The Public Body – How to Create Commercially Viable National Meteorological and Hydrological Services

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Abstract

This paper explores the legal and administrative steps to be taken for National Meteorological and Hydrological Services (NMHSs) to offer commercial services in addition to their statutory public duties. Considering all the different operating models described in an earlier paper and assuming the government/NMHS willingness to innovate and test new approaches to improve hydromet services, we recommend that an NMHS, which presently operates as a government department, becomes a public body as defined in law. A public body is a legal personality with considerable autonomy to conduct its own business with less day-to-day involvement of central government.

An organizational structure of the NMHS is proposed, which mirrors many private companies' efforts to differentiate their business offers to a range of clients. The commercial market is considered and potential approaches to establishing and sustaining the market are discussed. Several examples of how the benefit of weather data and forecasts emerges are reviewed. Commercial services tend to focus on the creation of integrated services where the producer and beneficiary work together to develop the solution. Increasingly collaboration between weather, data science, and IT experts through some form of public-private engagement is needed to develop viable support systems.

NMHSs often undertake commercial services as means to offset declining public funding. While additional revenue generation is possible, it is not a panacea. Care must be taken to restructure the NMHS to enhance its efficiency and effectiveness and thereby provide cost-effect services to all its clients – both public and private.

Introduction

The provision of adequate public weather, water, and climate services across numerous sectors from health care to education is challenging for many governments. Limited funding results in service provision that is well below basic national needs and international standards for the sector. Many National Meteorological and Hydrological Services (NMHSs) are unable to take advantage of advances in science and technology to provide a level of service that citizens should expect. A kneejerk reaction of government is often to require the NMHSs to find new revenue streams without developing fully a plan for the provision of rival and non-rival services (Rogers et al. 2021a). A legal framework is needed, which includes clearly defined roles and responsibilities of public and private sectors, data policies, and the regulation of services. It is also essential to create a level playing

field for the provision of competitive and co-produced services, which has been previously highlighted (Rogers et al. 2021b).

This paper proposes a business model for the provision of public and private goods services by an NMHS; either alone or in one or more partnerships with private sector service providers. Rogers et al. (2021b) highlighted the pros and cons of the five NMHSs' operating models. Here, the focus is on the *public body* model as the foundation for an NMHS engaged in the provision of public services and commercial activities.

Public Body

Rogers et al. 2021b describe the basic components of a public body and we summarize some of the salient details here. A public body can operate at arm's length from the central government. On the one hand this reduces political interference and gives more operational and management freedom; on the other, the public body is responsible for its own budgetary decisions. Public bodies are established based on public law and, depending on their level of autonomy, have a partially separate or fully separate legal personality (Greve et al. 1999). They may, however, be entitled to conclude contracts for the provision of services in accordance with private law. Governments usually refer to the additional discretionary funding mechanisms as commercial, although exclusivity normally associated with commercial activities is lacking (Rogers and Tsirkunov 2013). Assuming the government wants to retain the responsibility for public services, the goal is to shift the complexity of service provision to the public body. Some form of commercialization is often practiced in public bodies (Van Thiel 2012). Assuming an NMHS can be organized as a public body, we consider what this would look like in practise to avoid some of the past problems associated with public bodies providing commercial services.

Another feature of the public body model related to their ownership by the government department on which they depend, is the relationship with other government departments. Services provided by the public body may be sold to other departments. The owning department may require the public body to return an annual dividend to them. When the public body is contracted by other government departments, the financial return is, in effect, an overcharge if it contributes any dividend to the owning department. The emphasis on receiving income from multiple contracts to maintain services also has potential problems. Unless there is sufficient long-term financing from government, it may become difficult to maintain infrastructure, such as observational networks. Another risk is the potential to distort the commercial market limiting its potential as an engine for economic growth. Good business management, accounting, and auditing practices are essential. These issues are addressed in the following sections.

The Public Body NMHS

Legal Framework

The first step is enabling legislation that establishes the NMHS as an independent legal entity. Most weather laws explicitly provide for the establishment and operation of the NMHS as an independent legal entity in the form of a “legal person” or a “body corporate” depending on the legal tradition concerned, sometimes described an “agency” or “authority”. Such an NMHS has what is called independent legal personality and, therefore, the legal capacity to enter contracts in its own name (including contracts of employment), hold property, open bank accounts, and take and defend legal proceedings (Hodgson 2024).

An NMHS established as an independent legal entity can generate and retain its own funds and generally to be run more like a business. For example, in such cases, the NMHS staff may be freed from low civil servant pay-scales and procedures – and employed on the same basis and similar terms as in the private sector with bonuses and even performance related pay (Hodgson 2024).

