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# What Happens to Facts After Their Construction? Characteristics and functional roles of facts in the dissemination of knowledge across modelling communities

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**What happens to facts after their construction? Characteristics and functional roles of facts in the dissemination of knowledge across modelling communities**[1]

*Erika Mansnerus*

**Abstract**
The core question addressed in this paper is: What happens to facts after their construction? The main contribution is to analyse the different practices of disseminating, circulating and cross-fertilizing model-produced facts about *Haemophilus influenzae* type b and *Streptococcus pneumoniae* bacterial infections and the preventive public health measures against the invasive disease forms. Through the analysis, the paper shows how facts become *characterised* in different utilizing communities. It elaborates an account of the *functional roles* of facts that are capable of shaping the knowledge practices in the receiving communities. These analyses suggest how facts can travel beyond their production sites to be used as evidence in other domains.

## 1. Introduction

Construction of scientific facts paved the way, slowly but inevitably towards the understanding of scientific work. This tradition, however, mainly paid attention to the activities that took place behind the closed doors of construction sites, such as laboratories.[2] We are often bound with the perspective given, i.e. we are so familiar with the narratives of construction and production or knowledge that we may have forgotten to observe what happens to knowledge, or in our story facts, once they are produced? But what happens to facts after their construction? How do they accommodate themselves into different

[1] Acknowledgements: This study is conducted in a Leverhulme Trust/ESRC funded project Nature of Evidence: How Well Do facts Travel? (Grant no: F/07004/Z) at the

environments? Do they change their identities or stay *stubbornly* where they are as “hard facts” validating scientific findings?

In this paper, I will explore the *characteristics* and *functional roles* of facts, providing a perspective that elaborates how practices (and communities) circulate and dissemin something *as*

accommodated, applied, or even ignored in the process of building and using infectious disease models for research purposes and policy-making? By increasing our understand referencing[10] was done. The findings indicated three different ways of referencing: First, by merely referencing in very general terms, as if only "acknowledging the existence of the group." Secondly, the referencing focused on the computational techniques or methods used or initially developed in the papers. Thirdly, the referencing was to "factual claims" that are treated as firmly based assumptions in the publications as, for instance, existing knowledge of the phenomena, model-based estimates and parameter values, and model-produced facts. This third category of referencing is in our focus. I have chosen[11] three published models (Auranen 1996, Leino 2000, and Auranen 2000), which were cross-referenced 21 times as examples to analyse in detail in this article, and, hence, ground my story of the dissemination of facts upon. The analysis carries a dual focus: both on the communities of practitioners and on the facts themselves. This means that the paper presents both the elaborate modelling practices and discusses the different forms of transmission in relation to the practices. Furthermore, the analysis reveals how facts are adopted in the utilizing communities and what kind of functional roles they occupy in these settings.

The structure of this paper is as follows. In section 2, I will discuss the way in which modelling practices spread facts by describing three across different models, or how models carry facts into novel domains (in research or policy-making). In integrating modelling practices: it means building, using and applying models for specific purposes, in particular answering specified research questions in interdisciplinary communities. Even though these studies have enriched our understanding of the increasing importance of modelling in science, and given us vivid accounts of the heterogeneity of models as research objects, the question of generalisable evidence produced by modelling has not yet received proper attention in current studies. More precisely, models have been represented in their local contexts as the *primary* interest of analysis, however, our focus is on the facts produced in the models and disseminated via them to different domains. This is studied by analysing the *characteristics* and *functional roles* of facts in relation to the specific modelling practices.

In order to understand the dissemination of factual claims and their meaningfulness in complex simulation models in infectious disease studies, one needs to be familiar with the details of the epidemiological phenomena and the scope of the research questions guiding the modelling practice. I will first introduce the main characters of this story, namely *Haemophilus influenzae type* b bacteria (Hib) and *Streptococcus pneumoniae* (Pnc) and contextualise their importance from the public health perspective in order to focus on certain facts about them.

