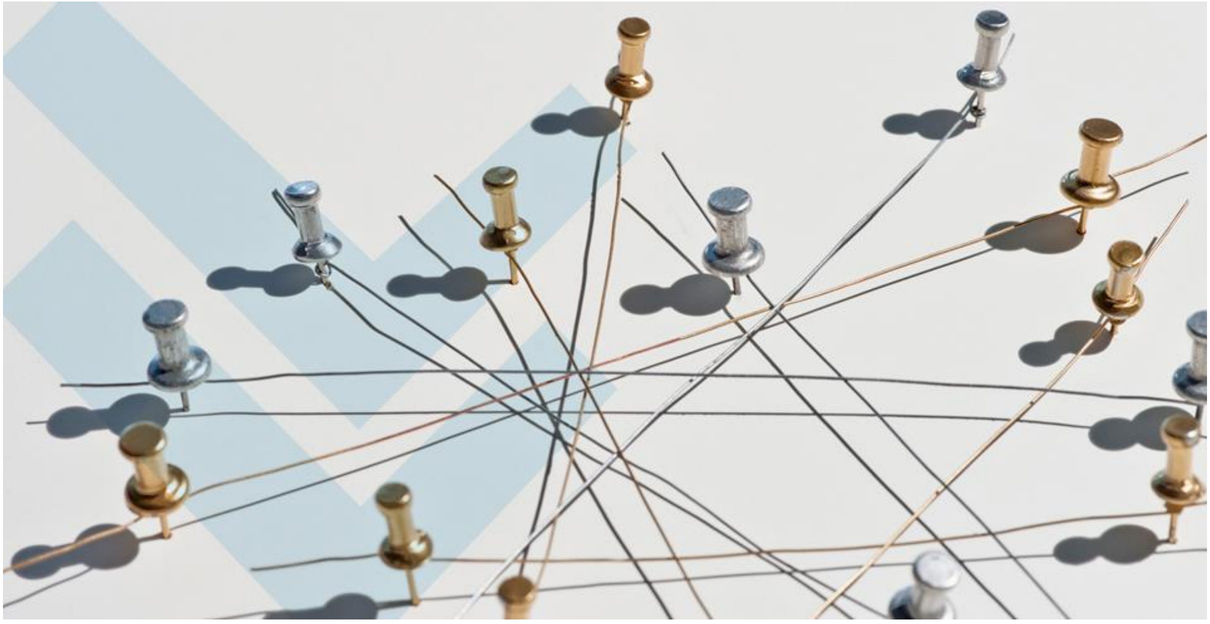
THE SWEDISH TRANSPORT ADMINISTRATION

INVESTIGATION OF MODELS FOR REGIONAL AND URBAN FREIGHT AND COMMERCIAL VEHICLE TRAFFIC

MODEL APPROACHES AND RECOMMENDATIONS FOR SWEDEN

2017-07-07



INVESTIGATION OF MODELS FOR REGIONAL AND URBAN FREIGHT AND COMMERCIAL VEHICLE TRAFFIC

Model approaches and recommendations for Sweden

The Swedish Transport Administration

CONSULTANTS

Logistics Landscapers AB
Box 5243
SE-402 24 Göteborg
Tel: +46 70 535 20 70
http://www.logisticslandscapers.se

WSP Analysis & Strategy
Box 13033
SE-402 51 Göteborg
Besök: Ullevigatan 19
Tel: +46 10 7225000
WSP Sverige AB
http://www.wspgroup.se

CONTACTS

Jonas Waidringer, Logistics Landscapers, +46 70 535 20 70, jonas@logisticslandscapers.se

Moa Berglund, WSP Analysis & Strategy, +46 10 722 73 28, moa.berglund@wspgroup.se

Carsten Sachse, the Swedish Transport Administration

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1 ABSTRACT

With a growing amount of commercial vehicle transport in urban areas, the agencies have an interest in assessing infrastructure investments and policy measures, such as regulations and taxes, in their mission to decrease negative societal effects related to the transports. In order to do so, e.g. the Swedish Transport Administration and regional and local authorities have an interest in employing forecast models. However, a functional regional model for freight and/or commercial vehicles is lacking in the Swedish planning system.