Two main approaches are taken in the weather laws reviewed to establish NMHSs as independent legal entities (Hodgson 2024). Under one approach, the NMHS is established using an existing type of a legal entity. This is the case in France where “There is created, under the name of Météo-France, a public establishment of the State of an administrative nature. This establishment, endowed with civil personality and financial autonomy, is placed under the supervision of the Minister in charge of transport.” This is a common type of autonomous public administrative entity in France, with its own body of rules and procedural requirements to which the weather law cross-refers. The French weather law had the effect of changing the legal status of previously existing public National Meteorological Service to enable it to engage in commercial activities (Hodgson 2024).

The other approach explicitly provides a legal personality in the weather law; that is, the weather law is the source of legal personality for the NMHS. The legislation almost invariably provides that the NMHS is established based on “public law” as opposed to “private law”[1].

Where weather legislation provides for the establishment of the NMHSs as public law bodies, it is important to ensure that they can undertake commercial activities based on private law rules, as regards the conclusion of contracts for example. The result is that the NMHS can function as a business notwithstanding its (public law) legal status. Examples of public bodies that provide commercial services include the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Kenya Meteorological Department (KMD), South African Weather Service (SAWS), and Tanzania Meteorological Authority (TMA). Each can leverage

[1] Private law is concerned with the legal relationship between ordinary private people, including private companies – an example is contract law, a branch of private law. In contrast, public law is concerned with the body of legal rules that regulates the conduct of both state bodies (like central and local government) and bodies that undertake public functions (like state agencies and universities). The distinction between public and private law is more marked in the legal systems of the civil law tradition, although it is also found in the common law tradition (Hodgson 2024).

their expertise and data to offer commercial services. Among these examples, only SAWS appears to provide detailed, audited financial statement in its annual report.

Management

Oversight Board

Hodgson (2024) also highlights that any entity with a legal personality requires a management or oversight board with members representing a variety of sectors. The tasks of the board of directors are generally spelled out in the weather law. These may include setting out the program of activities proposed the Chairman and Chief executive Officer; the budget and financial accounts; pricing policies for products and services; acquisitions, alienations and exchanges, rents, leases, and construction of buildings; donations; legal actions and settlements; loans; participation in bodies endowed with legal personality; the creation of subsidiaries and the acquisitions, extensions and disposal of financial holdings; annual activity report; internal regulations of the board of directors, and contracts and markets.

Director

The meteorological law will also provide for the appointment of a director or chief executive to lead the NMHS. It is usual for the government to appoint and preferably this is on merit. Term limits are often imposed.

Advisory Board

An advisory board is often prescribed. This may take the form of a technical council or consultative scientific committee to help the NMHS implement tasks on research and development or business development.

Role of Government

In the case of a public body NMHS, the duty of government is to oversee the performance of the entity through key performance indicators. This may be responsibility of the minister or, in some cases, the parliament. Another approach is to establish a regulating committee comprising mostly non-government people with the task of determining the level of use charges to be applied to different industries and to advise the minister in this regard. This regulating committee may also ensure fair commercial competition from both the NMHS and private weather services. Another approach is to establish a “supervising authority” or “meteorological services regulator” to carry out this function. If the NMHS provides only noncommercial services, it may be the designated regulator.

Financing, Staffing and Accounting Rules

As a legal entity, the NMHS can earn and retain its own income from economic contracts concluded with third parties and benefit from allocations from the state budget. It is also able to finance investment and refurbishment from its own sources, commercial bank loans and the state budget.

Staff in a legal entity are not necessarily civil servants, they may be temporarily seconded to the agency or more often employed in accordance with ordinary

employment law. Remuneration of staff is set by the oversight board based on the revenue of the NMHS. This would depend in large measure on the success of its economic activities. If the entity is transitioning from a government department to a public body, considerable care is needed to ensure that staffing is commensurate with the new tasks and available budget.

The accounting rules for a legal entity need to be established in the weather legislation. This may be adopted from other legislation related to public budget and accounting management or set out in detail. In general, an auditor will be appointed by the Oversight Board.

Once in place, a first step is to have a full understanding of the true cost and value of products and services (Thorpe and Rogers 2021, Rogers et al 2021b). This includes quantifying the actual costs of services, implementing process improvements, evaluating outsourcing, and aligning activities with strategy (Rogers et al. 2019, Rogers et al. 2022), rather than simply focusing on input expenses —staffing levels, equipment, and supplies. This requires a shift from budget management to macroeconomic effects and performance-based results measurement using tools based on the application of International Public Sector Accounting Standards (IPSAS). Applying these standards bridges the compatibility gap between public and private sectors' accounting methods and increases the transparency of public sector financial information regarding economic profitability (Ilie and Miose 2012, Rogers et al. 2022). This is essential if the NMHS is to create viable, competitive undertakings.

