The Development of Tide Prediction Machines

Doodson-Légé tide prediction machine, built in London in 1950. Photograph taken by H. M. Rawsthorne at NOC, Liverpool, on 15/01/2019; licensed under CC BY 4.0.

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coastal dwelling

marine navigation

operating docks

fishing

operating ports

operating harbours

coastal zone engineering

coastal surveying

beachgoing

watersports

naval operations

commercial shipping

houseboat living

biology

building flood defences

tidal power

ecology

weather forecasting

Tidal theory, analysis and prediction

$$H(t) = \sum_{i=1}^{i=N} A_i \cos(\omega_i t - \phi_i)$$

- BCE: Indian and Arabic civilisations recognising link between moon and tides
- Middle Ages: rule-of-thumb methods linked to phases of moon
- Tidal theories: Copernicus, Bacon, Galilei, Kepler, Descartes, Newton, Laplace
- Tidal analysis and prediction: Lubbock, Young, Airy, Thomson, Ferrel, Darwin, Proudman, Doodson
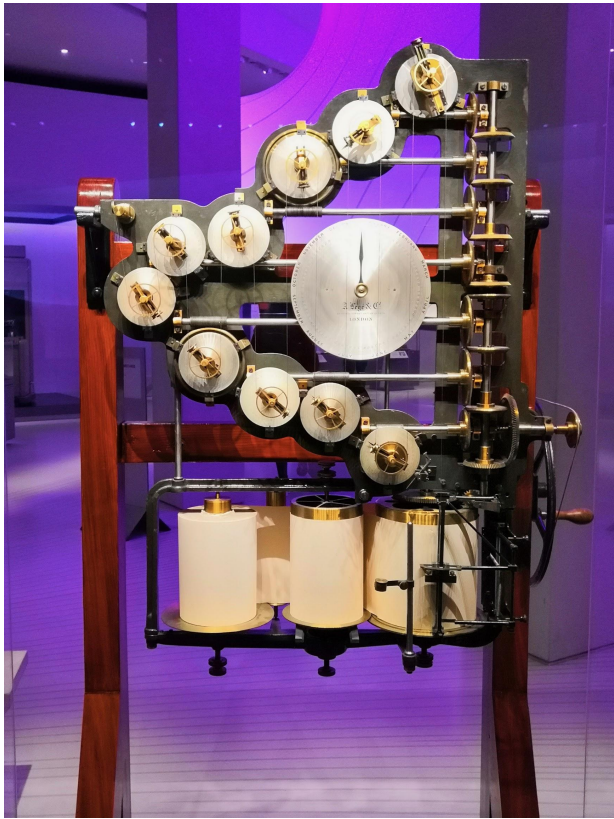
British Tide Predictor No.1, built in London in 1873. Photograph taken by H. M. Rawsthorne at Science Museum, London, on 02/02/2019; licensed under CC BY 4.0.

The development of tide prediction machines

- Mid-19th century: commercial shipping lines calling for improved prediction service
- Calculations by hand no longer sufficient
- BAAS funded development of a machine to calculate tidal predictions
- First TPM designed by William Thomson, constructed in 1873 by A. Légé & Co. in London

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Doodson-Légé tide prediction machine, built in London in 1950. Photograph taken by H. M. Rawsthorne at NOC, Liverpool, on 15/01/2019; licensed under CC BY 4.0.

What are tide prediction machines?

- Analogue computers used for calculating tidal predictions
- Outputs: times and heights of high and low tide
- Based on tidal theory and tidal equation
- Total of 33 ever built
- Used across the world
- Always operated on land
- Superseded by digital computers

Bidston-Kelvin tide prediction machine, built in Glasgow in 1925. Photograph taken by H. M. Rawsthorne at SHOM, Brest, on 18/12/2018; licensed under CC BY 4.0.

Significance of tide prediction machines

- Required development of scientific theory and of technology
- Crucial to advancement of marine transport: commercial and military
- Used for WWII Normandy landing operations
- Important for building modern ports and effective flood defences

Bidston Observatory, Wirral Peninsula, Merseyside, built in 1866. Photograph taken by H. M. Rawsthorne on 08/01/2019; licensed under CC BY 4.0.

Local impact of tide prediction machines

- Contributions of Joseph Proudman and Arthur Doodson
- Proudman, Doodson and LOTI: worldwide reputation for tidal research and prediction
- Two tide prediction machines on display at National Oceanography Centre, Liverpool

PROSOPOGRAPHY

What is prosopography?