The freight transport and logistics system is a complex system characterized by many stakeholders and decision-makers with sometimes conflicting interests, and a large variety in characteristics of shipments and trips. This makes the system hard to model using the traditional methods that are often used for passenger transport forecasts. Further, regional or urban freight transport is tightly connected to surrounding systems such as the economic system including business models and consumption patterns and freight transport on the larger scale.

Models that are used for public sector decision-making must meet certain requirements in terms of transparency and quality. These requirements form a framework of different parameters that need to be considered when developing the models (see Figure 1 below).

This study aims to recommend actions for Swedish agencies, primarily the Swedish Transport Administration, in order to enable future high-quality analyses and forecasts of regional and urban freight and commercial transport.

Previous model approaches made in Sweden and other countries are described through a literature review, which has been complemented and facilitated by interviews with model experts in Sweden, Norway and Denmark. The focus of the literature review was on model reviews, descriptions of models that are implemented and applied as part of the agencies' planning process and especially promising approaches made in a research context. These considerations are motivated by the relevance for model implementation in the near future. Model approaches are briefly described in terms of model categories, going from simple forecasts based on historic vehicle count data for single links, to more advanced supply-chain based or vehicle tour based models. The more advanced and detailed the model category, the larger share of the agencies' analysis needs is met. However, the amount of necessary input data to feed the models also increases on the same scale, leading to larger investments of resources for model development and longer implementation times.

Many model approaches within the various classes have been suggested and developed by researchers around the world, often using a specific region or city as case studies. Further, a quite large number of states, especially in USA and Canada but also in Europe, have taken the approaches further and implemented freight forecast models and made the necessary data collection efforts. However, these implemented models are usually on the national (in Europe) or statewide (in North America) level, a scale that is more similar to

that of the SAMGODS model[1] than the regional or urban scale. A few exceptions have been found, and the most interesting approaches are described.

In the final section of the literature review, an alternative modelling perspective is introduced, as a complete to the traditional model perspective that is currently dominant. The traditional way to describe and model large complex systems is to go from top to bottom. The top-down methodologies are based on the presumption that knowledge is outside the “system”, that someone can measure and analyze the observable phenomenon of interest and from that decompose correctly to different subunits where the sub-problems are solved separately. This requires extensive knowledge of the system and all its components in the form of input about values, choices, etc.

An alternative is to start from the bottom and from there aggregate results. Bottom-up methodologies are instead based on a synthesizing philosophy, where the user presumes that he/she cannot understand the whole phenomenon of interest but can observe different activities and processes, and try to understand their behavior and their objectives. Then it is sufficient to be able to create so-called agents, which can be organizations, people, machines, etc. that have a function, such as an intermodal crane in an intermodal terminal.

In the final chapter, a number of conclusions for a feasible way forward in the Swedish context are formulated. The model gap, i.e. what desirable analyses that cannot be made using available models, is described. Existing models in Sweden could be merged in a common framework to describe most aspects of the current state of regional/urban freight transport, and partly to make business-as-usual forecasts. However, in order to make scenario analyses and impact assessments on the regional or urban level, new models need to be developed.

Next, the need for a long-term strategy regarding model development is discussed, and what such a strategy should include. Four crucial aspects that define the current needs and opportunities are described more in detail:

- Data supply – available data and novel conditions
- A widened view of scenarios at the planning horizon
- Communication of model employment and inclusion of stakeholders
- Modern model development techniques

A structure for model development decisions at different levels – model landscape, model architecture and model techniques – is presented.

Thereafter, conclusions are summarized. After completing this report until this stage, a workshop was held with invited model experts. The workshop had two purposes; an external assessment of the findings of the study and to discuss possibilities and challenges for future development.

The workshop opened with a presentation of the findings of this report and thereafter, short presentations from five invited speakers were given. The discussion was primarily focused on; the challenges connected to data sources and data quality, modelling issues and the usefulness of the models

[1] The Swedish national freight forecast model

depending on different stakeholders' needs, such as the Swedish Transport Administration.