*Haemophilus influenzae type* b (Hib) bacteria is also known as *Pfeiffer's* bacillus according to its discoverer Robert Pfeiffer who was able to isolate the germ in 1892.[15]

vaccines, so called *polysaccharides,* were introduced. To improve their efficacy, *conjugate* vaccines were developed in the 1980s and implemented as part of national immunisation systems 1985 in the USA, In the following analysis of the ways in which models produce and distribute factual knowledge, these public health questions are the starting point for model-building.

There are different ways of addressing the dissemination of factual knowledge across research communities and their models. However, our story aims at the rather detailed level, in order to reveal how the facts are integrated into models in the different phases of the process. A general frame is an adaptation of the stepwise procedure of modelling. This frame is developed to trace the ways in which facts function through the dissemination and circulation process across different context. The stepwise procedure[18] means that modelling process can be divided into different 'sub practices' that are relatively universal for the model-building process. It captures all the phases from formulating the initial model question, through the design, quantification, validation to prediction and decision-making based on modelling. Through this we can understand, not only how the practices shape the modelled phenomena, but also how they facilitate the exchange of knowledge claims: facts produced and applied in the process. I use these steps, to introduce the modelling process as an environment to monitor the exchange and circulation of facts. This reveals two hidden aspects in modelling. First, the facts delivered through one step in the modelling process, could be received in another step or phase during the process. This tells us that there are different ways to identify and apply factual claims in models. Secondly, the analysis of the micro-practices enables us to see the importance of models in the dissemination of facts. For example, the laborious phase of model quantification (parameterisation[19]) becomes easier, if one is able to apply a given estimate established in another model.

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[18] This paper applies an approach presented in Habbema et. al. (1996).
[19] In climate modelling, parameterisation is a more commonly used term than quantification, both terms refer to the same set of practices.

In a closer analysis, we are able to define three different “modes

In brief, this story tells us about the generalisation of model-based knowledge through the different modes of dissemination, it gives us a unique perspective on how this happens inside modelling procedure within which facts are delivered and received, and it allows us discuss the main question: How do practices move facts around?

Let us first illustrate the modes of dissemination with the following graph. The facts estabilished in the 1996 GNKM model were *circulated* and *cross-fertilised* in two further models (1999, 2004), built at a later stage. Modelling techniques were disseminated as a template, acknowledged only as a possible approach in O'Brien et. al. (2003).

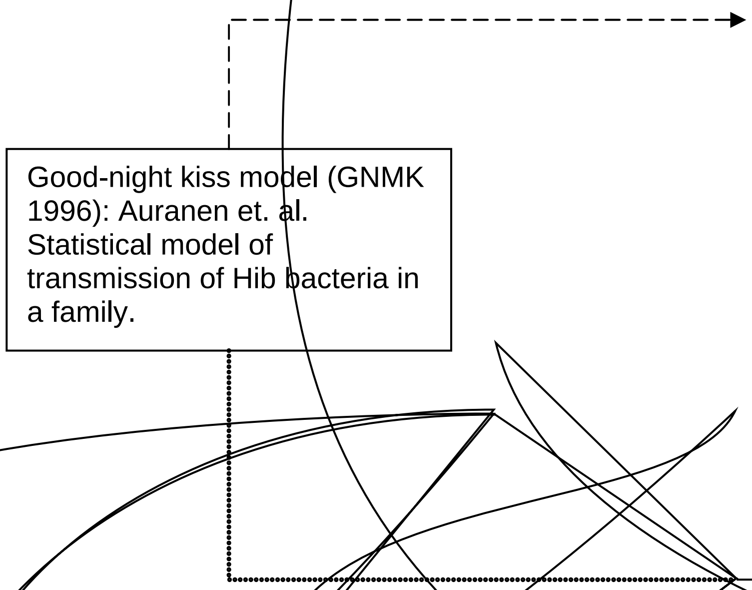



**Figure 1:** Illustration of three modes of dissemination of facts and templates from the Good-night kiss model (1996).

Figure 1 shows how facts (1-4) and a template of modelling techniques were disseminated from the parent model (GNKM) to three other models, over a longer period of time. The estimate for the force of infection was circulated to a later built model (1999). The mode is described as circulation, since the adoption of that estimate actually required returning to the parent model (1996) in order to detect how to calculate it in a novel context. Cross-fertilization, which is a form of

This example shows that both facts and templates are disseminated to new contexts. Interestingly, we also observe that the adoption of the fact the different communities attribute to them, and by exploring the *functional roles* they take in the new contexts.