Define group of people to be studied

Construct hypotheses and questions about group

Translate hypotheses and questions into questionnaire

Use authoritative sources to answer questionnaire for every member of group
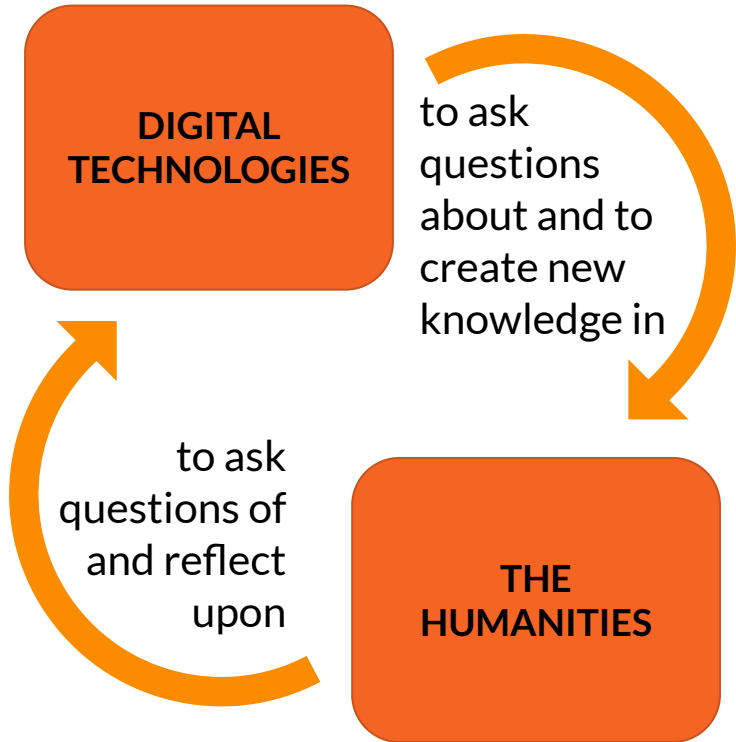
Create database of answers

Analyse data in database to answer initial questions

- Research approach usually used by historians to study the lives of groups of people
- Involves creating collective biography or gathering data about common aspects of lives of individuals within group
- Data can be compared, synthesised and analysed

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What is digital humanities?

- Interdisciplinary area of study between humanities and digital technology
- DH digital technologies come in form of tools, applications and software (purpose-built for DH or not)

DIGITAL TECHNOLOGIES

to ask questions about and to create new knowledge in

to ask questions of and reflect upon

THE HUMANITIES

Tide prediction machines, prosopography and digital humanities: how do they fit together?

- Want to study "lives" of tide prediction machines as a collection of artefacts
- Going to adapt prosopography for study of artefacts
- Going to make use of digital humanities tools for data analysis