Operational Structure of the Public Body NMHS

The aim here is to structure the legal entity so that it can carry out tasks financed from various sources in a manner that respects competitive markets and prevents cross-subsidies and maintains a positive balance sheet. Rogers et al (2021a) defined a matrix of private, public and club goods, and common-pool resources (Figure 1).

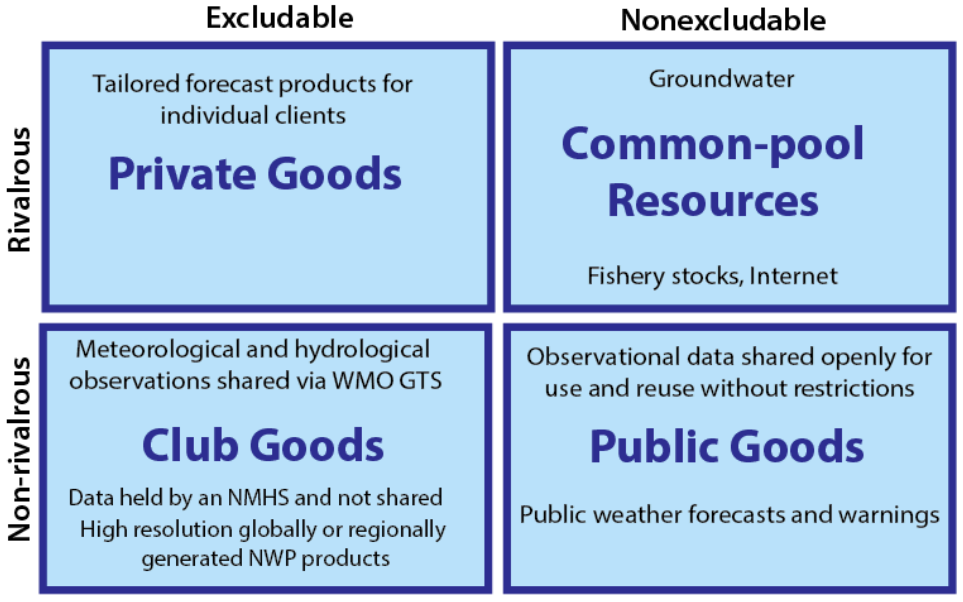

Figure 1 A definition matrix of private, public and club goods, and common-pool resources (Rogers et al. 2021a)

We start with the concept of the departmental model as a baseline. In this model the NMHS is proscribed from providing any form of commercial service and shares all its own data for use and reuse without restriction. This is an ideal situation where the NMHS is adequately financed by the state budget (e.g., NOAA National Weather Service); however, this situation is rare and often the result of legislation aimed at restricting the role of government actors in the commercial sector. Its public tasks are limited only by the level of government investment. In practice, the public task requirements are often greater than the available budget and NMHSs, in almost all developing countries, are unable to meet performance indicators that conform to the international norm for public meteorological and hydrological tasks. The level of service is unlikely to be sufficient to ensure the safety of lives, livelihoods, or economic security in the face of high impact weather.

How to address this issue without distorting the basic elements of a public goods service? One approach is to fall back on restricting access to a basic commodity – observational data – maintaining all these data as club goods and therefore excludable but non-rivalrous; that is, they are infinitely useable. These data may then be sold or licensed, with limitations placed on their reuse. Rarely, if ever, does this approach generate any significant revenue when the transactional costs are considered. In general, and across many sectors, the provision of value-added services is preferred.

But how to maintain the basic, common public services that are the foundation of all meteorological services? We define the common services as the national observational networks; IT services to run numerical models and access products from WMO and other support centers; and the basic infrastructure and administrative structure. which supports the core activities of the NMHS. This is the backbone of all services provided to customers and beneficiaries. In the departmental model where the only purpose of the NMHS is to support the public task, these common services must be fully financed by the state budget. However, if the NMHS is a legal entity and able to engage in economic activities, the common service costs could be shared without violating the cross-subsidy rule (that is, charging a higher price to one customer to lower the price for another). Charging for observational data goes against a more desirable open data policy. If the policy supports open data to be made freely available to anyone to use and reuse without restriction, then all data in this category must be financed from the state budget. Or put another way, all observations financed by the state should be freely available to anyone. There are ample reasons discussed in the literature why this would be in the best interests of the economy (Rogers and Tsirkunov 2021). Other networks might also be available to the NMHS, and these data may be restricted.