The workshop was concluded by the authors of this report with the following statements:

- It is necessary to create a stable environment for the development and maintenance of methods and models for transport in general and for freight modelling in cities and regions specifically
- A model framework needs to be established where both the Swedish Transport Administration and other stakeholders such as the large cities can cooperate and invite others to co-develop models
- Enough resources have to be allocated in order to not only develop, but also to maintain and update the models over time
- Around 85 % of the Swedish population lives in urban areas due to the last centuries' urbanization which makes the cities and dense regions the most urgent need for modelling
- The possibilities to make use of existing data in new ways should be exhausted, in parallel with exploration of the opportunities of existing big data sets from the internet of things, social media etc. together with novel data processing techniques
- We are midst a paradigmatic change not only how we live our lives, but also data availability, computer capacity and modelling knowledge, which makes it paramount to initiate new approaches

In the last section of the report, recommendations are given. Based on the findings of this report we suggest that the Swedish Transport Administration initiates a multi-disciplinary R&D program that focuses on the dimensions laid forward in chapter 5. This R&D program should focus on:

1. Bring together the efforts already underway at the different governmental agencies, universities and consultant companies
2. The combination of available models for freight transportation that exist in Sweden, in order to maximize the utilization of efforts already made
3. The exploration of existing data from new and old sources, using novel techniques
4. A long-term flexible strategy, which includes;
    - clearly stated goals, needs and necessary resources - at the Swedish Transport Administration
    - a forum of other stakeholders
    - model framework where emphasis is put on defining the model landscape, architecture and available techniques in order to generate a road-map for model development, which should be regularly revised and include efforts to continuously evaluate the development
    - data supply, modern model development techniques, scenario generation and stakeholder involvement

It would also be beneficial to invite other stakeholders such as the larger cities in Sweden as well as our neighboring countries.

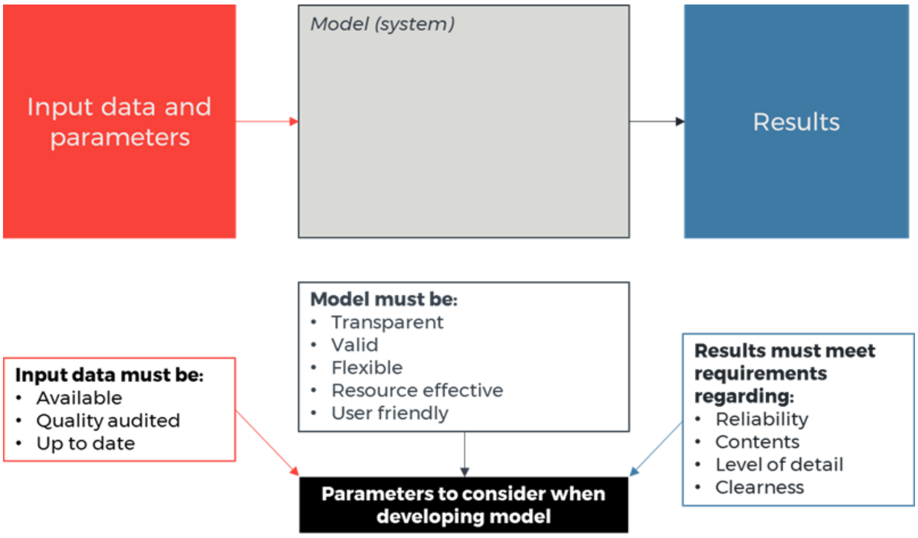

Figure 1: Requirements of model (systems) used in the Swedish Transport Administration's planning process. Adapted from Sweco & WSP (2017)

2 ABSTRACT IN SWEDISH

Näringslivets transporter i storstäder och tätorter ökar. Som en del av sitt arbete för att minska de negativa samhälleliga effekterna av transporterna (utsläpp, trängsel, buller, etc.), har myndigheterna därför behov av att utvärdera infrastrukturåtgärder och policyförslag så som regleringar och skatter eller avgifter. För att kunna göra detta vill bland annat Trafikverket och lokala och regionala myndigheter kunna använda prognosmodeller. Dock saknas en fungerande modell för regionala gods- och servicetransporter i det svenska planeringssystemet.

