role in improving what the Canary Islands offered by connecting the cultivation and storage areas with the distribution networks, where the cabotage ports would have had a prominent position. The evolution of the communications networks of the Canary Islands, beyond the original submarine telegraph cables, not only strengthened the competitive capacity of these crops by incorporating inland networks with the first telephone networks or by allowing connection with ships at sea through the new wireless telegraphy, but also led to the growth of other areas in the service sector, such as logistics, banking and a nascent tourism sector.

48. The condition of the roads was an ongoing topic of debate. See, for example, Spanish Parliament, *Diario de Sesiones del Congreso*, 113 (28 February 1880), 2074–5. It was described as 'poorly developed, weak for the development of the domestic market, and detrimental to the progress of foreign trade'.
49. Silva, 'A introduzão'.

The application of this type of analysis, with a model of the influence of technology on the evolution of economy, opens up new possibilities for the study of other subjects of historical analysis, an example of which may be the evolution of air traffic in these archipelagos in the interwar period, where once again one of the archipelagos gained an essential competitive advantage in the postal routes between Europe and South America.

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