Financing the Observational Networks

Observational networks may comprise multiple observational systems and owners – different public entities and private firms. The basic public task, however limited, is supported by a set of observations that should be compliant with WMO requirements. Provision of WMO Global Basic Observing Network (GBON)[2] compliant or any “fit-for-purpose” data requires appropriate organization of

[2] https://community.wmo.int/en/activity-areas/wigos/gbon

observation system including multiple-interrelated components including availability of qualified and sufficient staff, operations and maintenance, quality control, telecommunication systems, among others (Grimes et al, 2022). Total cost of ownership of observation networks plays important role in designing and operating observations networks sustainably. In addition to the public task observational network, regulated services for aviation require more, and often more complex, observing systems. Since international regulations provide for full cost recovery, operations and maintenance costs are supported. A pool of technicians and observers could support both networks creating an economy of scale to minimize costs to both. The data from each network could be used for aviation safety and for the public task. However, further restrictions on the use of the observational network supported by the airline industry would be possible. The NMHS could also maintain networks for other owners; in effect, providing data-as-a-service but more commonly providing joint operations; see for example, US, UK, Australia and Canada. Alternatives have also been postulated including outsourcing the observational network. Justification for either approach requires a fully costed business case, which must consider the strategic implications for the NMHSs (Rogers et al. 2021a, Rogers et al. 2019).

Organization of the NMHS

Figure 2 illustrates how the public body could be structured. All the entries labeled services – common, public weather, government, regulated and commercial – represent distinct business units. Common Services is a cost center, which does not generate revenue but incurs expenses to the public body for its operations.

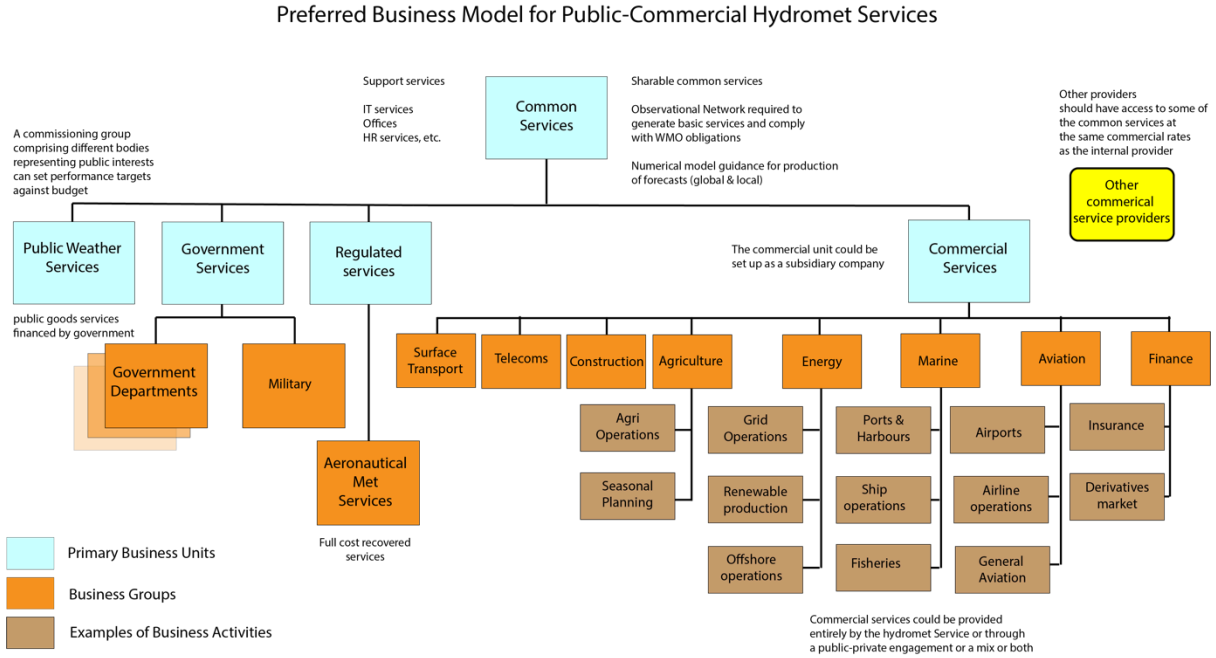

Figure 2 Public Body NMHS comprising separate primary business units, business groups and examples of business activities. The choice of entities to include is illustrative rather than exhaustive.