Next, we will explore through an example, how different research communities identify and recognise ‘factual’ claims, what kind of status they give to them, and how they use them. Does an epidemiological ‘fact’ become a statistical estimate in the process? This is a way to see how different pieces of evidence actually nurture different communities, and enable them to enhance their research goals, while the facts carry the trace of their origin with them.

### *2.2 Networks of Dissemination*

Facts seem to facilitate the formation of social networks. The primary adoption of a fact furthers the mutual contact between different modelling groups. Dissemination of facts facilitates and enhances personal relations among the researchers. As one interviewee told me, a referee process pointed him to the facts published in a Helsinki paper on Hib models. This, then, encouraged him to meet the modellers in a forthcoming conference and share ideas. Networks seem to be built upon the epistemic primacy of disseminated facts. As we observed in the previous section, models were capable of carrying *traces* of facts, when the methods and techniques were disseminated across the communities and domains of research.

To get a detailed idea of the ways in which facts spread across different models to create networks, I provide the following example of the early transmission model, the Good-night Kiss Model (GNKM, 1996), which serves as the origin of the facts. From this model, the facts are disseminated to other Hib and Pnc studies, referenced by different research groups, and they even end up in a WHO vaccination policy report to promote Pnc vaccines. The following illustration shows the

[24] Humphreys (2004) argues that a template is a rather universal set of equations, methods or techniques that is capable of adapting from one field to another.

*referential ties* between the models, ties that facilitate and maintain the *dissemination* of facts. However, this illustration does not tell us how the facts were identified, used, acknowledged in the different models – in other words, the *characteristics* and *functional roles* are yet to be explored.

**Figure 3:** Illustration of the "family-tree" of the parent Helsinki model (GNKM 1996) to other models on Hib and Pnc. The names are the names of the models that use and apply the facts; the location refers to the geographical site of the modelling group or the origin of the report in which the fact was used. This illustration shows how research networks emerge from the dissemination of facts established in a single model.

Let us study in detail how the facts from a single model wereom the dn0.001 Tc-0.0003 T

The model itself[25] represents the beginning of the modelling collaboration, since it was the very first of the set of models built during the Helsinki project.[26] In the following years, the Helsinki group, built a set of Hib (M3, M4) and PnC (M5) models  in which facts established in GNKM were *circulated* and *cross-fertilized*. For example, a cluster of Hib transmission facts (age-specificity of carriage, duration of immunity, dynamics of transmission) were fed into the 2004 model (M4) that simulated transmission in a structured population (which means that the age-structure is clearly specified in the model). But the facts also reached and travelled beyond the Helsinki group. Efforts establishing links to other researchers thus created a research network: the 2004 model on transmission in families (M6), built by a group at the Health Protection Agency and Warwick University, utilised the fact that the course of Hib infection follows the S-I-S pattern in a population in their PnC model to structure the similar kind of dynamics. Moreover, a fact of transmission rate established in GNKM was adopted in a set of models (M2) published by researchers from Oxford. This detailed story of a singular model and its capability to

### 3. Characteristics of facts

Character is oftentimes linked with innate nature of things – even the everyday use of character in sentences such as “she’s got quite a character” implies that there is something special in the person herself. However, we may take another look, and consider “character” as something that is given by the community – character as socially defined property of persons and things. This shift in the perspective helps us to be more precise on what we mean by “characteristics of facts.” While observing the characteristics, our focus is on the *changes* we attribute to the characteristics of facts in the course of the various modes of dissemination.