Define group of artefacts to be studied

Construct hypotheses and questions about group

Translate hypotheses and questions into questionnaire

Use authoritative sources to answer questionnaire for every member of group

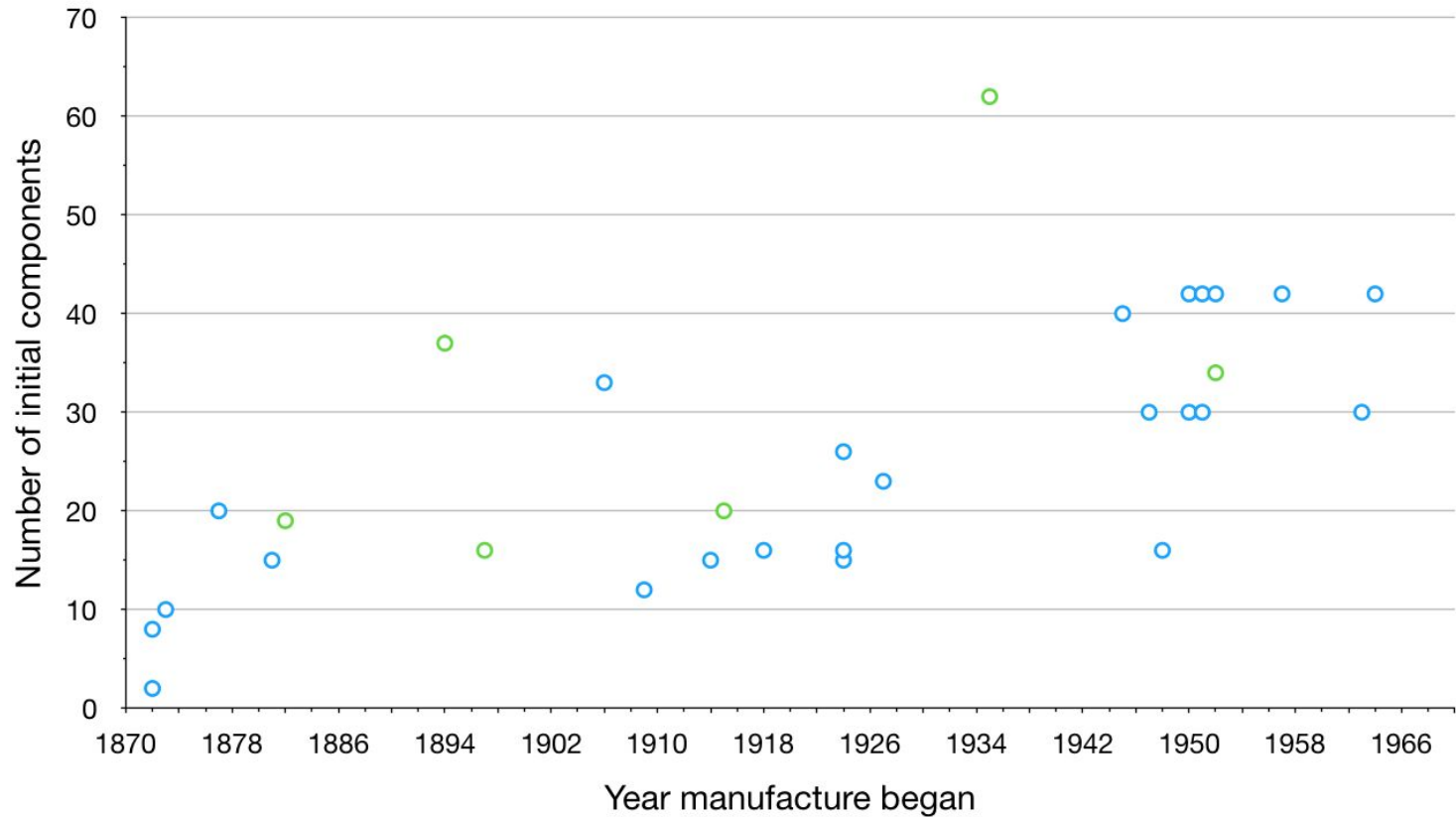| Create database of answers |
|---|

Analyse data in database to answer initial questions

Adaptation of prosopography

- Analogy between life of a person and existence of an artefact
- Each has a unique story to tell and is impacted by events and relations
- Can prosopography be successfully applied to study the "lives" of groups of artefacts?

Worldwide TPMs (inc. prototypes)