Each of the other business units are assumed to operate independently with their own business plans and rules. Each supports the cost center in proportion to amount of services they require and at the same cost per unit of activity. Since most of these services are club goods, the combined revenue from each of the business units

reduces the overall expenses of the common services unit. The more revenue generating business units, the lower the expenses of each. The Austrian Meteorological Service (ZAMG)[3] is a good example where commercial services cover a significant part of ZAMG's overall costs. Cross-subsidies are prohibited with separate cost allocations, which are audited annually, made for both public and commercial activities (Rogers et al. 2022). Cross-subsidies are highlighted because the dominant position of the national service provider could enable it to offer lower prices to commercial customers; in effect, subsidizing its commercial services unfairly.

Each business unit and its business group(s) function according to their specific tasks and customers. The Public Weather Services business unit is structured to support the public task defined by legislation and funded from the state budget. Pricing may be set by an independent body comprising representatives of public, including civil protection and the media[4] or the job may fall to a regulator. Pricing must consider all the costs of the public task included the share of common services. The latter will be the most volatile since this will depend on the success of all business units. It is common practice in the private sector to allow business units to have their own staffing and remuneration arrangements. The Public Weather Services business unit would operate on a not-for-profit basis unless otherwise agreed with the government. The government might choose to underwrite some of the expenses of the common services unit, thus reducing all business unit costs.

At present, the only formally regulated service is for civil aviation. Services are provided on a cost-recovery basis. The level of services would be defined between the business unit responsible and the regulator. Ideally the same regulator would also oversee the other business units' operations ensuring the aviation sector of compliance with the rules on cost recovery for aeronautical meteorological services. The International Air Transport Association (IATA) has long argued that airlines should pay only for a fair share of cost-efficient meteorological services: Further, they have proposed that data derived from aeronautical meteorological products and services should be exploited commercially to offset costs for aviation[5]. The steps proposed here would enable this to be put into practice by separating those costs associated with public tasks supported by government from the additional observations and services provided exclusively for international aviation.

It is important for the government and civil aviation authorities to ensure that the revenue generated by overflights, takeoffs and landings is paid to the NMHS. As noted earlier this should be defined in legislation. In practice many NMHSs do not receive the income required to provide the service, in effect subsidizing the expense through the public task despite the revenue from the aviation being received by the designated authority.

Here we treat services for other government departments as a distinct business unit. As semi-autonomous unit they could offer services at different rates. For example, if

[3] Zentralanstalt für Meteorologie und Geodynamik (ZAMG) within GeoSphere Austria

[4] In the UK, an independent group overseas the Met Office's public weather service. This group comprises about twenty members drawn from a range of public entities and devolved governments, which the Met Office serves.

[5] https://www.iata.org/contentassets/37dcb987d8af4be49233c5b49c2faf74/meteorological-charges.pdf

services to the military required clearances or extra security, these services should be constructed differently from other government customers and probably at a higher rate of return. Some government departments might also be partners to deliver new services. This is discussed in more detail later in the partnerships section.

How each business unit operates, and their staffing depends on the nature of the business and the size of the organization. The commercial services should operate separately from the public services but as a minimum transparent accounting practices must be adopted. In all circumstances, each unit should have knowledge of the customer and relationship managers to ensure that the customer is satisfied with the services provided.

Commercial Services

Some argue that creating multiple business units or even separate companies within a single organization is an unnecessary step; however, this is the most effective way to prevent cross-subsidies and provides financial transparency. It does not necessarily mean separate premises or even offices, rather it is the means to keep track of activities intended for a particular customer be it aviation, public weather services or commercial services. The commercial business unit of the NMHS provides the widest range of services and can charge market rates for the services provided.

Adherence to market principles is a must to create a stable business environment for all vendors. The operational structure proposed here is the most likely to avoid intentional or inadvertent cross-subsidies. Always of concern is the risk that public funds could subsidize commercial activities and, in turn, distort the market (Rogers et al. 2021b). This must also be addressed by ensuring private firms have equal access to the common services; for example, having access to data on the same terms as each NMHS' business units. The regulator has an important role here to oversee the entire market and, if specified in the weather law, to license all private sector service providers. The commercial services business unit would be the only one producing an income above cost for the NMHS unless otherwise specified in legislation. Having a commercial arm enables the NMHS to participate in competitive bidding processes conducted by public authorities and public corporations. To ensure value for money, public entities requiring access to meteorological services are increasingly using commercial tenders to take advantage of competitive market conditions.