Could we consider the *characteristics* in terms of social recognition and identification of facts, metaphorically as their *social identity*? Increasing the conceptual framework may have its own downside, but let us play with the idea of a *social identity of a fact*. The basic assumption is that modellers, either in the building or application practices, identify facts according to their usefulness and applicability. They recognise the knowledge claims and re-interpret, adopt, shape or ignore them in due course of their work. Social identity,[27] as a metaphor, relies on the socio-cultural understanding of the concept: It is way of behaving or becoming oneself in a community. Our metaphor of the social identity of a fact should be understood as a concept that underlines the importance of the community interpretation, use, application, recognition and adoption of factual claims. These different practices directed towards the facts are the practices by which we *characterise* them or *identify* them. Hence, the community, in a crucial way, shapes the factual knowledge.

[27] A social identity of a person relies on a dialogical relation to other people. For example, if we follow Vygotskian ideas of child development, we learn that in a dialogical relation with the community, a child develops skills of using tools, material and symbolic means (language) and therefore becomes part of the community. (Vygotsky 1978).

The environment, in which a fact is acknowledged or accommodated, can also initiate changes in the character of a “fact.” The information content of the fact may also vary. Hence, the characteristics of facts can be presented in two axes (see Figure 4): Flexibility in relation to the environment or content, and in terms of their ‘weight’. These axes are discussed in terms of *stubborn* and *chameleon* facts and *enriched* and *simplified* facts. Let us first explore the characteristics presented in Table 1.

**Table 1:** Summary of the analysis of the characterizations of facts.

| Characterisation and definition of a fact | Example | Description of a fact | Why the specific character? |
|---|---|---|---|
| **Stubborn**[28]<br>A fact that is resistant to change. May require some auxiliary measures to be operationalised or quantified in a model. | Cluster of facts of Hib transmission. | “Transmission of Hib occurs through asymptomatic carriers. Most episodes of Hib carriage pass without clinical symptoms, and only in rare cases does carriage proceed to invasive disease.”(2004) | A ‘fact’ that repeats the cluster of claims about Hib transmission, and although it links that knowledge to the 1996 model, it actually relies on general epidemiological understanding of Hib transmission dynamics. |
| **Chameleon**<br>A fact that accommodates well in a new environment.<br>A fact that easily or frequently changes its appearance – or its “colour”. | A fact that exemplifies the dynamics of transmission (in a Hib immunity model, Auranen 1996). | “[As in Auranen 1996], we set the transition from C to S to be dependent on a constant recovery rate.” (Melegaro 2004) | A fact of the dynamics of transmission pattern (SIS-model) describing the immunity, was accommodated in a Pnc study (Pnc follows a similar but not identical immunity dynamics as Hib). It was easily adopted and modified to fit Pnc. |
| **Enriched**<br>A fact that becomes bloated (i.e. swollen with something extra, like a swamp | Estimates of the force of infection. | “In the previous study on Hib carriage in families D1t21.153D(study on Hib )richHib | |

| | | | |
|---|---|---|---|
| that is swollen from liquid). A fact that is enriched. | | probably related to different nature of data. In that article, data on antibodies was not included." | with the data from antibodies and the importance of estimating the force of infection in relation to all details of transmission dynamics was discussed (carriage, antibody levels, cross-reactive bacteria). |
| **Simplified** A fact that is simplified, or slim, capturing only the very plain core of the fact. | Estimates for a Hib transmission rate in a family. | "For example, Hib transmission rate is thought to be greater within families whose members have experienced Hib disease." | A fact, a sophisticated estimate for a transmission rate in a family was simplified into a factual claim 'thought to be greater', even though it was originally a numerical estimate. |

As table 1 summarises, *stubbornness* characterises a fact that is resistant to change during its travels. In our story, the cluster of Hib transmission facts are exemplary representatives of *stubborn facts*. Why is that? From the epidemiological studies[29] we learnt that reaching the understanding of Hib transmission dynamics is a rather challenging task. The details and specificities required thorough understanding not only the pathogen but its circulation in specific age-groups, its capability to hide in asymptomatic carriers, and its incapability to enforce permanent immunity. Due to these challenging facts, it also became the major player in the models in order to estimate the vaccination effects, to optimise the herd immunity threshold and to produce evidence for recommendations for the implementation of the expensive conjugate vaccines. *Stubbornness* is a way to describe this cluster of facts as unchangeable, inflexible, and, perhaps, robust.