Transport- och logistiksystemet är ett komplext system som karaktäriseras av många beslutsfattare och aktörer med olika intressen som ibland står i motsatsförhållande till varandra, och en stor variation mellan olika sändningars och transporters egenskaper. Det gör systemet svårt att modellera med de traditionella metoder som ofta används för persontransportprognoser. Vidare är regionala och urbana godstransporter tätt ihopkopplade med omgivande system så som det ekonomiska systemet inklusive affärsmodeller och konsumtionsmönster samt godstransporter på nationell och internationell nivå.

Modeller som används för offentligt beslutsfattande måste möta vissa krav avseende transparens och kvalitet. Dessa krav bildar ett ramverk av olika parametrar som måste beaktas när modellerna utvecklas (se Figur 1 ovan, som placerar parametrarna i modellberäkningens olika faser – indata och parametrar måste vara (i) tillgängliga, (ii) kvalitetssäkrade och (iii) aktuella. Själva modellen (eller modellsystemet) måste vara (iv) transparent, (v) valid, (vi) flexibel, (vii) resurseffektiv och (viii) användarvänlig. Slutligen måste modellresultaten vara (ix) tillförlitliga, (x) innehålla efterfrågad typ av information, (xi) ha en lämplig detaljgrad och (xii) vara tydliga).

Denna studie syftar till att rekommendera en handlingsplan för svenska myndigheter, specifikt Trafikverket, för att möjliggöra framtida högkvalitativa analyser och prognoser av näringslivets transporter i region och stad.

Tidigare modellapproacher som gjorts i Sverige och i andra länder beskrivs genom en litteraturstudie, som har kompletterats med och vägletts av intervjuer med modellexperter i Sverige, Norge och Danmark. Litteraturstudiens fokus var på

- modellsammanställningar och jämförelser,
- beskrivningar av modeller som är implementerade och används av myndigheter som en del av deras planeringsprocess, samt
- särskilt lovande approacher som presenterats i en forskningskontext.

Dessa avgränsningar motiveras av relevansen för svensk modellutveckling i en nära framtid. Modellapproacher beskrivs kortfattat i termer av modellkategorier, på en skala från enkla framskrivningar baserade på historiska trafikräkningar på enskilda länkar, till mer avancerade modeller baserade på försörjningskedjor eller ruttsimulering. Ju mer avancerad och detaljerad modelltyp, desto större andel av myndigheternas analysbehov kan den möta. Dock ökar även den nödvändiga mängden indata längs med samma skala, vilket bidrar till större resursbehov för modellutveckling och längre implementeringstider.

Många modellapproacher inom olika kategorier har föreslagits och utvecklats av forskare runt om i världen, ofta med en särskild region eller stad som fallstudie. Vidare har ett ganska stort antal länder och delstater, speciellt i Nordamerika men även i Europa, tagit approacherna längre och implementerat godsprognosmodeller och gjort de nödvändiga datainsamlingsinsatserna. Dock är dessa implementerade modeller ofta på nationell (i Europa) eller delstatsnivå (i USA och Canada), en skala som snarare är jämförbar med SAMGODS än med den regionala eller urbana nivån som är ämnet för denna studie. Ett fåtal undantag har identifierats och de mest intressanta approacherna beskrivs.

I det sista avsnittet i litteraturstudien introduceras ett alternativt modelleringsperspektiv, som ett komplement till det mer traditionella perspektivet som är dominerande inom området. Det traditionella sättet att beskriva och modellera stora komplexa system är att gå uppifrån och ned. Top-down-metodologierna utgår från antagandet att information eller kunskap finns utanför systemet, att man kan mäta och analysera det aktuella fenomenet och dela upp det i olika enheter och lösa de olika delproblemen separat. Detta kräver djup kunskap om systemet och alla dess komponenter i form av information om värden, val, med mera.

Ett alternativ är att starta nedifrån och därifrån aggregera resultat. Bottom-up-metodologier utgår istället från systemteori där modelleraren antar att han eller hon inte kan förstå hela det aktuella fenomenet, men däremot kan observera olika aktiviteter och processer, och försöka förstå beteenden och målsättningar. I dessa fall räcker det att kunna skapa så kallade agenter, vilka kan vara organisationer, personer, maskiner, etc. som har en funktion, som exempelvis en kran i en intermodal terminal.