Developing the Market

The provision of commercial services, of course, depends on the existence of a market and this may not be the case in many low-income countries with limited economic activity. NMHSs are not often seen as engines for economic development; however, as climate change impacts the growth of smaller economies, the role of NMHSs in "weatherproofing" the economy should be considered. As pointed out by Rogers et al. (2021b) in line with the UN's sustainable development *goals* (SDGs), UN Framework on Climate Change, Sendai Framework on Disaster Risk Reduction and Addis Ababa Agenda for Sustainable Financing, the aim of the country is to create prosperity through a sustainable economy and to minimize harm to the population due to environmental and other hazards. In achieving these goals, the

NMHS may be seen as both a provider of vital forecasts and warnings to protect life and property and as the catalyst to create an economy that can capitalize on weather intelligence (Rogers et al. 2021b, Thorpe and Rogers 2021).

In 2017, to reinvigorate its competitive weather services market, Japan created the Weather Business Consortium (WXBC) with the aim of promoting the use weather data in across multiple business sectors. By the end of February 2023, the consortium had over 1200 members from government, academia, and industry. It has two working groups: one focused on creating new weather businesses and one focused on human resource development. Their services include a Weather Data API catalogue provided by WXBC members and cases studies on the use of weather data in various industries to help to create new connections with users. One case study, for example, describes the use of weather data to help support dynamic pricing for a coin-operated laundry enterprise[6]. Examples of potential commercial activities are shown in Table 1 (Rogers et al. 2022).

Table 1Some of the potential commercial weather activities (source: Rogers et al. 2022)

Tailored Services (non-Public Task)	*Description*
Water Resources	Provide rainfall forecasts to manage dam operations to avoid overtopping and operator induced downstream flooding. Experienced forecaster intervention may be of high value.
Insurance	Data service providing *quality assured* gridded digital information suitable to optimally price insurance certificates
Wind farms	Weather forecast products designed to optimize scheduled maintenance for onshore and offshore infrastructure. Experienced forecaster intervention may be of high value.
Wind energy	Integration of meteorological parameters into software tools used to manage energy generation
Energy distribution	Peak load estimates, optimization and minimization of electrical energy production costs, protection of infrastructure
Licensing of commercial service providers	Establish standards and requirements for the operation of commercial weather services in country (would require national legislation)
Agricultural business	Integration of weather information in precision agriculture software systems to improve the efficiency of planting, farming inputs and cropping. Enhanced farm/climate extension workers
Marine Port operations	Integration of weather and sea information into port operations software designed to optimize the efficiency of ports. Includes information of high winds, sea state, lightning, etc. Experienced forecaster intervention may be of high value Could be integrated with shipboard systems operated commercially by shipping companies to optimize port arrivals and along route fuel use
Airport operations	Terminal area forecasts, Significant weather and other information as required by civil aviation. Should have an approved quality management system in place.
Rail transport	High speed train operations are highly susceptible to winds. Require monitoring and forecasting system along route. Information integrated into scheduling and timetables
Road transport	Optimizing routing, departure times of lorries/trucks and long-range buses/coaches – information integrated into schedules and timetables
Coastal sea transport	Optimize ferry sailings to maximize passenger comfort – information integrated into schedules and timetables
Marine Operations	Marine forecasts for offshore activities (oil & gas)
Retail	Optimizing sales of food products and clothing
Tourism	Optimizing tourist experiences with enhanced local weather information at important geographical locations
Construction	Integration of weather information into construction schedules to minimize costs and delays
Telecommunication	Lightning detection and rainfall for signal optimization and infrastructure protection

[6] https://www.wxbc.jp/exampleandinterview/interview/#gsc.tab=0

Deducing Benefit

The economic value or benefit of weather forecasts comes from improved financial and related outcomes for the user of weather data and information. Understanding the economic value to weather-sensitive sectors is the appropriate point of departure for more detailed studies of the potential growth for weather services within specific markets.

The benefit of weather forecasts cannot be deduced from the consumption of weather data. Rather, it emerges from the improvement of decisions by economic stakeholders thanks to weather-related information. This is derived from economic data from interviewed users. Frei et al. (2014) considered the economic and social functions of road transport in Switzerland to illustrate this point (Figure 3).