| No. | Name | Prototype/ operational | Manufacture began | Manufacture finished | Manufacturer | City of manufacture | Country of manufacture | Initial number of constituents | Refurbishment year | New number of constituents | First operation city | Year moved during operation | Final operation city | Year decommissioned | Reason for decommissioning | Modern refurbishment year | Current owner | Current place | Current country | Current city | Current status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPM-KP1 | Kelvin Model made for the BAAS | Prototype | 1872 | 1872 | Messrs. White | Glasgow | UK | 8 | | | | | | | Prototype | | | | | | |
| 1 | Kelvin's First TPM | Operational | 1873 | 1873 | Alexander Légé & Co. | London | UK | 10 | | | London | | London | | | | The Science Museum | Science Museum | UK | London | On display to public |
| TPM-KP2 | Kelvin 2-Component Machine | Prototype | 1872 | 1873 | Alexander Légé & Co. | London | UK | 2 | | | | | | | Prototype | | | | | | |
| 2 | India Office Machine | Operational | 1877 | 1879 | Alexander Légé & Co. | London | UK | 20 | 1891 | 24 | London | 1921 | Dehradun | 1952 | Replaced by newer TPM | | Museum of the Survey of India | Museum of the Survey of India | India | Dehradun | On display to public |
| 3 | British TPM No. 3 | Operational | 1881 | 1881 | Kelvin and White | Glasgow | UK | 15 | 1901 | 16 | Paris | | Paris | | | | Musée des Arts et Métiers | Musée des Arts et Métiers | France | Paris | |
| 4 | US & C&GS No. 1 | Operational | 1882 | 1882 | Fauth and Co. | Washington, D.C. | USA | 19 | | | Washington, D.C. | | Washington, D.C. | 1914 | | | Smithsonian National Museum of American History | Smithsonian National Museum of American History | USA | Washington, D.C. | In storage |
| TPM-X2 | Australian TPM | Operational | 1897 | 1897 | Alexander Inglis | Adelaide | Australia | 16 | | | Adelaide | | Adelaide | | | | | | | | |
| 5 | Roberts-Légé Machine | Operational | 1906 | 1908 | Alexander Légé & Co. | London | UK | 33 | 1936 | 40 | London | 1929 | Bidston | | | 2015 | National Museums Liverpool | National Oceanography Centre | UK | Liverpool | Viewed by arrangement |
| 6 | US & C&GS No. 2 | Operational | 1894 | 1910 | US Coast & Geodetic Survey | Washington, D.C. | USA | 37 | | | Washington, D.C. | | Washington, D.C. | | | 2015 | National Oceanic and Atmospheric Administration | National Oceanic and Atmospheric Administration Science Center | USA | Silver Spring | Viewed by arrangement |
| 7 | British TPM No. 4 | Operational | 1909 | 1910 | Kelvin and White | Glasgow | UK | 12 | | | Rio de Janeiro | | Rio de Janeiro | | | | Museu Náutico de Bahia | Museu Náutico de Bahia | Brazil | Salvador | On display to public |
| 8 | Japan Kelvin Machine No. 1 | Operational | 1914 | 1914 | Kelvin, Bottomley and Baird | Glasgow | UK | 15 | | | Tokyo | | Tokyo | 1923 | Accidental destruction | | | | | | Destroyed |
| 9 | German TPM No. 1 | Operational | 1915 | 1916 | Toepfer und Sohn | Potsdam | Germany | 20 | 1931 | | Hamburg | | Hamburg | | | | Deutsches Schiffahrtsmuseum | Deutsches Schiffahrtsmuseum | Germany | Bremerhaven | On display to public |
| 10 | Argentina TPM No. 1 | Operational | 1918 | 1918 | Kelvin, Bottomley and Baird | Glasgow | UK | 16 | | | Buenos Aires | | Buenos Aires | 1953 | | | Observatorio Naval Buenos Aires | Observatorio Naval Buenos Aires | Argentina | Buenos Aires | |
| 11 | Japan Kelvin Machine No. 2 | Operational | 1924 | 1924 | Kelvin, Bottomley and Baird | Glasgow | UK | 15 | | | Tokyo | | Tokyo | | | | Japan Coast Guard Academy | Japan Coast Guard Academy | Japan | Hiroshima | |
| 12 | Japan Kelvin Machine No. 3 | Operational | 1924 | 1924 | Kelvin, Bottomley and Baird | Glasgow | UK | 15 | | | Tokyo | | Tokyo | 1960 | | | National Museum of Nature and Science | National Museum of Nature and Science | Japan | Tokyo | On display to public |
| 13 | Lisbon Machine | Operational | 1924 | 1924 | Kelvin, Bottomley and Baird | Glasgow | UK | 16 | | | Lisbon | | Lisbon | | | | Instituto Hidrográfico | Library of the Instituto Hidrográfico | Portugal | Lisbon | On display to public |