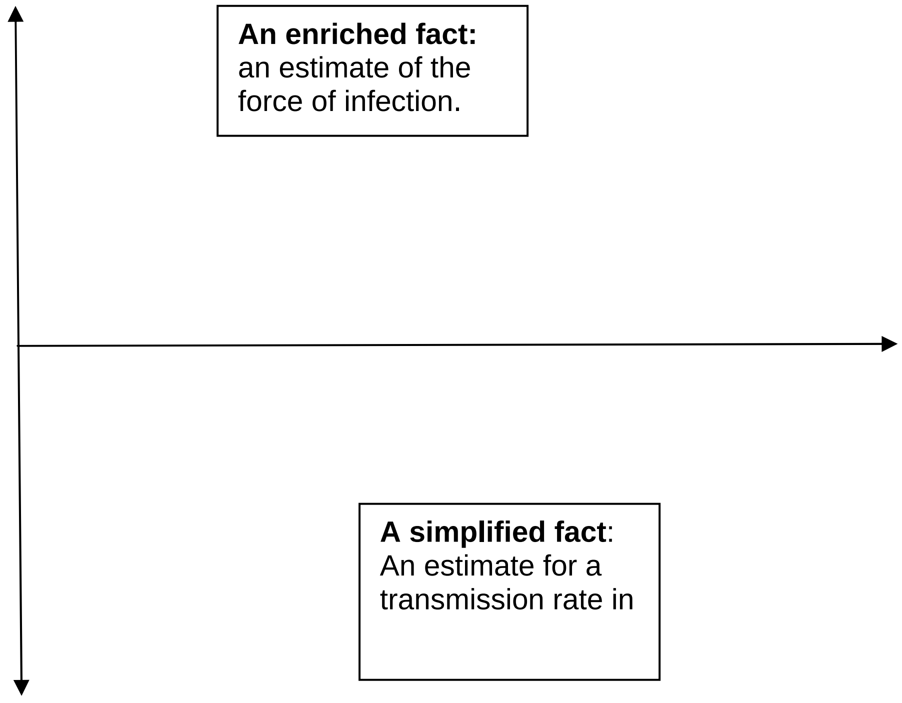
[29] Explored in Mattila (2008).

The contrary characters to the *stubborn* are *chameleons*: facts that are easily accommodated to new environments. A model structure, as a part of the model design process, is an important step in modelling practices. It is a phase in which one needs to incorporate the knowledge of the infection dynamics, the population structure and transitions among these "pools." At the same time the structure will feed into the quantification, and each transitional step will be denoted with parameters, which lead to the estimation process. The SIS structure, which carries the fact of the transmission pattern of Hib and the status of immunity caused by the infection, was adopted by a group that studied the transmission of Pnc. They clearly adopt it by saying that: "As in Auranen, we set the transition from C->S to be dependent on a constant recovery rate" (Melegaro et. al. 2004). This fact could be seen as a *chameleon*: it is taken, modified, and adjusted to accommodate the Pnc transmission and what is known of it. Even though it was not strongly modified in the new context, its character as a *chameleon* is supported with the idea that it is easily adjustable from its old into a new context, which in this case is the transition from Hib to Pnc.

These characteristics, the *stubborn* and the *chameleons* are related to the environment, either they resist the relocation or they accommodate well. We have, however, also obse reactive bacteria and other details of the transmission dynamics were added into it – bloating it and giving more weight to its factual content.

In another example of this kind, we find a model examining long term persistence of immunity after vaccinations also adopted the estimates for the dynamics of natural immunity as a valid ‘fact’ of prediction upon which they were able to build the vaccination model[30]. In a similar way, a model-based prediction was taken as a fact into a model on *Pneumococcal* carriage[31]. Interestingly though, this estimate was re-enforced by observed data-based trends in Hib infections studied in England and Wales[32]. What can we conclude from these adaptations of the immunity decline rate, as the model-laden facts? In the case of the vaccination study and the Pnc carriage, the decline rate is an enriched fact, taken into a new context and bloated with information from the existing literature and datasets.