I det avslutande kapitlet formuleras ett antal slutsatser om en lämplig väg framåt i den svenska kontexten. Modell-gapet, det vill säga vilka önskvärda analyser som inte kan utföras med idag tillgängliga modeller, beskrivs. Befintliga modeller i Sverige kan kombineras i ett gemensamt ramverk för att beskriva de flesta aspekter av nuläget för näringslivets transporter i region och storstad, och delvis för att göra business-as-usual-prognoser eller framskrivningar. Men för att kunna göra scenarioanalyser och utvärdera effekter av åtgärder på regional eller urban nivå, behöver nya modeller utvecklas.

Därefter diskuteras behovet av en långsiktig strategi för modellutveckling, och vad en sådan strategi bör innehålla. Fyra viktiga aspekter som definierar aktuella behov och möjligheter beskrivs mer i detalj:

- Dataförsörjning – tillgänglig data och nya förutsättningar
- Ett vidare spann av scenarier vid planeringshorisonten
- Kommunikation gällande modellberäkningar och inkludering av intressenter
- Moderna modellutvecklingstekniker

En struktur för modellutvecklingsbeslut på olika nivåer – modellandskap, modellarkitektur och modelltekniker – föreslås.

Sedan sammanfattas slutsatserna. Efter att rapporten färdigställts fram till detta skede, hölls en workshop med inbjudna modellexperter. Workshopen hade två syften – en extern granskning av studiens resultat och att diskutera möjligheter och utmaningar för framtida utveckling.

Workshopen startade med en presentation av studiens resultat och därefter gavs korta presentationer från inbjudna talare. Diskussionen kretsade primärt runt utmaningarna kopplade till datakällor och datakvalitet, modelleringsfrågor och modellernas användbarhet beroende på olika intressenters behov, exempelvis Trafikverket.

Författarna till denna rapport sammanfattar workshopen med följande slutsatser:

- Det är nödvändigt att skapa en stabil miljö för utvecklingen och förvaltningen av metoder och modeller för transport i allmänhet och för näringslivets transporter i storstad och region i synnerhet
- Ett modellramverk behöver skapas där både Trafikverket och andra intressenter så som storstadskommunerna kan samarbeta och bjuda in andra för att gemensamt utveckla modeller
- Tillräckliga resurser måste allokeras till att inte bara utveckla, utan även underhålla, förvalta och uppdatera modellerna över tid
- Runt 85 % av Sveriges befolkning bor i, eller nära städer som följd av de senaste seklens urbanisering, vilket gör städer och tätbefolkade områden till de mest angelägna att modellera
- Möjligheterna att utnyttja befintlig indata på nya sätt bör uttömmas, parallellt med att möjligheterna utforskas med befintliga big data-mängder från the internet of things, sociala media, med mera i kombination med nya databearbetningstekniker
- Vi är mitt i ett paradigmskifte inte bara i hur vi lever våra liv, men också vad gäller datatillgång, beräkningskapacitet och modelleringskunskap, vilket gör det prioriterat att initiera nya approacher

I rapportens sista avsnitt ges rekommendationerna. Baserat på resultaten av denna studie föreslår vi att Trafikverket initierar ett multidisciplinärt forsknings- och utvecklingsprogram som fokuserar på de dimensioner som beskrivits i kapitel 5, nämligen:

1. Att sammanföra och dela de insatser som redan pågår hos olika myndigheter, universitet och konsultfirmor
2. Kombinationen av befintliga modeller för näringslivets transporter i Sverige, för att maximera nyttan av redan gjorda insatser
3. Utforskandet av befintlig data från gamla och nya källor, med nya tekniker
4. En långsiktig men flexibel strategi, som;
    - tydligt anger mål, behov och nödvändiga resurser för Trafikverket,
    - Inkluderar ett forum av andra intressenter
    - Innefattar ett modellramverk med fokus på att definiera modellandskap, -arkitektur och tillgängliga tekniker, med syfte att skapa en färdplan för modellutveckling. Denna färdplan bör revideras regelbundet och inkludera insatser för att kontinuerlig utvärdering
    - Inklusive datatillgång, moderna modellutvecklingstekniker, scenariogenerering och inkludering av intressenter

Det vore också fördelaktigt att bjuda in andra aktörer, så som de större städerna i Sverige samt våra grannländer.