| 14 | Bidston-Kelvin Machine | Operational | 1924 | 1925 | Kelvin, Bottomley and Baird | Glasgow | UK | 26 | | 29 | Bidston | 1950 | Paris | 1966 | Replaced by digital computers | | Service Hydrographique et Océanographique de la Marine | Service Hydrographique et Océanographique de la Marine | France | Brest | Viewed by arrangement |
| 15 | Brazil Kelvin Machine | Operational | 1927 | 1927 | Kelvin, Bottomley and Baird | Glasgow | UK | 23 | | | Rio de Janeiro | | Rio de Janeiro | 1967 | | | Museu de Astronomia e Ciências Afins | Museu de Astronomia e Ciências Afins | Brazil | Rio de Janeiro | |
| 16 | German TPM No. 2 | Operational | 1935 | 1939 | Aude und Reipert | Potsdam | Germany | 62 | | | Hamburg | | Hamburg | | | | Deutsches Museum | Deutsches Museum | Germany | Munich | On display to public |
| 17 | Russia Doodson-Légé Machine | Operational | 1945 | 1945 | Alexander Légé & Co. | London | UK | 40 | | | Moscow | | Moscow | 1969 | Replaced by digital computers | | | | | | Destroyed |
| 18 | Norway Kelvin Machine | Operational | 1947 | 1947 | Chadburns | Liverpool | UK | 30 | | | Oslo | | Oslo | | | | Stavanger Maritime Museum | Stavanger Maritime Museum | Norway | Stavanger | On display to public |
| 19 | Madrid Kelvin Machine | Operational | 1948 | 1948 | Kelvin and Hughes | Glasgow | UK | 16 | | | Madrid | | Madrid | | | | Instituto Hidrográfico de la Marina | Instituto Hidrográfico de la Marina | Spain | Cádiz | In storage |
| 20 | Bidston Doodson-Légé Machine | Operational | 1950 | 1950 | Alexander Légé & Co. | London | UK | 42 | | | Bidston | | Bidston | | Replaced by digital computers | 2015 | National Museums Liverpool | National Oceanography Centre | UK | Liverpool | Viewed by arrangement |
| 21 | Manila Doodson-Légé Machine | Operational | 1950 | 1950 | Alexander Légé & Co. | London | UK | 30 | | | Manila | | Manila | | | | National Mapping and Resource Information Authority, Hydrography Department | National Mapping and Resource Information Authority, Hydrography Department | Philipines | Manila | On display to public |
| 22 | India Doodson-Légé Machine | Operational | 1951 | 1951 | Alexander Légé & Co. | London | UK | 42 | | | Dehradun | | Dehradun | | | | Museum of the Survey of India | Museum of the Survey of India | India | Dehradun | Viewed by arrangement |
| 23 | Siam Doodson-Légé Machine | Operational | 1951 | 1951 | Alexander Légé & Co. | London | UK | 30 | | | Bangkok | | Bangkok | 1977 | | | Royal Thai Navy | Thai Hydrographic History, Royal Thai Navy, Hydrographic Department | Thailand | Bangkok | On display to public |
| 24 | Argentina Doodson-Légé Machine | Operational | 1952 | 1952 | Alexander Légé & Co. | London | UK | 42 | | | Buenos Aires | | Buenos Aires | | | | Museo Naval de la Nación | Museo Naval de la Nación | Argentina | Buenos Aires | On display to public |
| 25 | German TPM No. 3 | Operational | 1952 | 1955 | VEB Karl-Marx-Werk | Potsdam | Germany | 34 | | | Rostock | | Rostock | | | | Deutsches Schiffahrtsmuseum | Deutsches Schiffahrtsmuseum | Germany | Bremerhaven | On display to public |
| TPM-X3 | Japan Doodson-Légé Machine | Operational | 1957 | 1957 | Alexander Légé & Co. | London | UK | 42 | | | Tokyo | | Tokyo | | | | Hydrographic and Oceanographic Department, Japan Coast Guard | Hydrographic and Oceanographic Department Museum | Japan | Tokyo | On display to public |
| TPM-X5 | Indonesia Doodson-Légé Machine | Operational | 1963 | 1963 | Alexander Légé & Co. | London | UK | 30 | | | | | | 1987 | Replaced by digital computers | | | | | | Destroyed |
| TPM-X6 | Burma Doodson-Légé Machine | Operational | 1964 | 1964 | Alexander Légé & Co. | London | UK | 42 | | | | | | 1990 | | | | | Myanmar | Yangon | |
| TPM-X1 | Koenings' 4-Component Machine | Operational | | | | | France | 4 | | | | | | | | | | | | | |
| TPM-X4 | Kobe Machine | Operational | | | | | Japan | | | | | | | | | | Kobe University | | Japan | Kobe | |