An example of a simplified ‘fact’ is a model-based estimate for a Hib transmission rate in a family. Even though this rate was the outcome of a highly sophisticated transmission model, it was used only as a comparative reference point, without a connection to the numerical estimate it had in the original model. It was slimmed and simplified, and yet circulated to new contexts. We


**An enriched fact:** an estimate of the force of infection.
**A simplified fact**: An estimate for a transmission rate in

interpretations that accommodate them well, or keep them as they are, in the new sites.

## 4. Functional roles of facts

Characteristics of facts told us how knowledge claims become *mediator* reconciling and mediating different approaches, and *container* storing information.

**Table 2:** Functional roles of facts: their definitions and examples.

| Functional role and its definition | Description of the 'fact' within the case |
|---|---|
| **Broker** (example 1)<br>A fact that is capable of creating and negotiating a space, opening new lines of research, asking new questions, expanding ongoing processes. | Fact: The fact states that immunity to Hib is not permanent. This fact is established in a model structure for the immunity model on Hib originally described in Auranen 1996.<br>In Auranen 2004 it functions as a *broker* since it documents the original variation of immunity to Hib in the model structure and incorporates it with further knowledge on different factors influencing transmission (that were studied in Auranen 2004).<br>"Transmission is influenced by the recurrent nature of carriage acquisition, and the typical clustering of Hib carriage in a family and day-care settings." (Auranen 2004: 947) |
| **Broker** (example 2) | Fact: The fact shows Hib transmission rate in a closed population taking into account the basic dynamics (structure of the family, children's relatedness in peer groups).<br>The fact functions as a *broker*, since it opens new research in Pnc studies by giving the direction (transmission in a family) and the estimated rate.<br>"Following the work by Auranen and colleagues, the model considers transmission of Pnc within the household" (Melegaro 2004: 435). |
| **Mediator** (example 1)<br>A fact that reconciles two approaches, techniques, methods, datasets, parameter values; intervening 'fact' that effects reconciliation. | A fact to describe the dependency between individuals and close contacts in transmission dynamics.<br>In Auranen 2000, it functions as a *mediator* between Hib and Pnc studies by reconciling how to express the basic dynamics.<br>"When modelling disease transmission, it is important to acknowledge dependency between binary sequences of individuals with close contacts. Because of this dependency, the states of Markov process in a family are actually vector of ones and zeros, which simultaneously denote the infection state of all family members" (Auranen 1996). |
| **Mediator** (example 2) | A fact to describe indirect effects from Hib conjugate vaccines (reduction in carriage and boosting of immunity levels). It states that conjugate vaccines are able to reduce colonization of Hib in nasopharynx.<br>The fact functions as a *mediator* since it bridges the gap between Hib and PnC studies, mediates between childhood and adulthood studies.<br>In Lexau (2005): "How much vaccine coverage is needed for indirect effects remains a key question. A model evaluating this in Hib conjugate vaccine showed |

> Hib carriage in family and day-care settings."
> (Auranen 2004: 947.)

In this case, the way in which GNKM circulates the 'facts on transmission' actually the provides the basic model structure. In 2004 model this is further modified and used and hence that 'fact' is recognised as a *broker*, since it stimulates more research, more specifications and negotiates a new space by doing so. The main shift was that the transmission in a tight family-structure was now considered in different small-groups (day care setting and school).

*The mediator* functions between different approaches, problems, domains by enhancing reconciliation. In our analysis, *mediators* were facts that increased the reconciliation between the epidemiological data derived from surveys or experimental settings[34] and the model. As our example pointed out, the fact described the effects of conjugate vaccines for Hib and reconciled the lack of knowledge on conjugates' effects on immunity in the case of PnC in adults. Hence, it functions not only between different types of pathogens but also between different groups in the studied population.