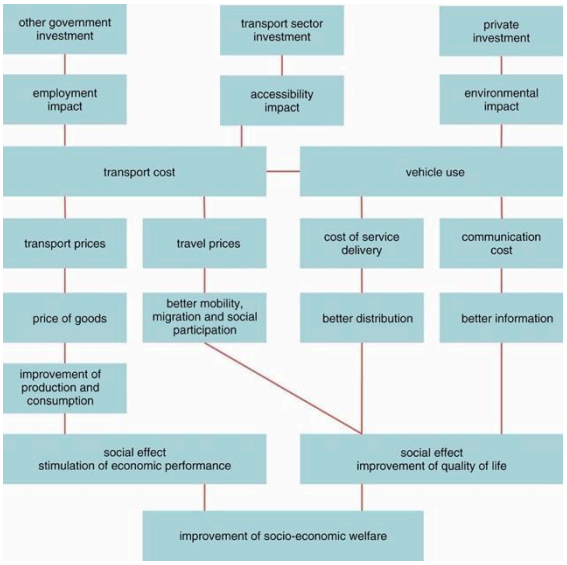

Figure 3 Economic contributions and social functions of road transport investments (Frei et al. 2014)

Weather information can be divided into two categories forecasts and alarms. The latter is generally a free public goods service, the former may be subject to the payment of a fee. Frei et al. (2014) created a methodology to study the economic impact of meteorology on the road transportation sector, which could be adapted to other economic sectors. They defined stakeholders in road transportation as the following:

- public road maintenance services of national and regional roads, including sub-contractors
- national traffic management control centers which are responsible for the traffic management of all national roads
- freight transport companies with the following operations
    - –transport of piece goods
    - –logistics of supermarket chains (only one class of goods analysed)

    - –transport of fuel, and
    - –transport of building materials
- public road transport
    - –in agglomerations and cities, and
    - –in rural areas
- individual traffic.

The use of meteorological information in connection with road traffic related to the transport of goods generates an economic benefit for the national economy. This has four different dimensions:

- increased profitability of companies which leads to an increase in the total value added for the economy
- less government spending due to resource-saving in the provision of public services (either directly through the public sector or indirectly through state-owned companies)
- avoiding damage to infrastructure and equipment as well as avoiding health risks and personal injury, and
- individual benefits in terms of travel time savings.

Figure 4 summarizes the economic model of the impact of meteorological services (Frei et al. 2014). A common technique to determine the value of weather information is a prescriptive model. The approach in prescriptive models is to view meteorological information as a factor in the decision-making process that can be used by decision-makers to reduce uncertainty. In these models, decision-makers choose actions that either maximize expected profits or minimize expected costs, under conditions of imperfect knowledge about weather conditions (Frei et al. 2014). The economic benefit is determined through interviews with different stakeholders using a standard questionnaire complemented by face-to-face discussions. A key element is the definition of a reference condition. This is a situation when the forecasting system is available compared to a situation in which no forecasts are available while all other influencing factors remain constant. The interviews focus on determining avoided government spending from which it is possible to derive a hypothetical monetary impact of the unavailability of weather forecasts; additional value added; avoided damage costs; and avoided individual travel time costs.

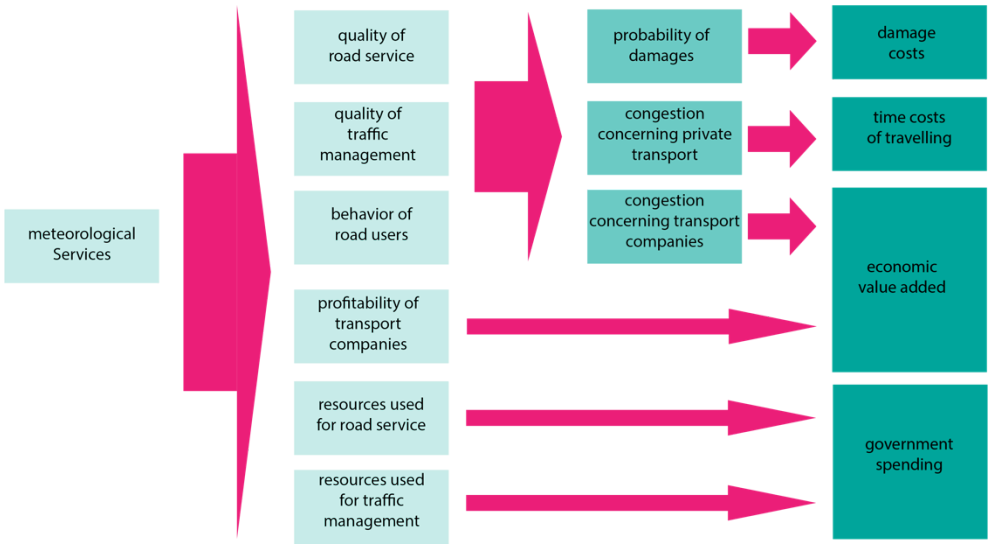

Figure 4 Model of the economic impact of meteorological services in the Swiss road transportation sector (source: Frei et al. 2014)

Von Grünigen et al. (2014) applied a similar methodology to the aviation sector to analyze how the use of terminal area forecasts (TAFs) can reduce fuel and flight deviation costs for airlines. They developed a decision-making model that considers the cost of carrying additional fuel based on forecast conditions at the destination airport. Without additional fuel there is a risk of deviating to an alternative airport, which would lead to additional costs.