Graph showing variation of number of initial components built in tide prediction machines over time. Made by H. M. Rawsthorne using Numbers.

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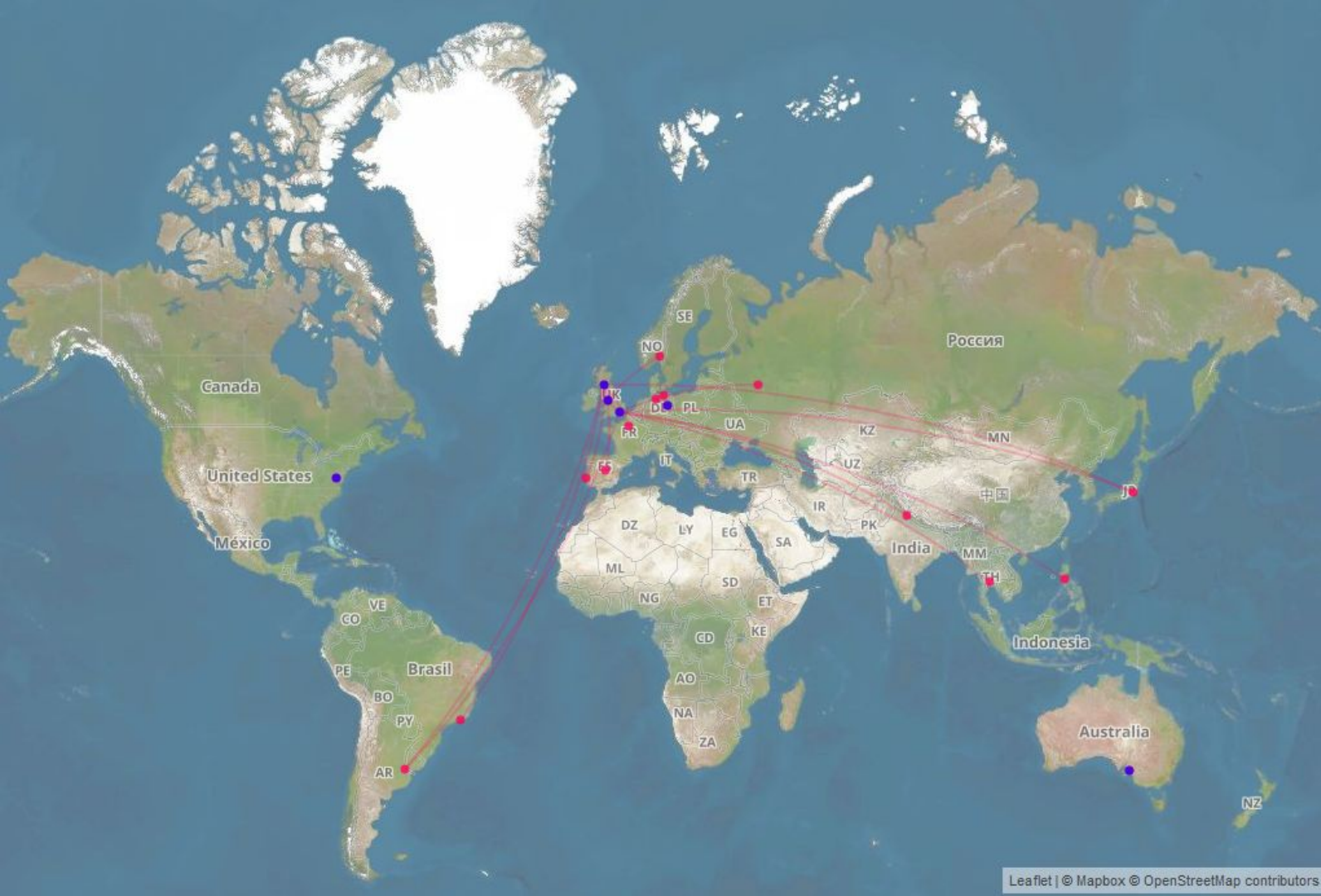
Map showing links between manufacture location (purple) and operation location (red) of tide prediction machines. Made by H. M. Rawsthorne using Palladio.