3 INTRODUCTION

3.1 BACKGROUND

Freight transport in Sweden is growing, as is the share of goods that is transported by road vehicles. The last 50 years, ton-kilometers in Sweden more than doubled and during the same time freight transport on road doubled its share, leading to a 400 % increase in ton-kilometers on road. The official forecasts published by the Swedish Transport Administration estimate a continued growth of road freight transport by 1.8 % per year until 2040 (The Swedish Transport Administration, 2016).

With a growing population in cities and metropolitan areas, and road transport as the dominating mode of transport for the distribution of goods and for providing services, a large share of current and forecasted road transport is likely to take place in densely populated areas. The Swedish Transport Administration's policy documents for Research and Innovation states, among other things, that "Well-developed and cost-effective logistics and freight transport systems are a prerequisite for trade and industry growth, and thus for the development of society at large" (The Swedish Transport Administration, 2012b). These systems shall interact with cost effective passenger transports for increased accessibility and mobility.

While these transports provide necessary goods and services for the population and businesses, they are also connected to a number of negative effects. Except for the global effects of greenhouse gas emissions, the increasing freight transport contributes to local problems such as congestion, pollution, noise and traffic accidents.

The regional and national agencies aim at decreasing these negative effects through infrastructure investments and policy measures such as regulations and taxes. These are strategic, long-term and often costly measures and the agencies wish to evaluate the effects beforehand as a part of their decision-making, through e.g. cost-benefit analyses or other assessment methods. Transport forecasting models play a vital role in the assessments and should ideally enable decision-makers to evaluate effects of measures in different scenarios with respect to e.g. future land use, economic growth, changing consumption patterns and technology. It is primarily the Swedish Transport Administration, the Transport Analysis agency and some of the municipalities and county administrations that employ (or wish to employ) such models. The available models are continuously developed, but in parallel, the conditions in terms of computational resources, data collection and big data techniques have changed dramatically the last decade, offering new possibilities for analyses.

The needs of society are large and difficult to grasp, and an important part of the Transport Administration's mission is to prioritize and allocate the available resources in the best way. Sweden has a well-developed support for analysis and prioritizing through economic calculations for passenger transports, mainly via the SAMPERS model[2], whose development began in the late 70s.

There is also good access to passenger transport data that allows for statistical analysis of the total population and sub-populations whose values and choices have been studied and valuation profiles have been developed. For freight, the situation is different, partly because of other conditions with respect to the input data and that freight and business cannot be described in the same terms of statistical populations.

Currently, the Swedish Transport Administration employ passenger travel forecast models at the regional scale, as well as the national passenger and freight transport models. For regional freight and commercial vehicle traffic, fixed lorry and commercial vehicle matrices are generated for use in the regional passenger models (this is described in a later chapter).

However, a functional regional model for freight and/or commercial vehicles is lacking in the planning system.

The Swedish Transport Administration has funded this study to set out to fill that gap. This study comprises freight transport (i.e. the movement of goods) as well as commercial vehicle traffic (i.e. the movements of different types of vehicles generated by the movement of goods or by providing services). The terms (and variants thereof) are used interchangeably throughout the study. When one of the two is specifically regarded, it will be explained.

In 2015, the Swedish Transport Administration funded another study on the need for developed knowledge on regional commercial transport (Sweco, 2015a). The study states that the Swedish Transport Administration has an interest in making cost-benefit analyses, policy analyses on e.g. congestion charging, road taxes and regulations as well as forecasts. Metropolitan municipalities are interested in the availability aspects of an attractive city and there are questions on a regional level as well that freight modeling could help answer.

These needs form the main demand for tools for regional or urban freight transport modeling.

In their conclusions, Sweco recommends an evaluation of available models and model techniques, based on the identified needs for analyses of regional commercial transport. This evaluation should include a specification of desired functionality of the model(s) as well as the different models' need for input data and estimated resources needed for implementation. Further, they recommend an international review.

In 2014, the Swedish Transport Administration funded another study (Logistics Landscapers & Lund University, 2014) that was aimed at evaluating and demonstrate other approaches usability in a society with increasing complexity and increasingly integrated functions and systems, based on CAS (Complex Adaptive Systems) and ABM (Agent Based Modeling). This study recommended that the Swedish Transport Administration should initiate a pilot study in order to evaluate the potential for developing a complex adaptive systems model for the Swedish national logistics and transportation system. This new model should be formed as a

[2] SAMPERS is the national forecast model for passenger transport, which is often used by the Swedish Transport Administration for e.g. the long-term infrastructure plan

shell allowing the use of agent based modelling in combination with already existing models, such as SAMGODS.