The Dynamics of natural immunity model (DNIM) as a source model studied the impact of conjugate vaccines and their capability to reduce natural immunity in a population. Such vaccines had the property of reducing carriage of Hib in vaccinated populations, which may have resulted in waning of natural immunity also among the unvaccinated. This model was developed upon a hierarchical Bayesian model to predict duration of immunity to Hib (Auranen 1999) and it was based on data from follow-up measurements of Hib antibody data in Finland (gathered during a polysaccharide vaccine efficacy trial in the 1970s). This model provided the core of the immunity model implemented in 2004, into the individual-based population simulation model (Auranen 2004), and interestingly though, the dynamics of natural immunity model functioned as a “shared memory” repository during the simulation process. On the basis of the interactional data, I observed that while some of the Helsinki models functioned as repositories or storage spaces, as described by the Helsinki modellers, it was not the whole of the model that was used as such, some particular facts were adopted or adjusted in the simulation model. What were then the facts adopted from this model? The Dynamics model (DNIM), for example, established the ‘fact’ that vaccination affected the sub-clinical infections occurring between vaccinations and the antibody

similar way, the exchange of facts from within the production domain to use and to apply them can be elaborated in terms of their functional roles. When facts are seen as *brokers*, *mediators* or *containers*, we are subscribing to a more dynamic account of evidence: observing what kinds of functional roles are given to facts in different domains. So, our efforts to understand the ways in which facts are disseminated across various domains help us to evaluate not just model-based evidence but its usability and applicability in further producing and using domains.

**Appendix:** The full table summarising the modes of dissemination in relation to the three source models. Examples illustrated in the Figures 1-2 are on italics.

| **From: Source of a 'fact'** | **To: Destination of a 'fact'** | **The 'fact' that travels** | **A 'template', i.e. modelling technique or model structure** | **Mode of dissemination** |
|---|---|---|---|---|
| *Model 1 (GNKM): Auranen, K et. al. 1996: Statistical model of transmission of Hib bacteria in a family* | *Auranen et. al. 1999: A hierarchical Bayesian model to predict the duration of immunity to Hib* | *Estimation of the force of infection.* | | *Circulation: Estimate is derived from the 1996 model.* |
| | Auranen et.al. 2000: Transmission of pneumococcal carriage in families: a latent Markov process model for binary longitudinal data | A fact that when modelling disease transmission, one needs to acknowledge the dependency between individuals with close contacts. [Method of modelling transmission in terms of binary relations / Markov process]. | | *Circulation*: Specificity of disease transmission reported in 1996 model is revised in terms of expressing it as a binary process. |
| | *Auranen et. al. 2004: Modelling transmission, immunity and disease of Hib in a structured population* | *Specific cluster of facts of defining: Hib transmission dynamics in a closed population, age-specificity of Hib carriage and special features of Hib immunity model.* | | *Cross-fertilization: Particular facts established in 1996 model are fed into the 2004 simulation transmission model. '1996 model-based facts are cross-fertilized and the simulation model produces new 'fruits'.* |

| | | | | |
|---|---|---|---|---|
| | Coen et. al. 1998: Mathematical models of Hib | Hib transmission rate in a family | Hib transmission rate in a family | *Circulation:* A model-based fact of transmission rate is taken to the new Hib models. |
| | *O'Brien et. atl. 2003: Report from a WHO working group: standard method for detecting upper respiratory carriage of Streptococcus Pneumoniae* | . | *Modelling techniques as tools to estimate carriage dynamics.* | *Dissemination: To acknowledge the potential usefulness of modelling techniques for PnC studies.* |
| | Melegaro et. al. 2004: Estimating the transmission parameters of pneumococcal carriage in households | Transition between S-I-S. | | *Dissemination*: A model structure is adopted into a new context. |
| | Ashby, D 2006: Bayesian statistics in medicine: a 25 year review | | MCMC techniques. | *Dissemination:* MCMC techniques used in Auranen 1996 were referenced in Ashby as a statistical method. |
| Model 2 (DNIM): Leino et. al. 2000: Dynamics of natural immunity caused by subclinical infections, case study on Hib | Auranen et. al. 2004: Modelling transmission, immunity and disease of Hib in a structured population | Estimates of natural immunity based on the presented immunity model (2000: 954). | | *Dissemination*: Estimate adopted from 2000 model and implemented in 2004 transmission simulation model. |
| | Leino et. al. 2002: Hib and cross-reactive antigens in natural Hib infection dynamics: modelling two populations | Force of infection. | | *Circulation*: Estimate for the force of infection re-used in |