Year decommissioned

Year manufacture began
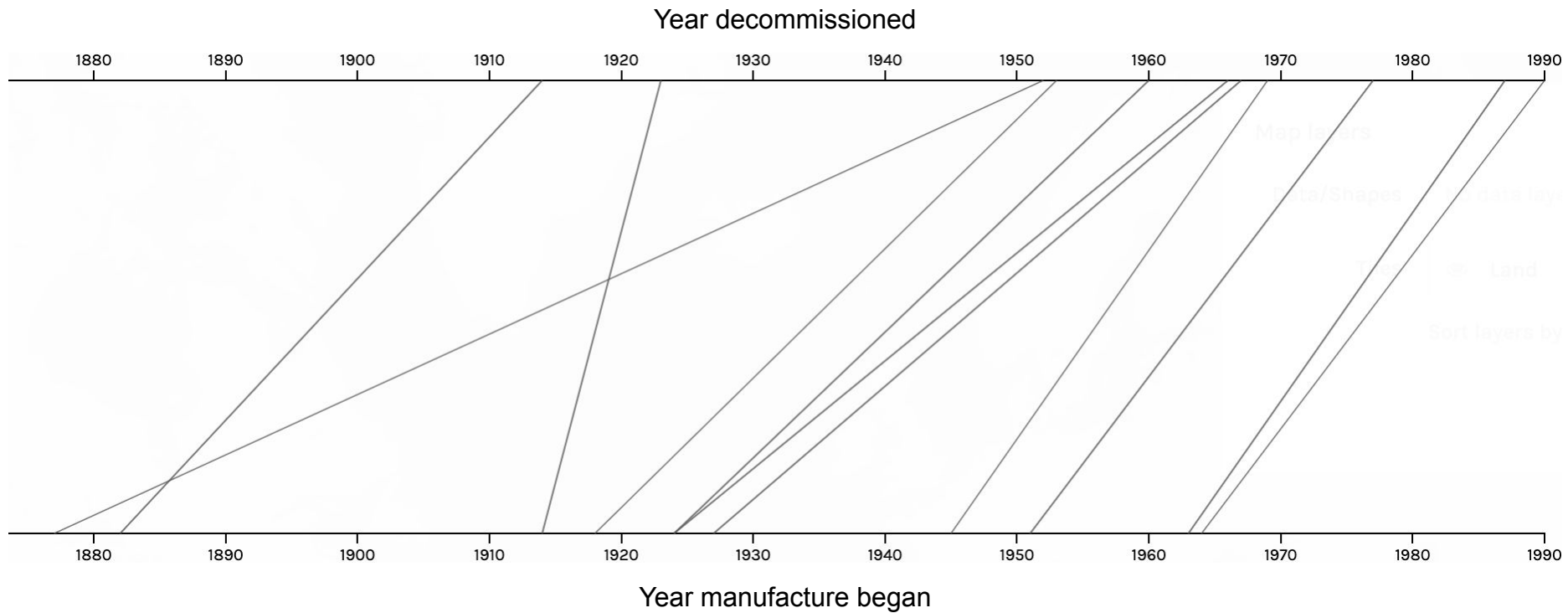
Timespan showing dates of manufacture (bottom) and dates of decommissioning (top) of tide prediction machines worldwide. Line gradient represents length of lifetime. Made by H. M. Rawsthorne using Palladio.

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Year manufacture ended
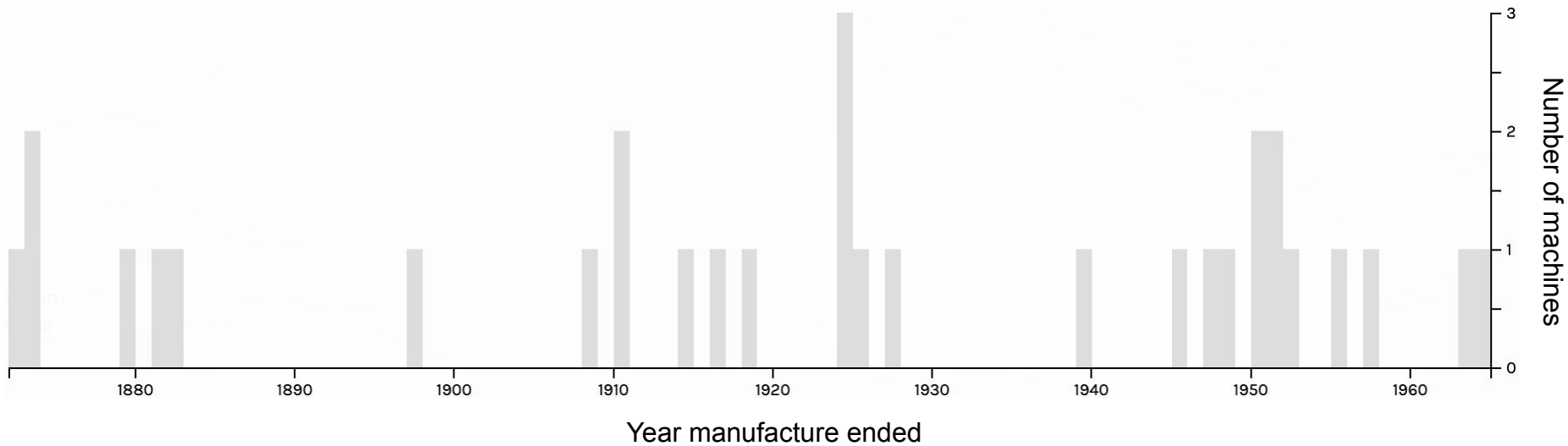
Number of machines