With data from airlines, airports and MeteoSwiss, the authors demonstrated that TAFs generate significant economic benefit for domestic airlines. In the study, the benefit to two airlines was between $12-$18 million per year accounting for about 60% of 110,000 landings. The model was developed in consultation with the airlines, highlighting the importance of explorative interviews to understanding the decision-making process rather than only relying on surveys. In general users of weather information know why they use it but have difficulty quantifying the benefit. The approach addresses this limitation.

Co-Production

As suggested above, many value-added commercial services provided by private companies or NMHSs are developed with the consumer and may be supported operationally as a co-produced decision support system embedded within the users' operations. It is clear from the examples that weather information is not the only factor considered in the decision-making process. In the case of airlines, for example, there are many other elements that influence the airlines' decisions including airport operations, flight plans, fuel costs, airline crews, and so on. Consequently, the weather services provider must work very closely with the customer. In general, transportation management systems for road, rail, air, and marine lend themselves to full integration of weather information. For many NMHSs, developing solutions for this sector may not be practical based on staffing levels, data science and IT capabilities.

An alternative approach may be to partner with another entity, often a private company to deliver commercial services. This is likely to be mutually beneficial when the private sector partner has complementary skills, and roles and responsibilities can be clearly differentiated. An IT focused company, or university department, or mobile telecom company, for example, are more likely ideal partners to co-produce bespoke commercial services than a private weather service provider. This is not to say that partnerships with the latter should be ruled out, rather they are more complicated to manage to ensure that all parties benefit since each may primarily have competing rather than complementary objectives. The ability to create joint ventures and partnerships is a skill that most private companies and universities have, but most government entities do not. So, it is important to build these proficiencies as a part of the creation of the public body NMHS.

Summary

The expectation that NMHSs would focus exclusively on their public task, leaving the rest of the weather business to the private sector and universities, is increasingly untenable. Government financing for all public services is limited, salaries are not

competitive with nongovernment jobs, and the non-weather skills required to provide new services requiring expertise in data science, IT, behavioral science, and consumer relations (even to fulfill the public task) are hard to acquire and retain. This problem affects all economies from the least to the most developed albeit in different ways.

Diversifying an NMHS's portfolio of activities to include competitive commercial services is one way to partially reduce the cost of supporting the public task. This would be achieved by expanding the use of and, therefore, financial support for common services – those shared product and services required by each NMHS business unit. The more additional services added, the lower the cost to all users.

The path to commercial success, however, is not straight forward and unlikely to reward in the short-term. A long-term, strategic approach is needed. Essential ingredients include

- the appropriate enabling legislation – here the public body is mooted as the best option; a weather service market or at least the ability to develop the market – an activity that can be developed without legislation
- an optimal organization with proper financial and business structures to carry out both public and commercial activities – here there is a preference for distinct business units, but other approaches are also possible providing public investment does not distort the commercial market through cross-subsidies; and
- the ability to create business partnerships with other entities to strengthen the commercial offers and possibly delivery of the public task.

The most significant investment in NMHSs is often the observational network, which is also the most challenging to maintain. Open data policies that favor free access to all publicly funded data may seem at odds with the desire to create additional streams of revenue. Restricting access to observational data has multiple adverse effects including limiting the development of the market, finding alternatives sources of meteorological and hydrological data and boycotting cooperation with the NMHS. Ensuring that the network is maintained adequately with limited or inadequate funding to support the public task and open data is not easy. It is suggested that pooling support for observational networks and providing data-as-a-service could be one solution.

The approach proposed is not a panacea for poorly financed public services. Rather, it is a means to create a more efficient and effective public weather service that can benefit from cost sharing of common services among different business users. It is also an opportunity to develop new technological skills and retain them through the provision of commercial services. Aviation is a good example of how a regulated service can work. This approach may be equally application to other commercial sectors including agriculture, water resources and transportation where the principal motivation is creating value for service.

Experimentation is needed in different country contexts to explore the viability of the public body NMHS. It is unlikely to be a universal fit but where feasible may enable NMHSs to contribute more effectively to "weatherproofing" their national economy.

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