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|---|---|---|---|---|
| | Mäkelä et. al. 2003: Long-term persistence of immunity after immunisation with Hib conjugate vaccine | A model estimate to predict antibody resistance after an initial response to Hib PS (polysaccharide vaccines). | | *Dissemination*: Particular estimate value adopted to give numerical form to the immunity response on polysachharides. |
| | Leino et. al 2001: Pneumococcal carriage in children during their first two years: important role of family exposure | A fact about carriage depicted a closed population. | | *Circulation*: Carriage model re-used in a PnC study. |
| | McVernon et. al. 2004: Trends in Hib infections in adults in England and Wales: surveillance study | Prediction of decline in natural immunity. | | *Dissemination*: Decline rate from Leino 2000. |
| *Model 3 (TPCM): Auranen et. al. 2000: Transmission of pneumococcal carriage in families: A latent Markov process model for binary longitudinal data* | *Leino et al: 2004: Indirect protection obtained by Hib vaccination: analysis in a structured population model* | *A fact about the microbial transmission.* | *A fact about the microbial transmission.* | *Dissemination: 'Factual' claim of transmission.* |
| | Eerola et.al. 2003: Joint modelling of recurrent infections and antibody response by Bayesian data augmentation | An estimation of average duration of carriage. | | *Dissemination*: Carriage estimate for Pnc. |
| | *Cauchemez et. al. 2006: Investigating Heterogeneity in Pneumococcal Transmission: A Bayesian MCMC Approach Applied to a Follow-up of Schools* | | *"An estimation of epidemiological parameters from field data has gained renewed interest in communicable diseases with the use of MCMC methods".* | *Dissemination: MCMC methods (article grounds their development among other approaches to Auranen 2000).* |

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| | Bartolucci 2006: Likelihood inference for a class of latent Markov models under linear hypotheses on the transition probabilities | | The latent Markov model was introduced by Wiggins for analysis of longitudinal data and has been successfully applied in several fields (medicine/ Auranen). | *Dissemination*: MCMC methods elaborated in a latent Markov model. |
| | *Cauchemez et. al. (2006): S-pneumoniae transmission according to inclusion of conjugate vaccines: Bayesian analysis of a longitudianl follow-up in schools* | *An estimation of transmission parameters.* | *An estimation of transmission parameters; data augmentation.* | *Dissemination: Both a model-estimate of transmission (both models study PnC transmission) and of data augmentation methods (elaborated in 2000 model in a form of a latent Markov model).* |
| | Cauchemez et. al. 2004: A Bayesian MCMC approach to study transmission of influenza: application to household longitudinal data | | Data augmentation method. | *Dissemination*: Data augmentation methods (elaborated in 2000 model in a form of a latent Markov model). |
| | *Melegaro et. al. 2004: Estimating the transmission parameters of pneumococcal carriage in households* | *Longitudinal carriage studies to gain insight into the pathogen's mechanism of carriage and transmission within hosts.* | | *Cross-fertilization: Particularly the carriage estimates were adopted from 2000 model to Melegaro 2003 model.* |
| | Cooper et. al. 2004: The analysis of hospital infection data using hidden Markov models | | MCMC methods. | *Dissemination*: MCMC methods, to model similar (but not identical) kind of data on a different pathogen. |

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| | *Jackson et. al. 2005: Use of strain typing data to estimate bacterial transmission rates in healthcare settings* | | *MCMC techniques.* | *Dissemination: MCMC methods to develop estimate of bacterial transmission rates for Pseudomonas aeruginosa and Staphylococcus aureus.* |
| | Mannan et. al. (2003): Latent mixed Markov modelling of smoking transitions using Monte Carlo bootstrapping | | Latent MCMC model. | *Dissemination:* MCMC techniques used in the latent model of smoking transitions. |

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