Timeline showing number of tide prediction machines that were finished being built each year worldwide. Made by H. M. Rawsthorne using Palladio.
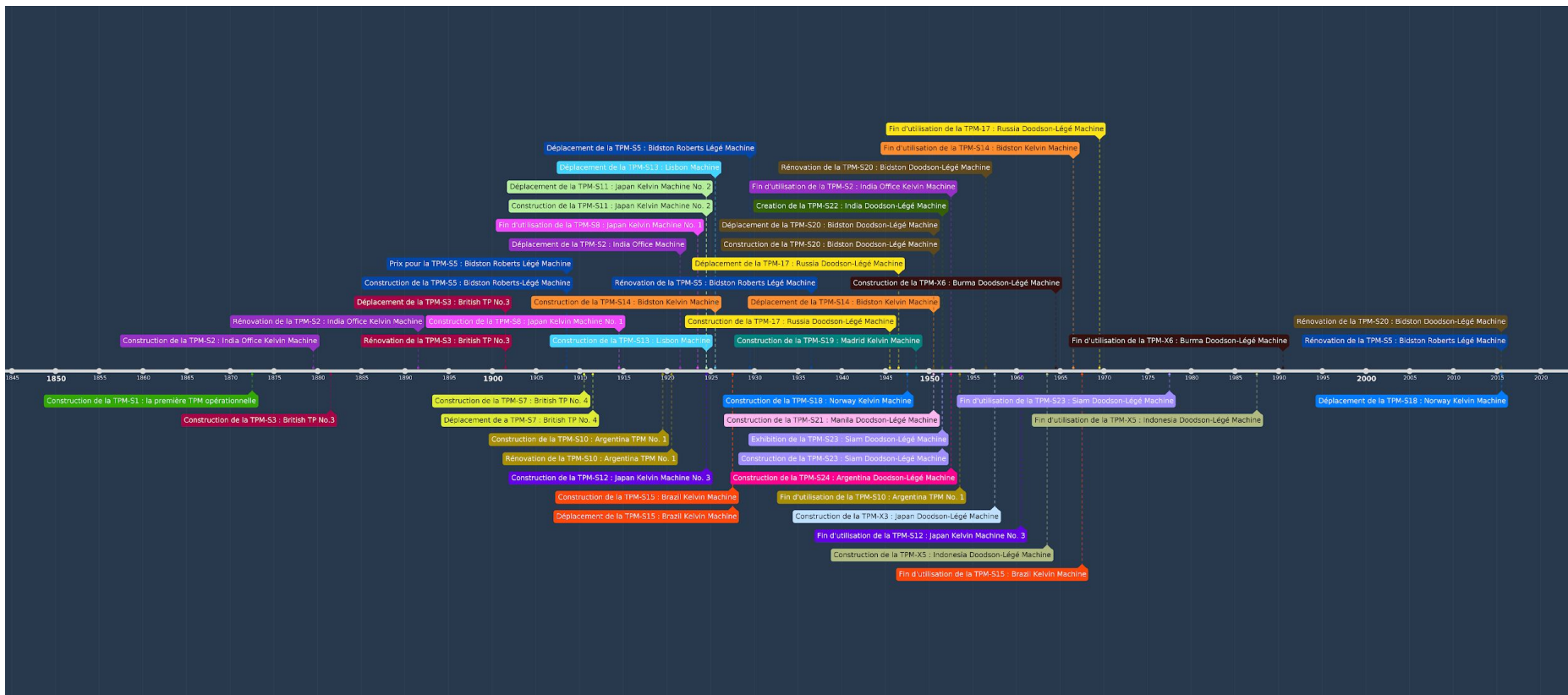
Timeline showing life events of all tide prediction machines manufactured in Great Britain. Made by H. M. Rawsthorne using Time.Graphics.

Results and evaluation

Tide prediction machines

- Analysis of life-cycle
- How machine build changed over time
- How foreign relations impacted exportation of machines
- Shaped by the sea

Artefact prosopography

- Successful
- Larger group needed
- Need to test with different type of artefact
- Digital humanities tools essential

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