This study aims to respond to several of the research questions proposed by Sweco, and can be seen as a continued development of both the mentioned pre-studies.

3.2 FRAME OF REFERENCE

This chapter briefly describes the frame of reference in two aspects: logistics and transportation, and freight modelling in order to set the basis for the report.

3.2.1 The logistics and transportation system

Logistics and transportation are two concepts that often are viewed and used as meaning the same thing, which creates a confusion about not only the relation between those two terms but also their meaning. One of the very first accounts of logistics as a concept in a scientific context was made by Ericsson, where he states that business logistics can be defined as the approach and principles that govern our way of planning, organizing, managing and controlling the flow of goods from supplier to end consumer (Ericsson, 1972). This is very close to another definition by Bowersox that states that physical distribution is the responsibility to design, administer and control the flow of raw materials and finished goods (Bowersox, 1978).

The concept of logistics has its origin in the military perspective regarding the physical operational treatment and transfer of goods, which focuses the need for the engineer to find workable solutions to the displacement, handling and storage problems. The use of the word logistics in the business community is a much more recent post World War II tradition, which is closely coupled to the growth of the information and communication industry. The development of logistics as a scientific discipline has occurred in parallel in both economics and engineering schools. It is mostly related to the private sector and the problem of handling goods to supply different needs in the supply networks and ultimately the demand of the end consumer.

Transportation, on the other hand, has mainly been focused on the transport of people (Sjöstedt, 1994). It is quite naturally focused on traffic engineering and the speed of the traffic flow representing the problem of traffic management, primarily cars on the road network, but also the other modes of transport.

The parallel development of the two disciplines has now brought them to a point where they overlap in theory, methods, models and terms used. This sometimes makes it hard to distinguish between the two disciplines and is a basis for misunderstandings. Therefore, it is important to understand the differences but also the commonalities between these two concepts. Figure 2 below is one way of showing the interrelation between Logistics and Transportation and the related concepts of Supply Chain Management and Mobility Management.

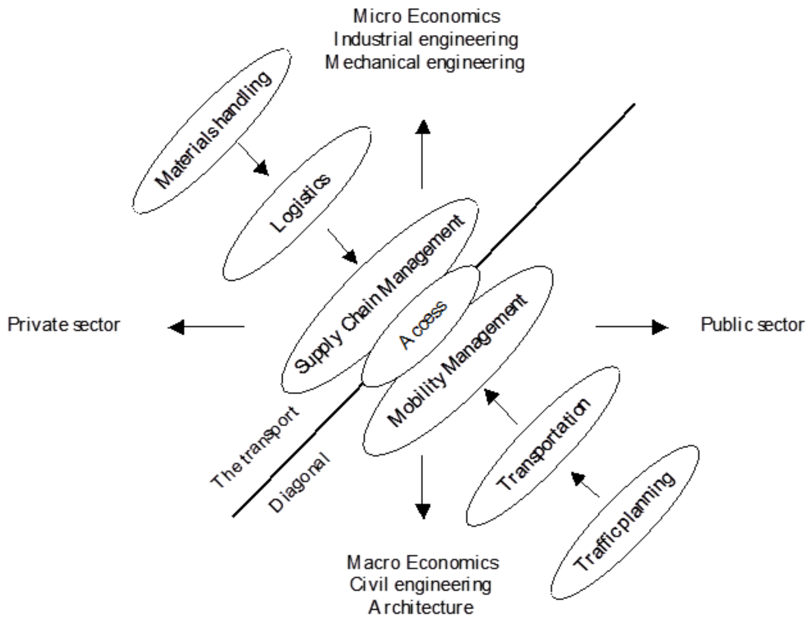

Figure 2: The relation between transportation and logistics (Sjöstedt, 1994), (Sjöstedt, 2001)

The common goal of supply chain management and mobility management is to provide accessibility (for humans, services and goods), i.e. to provide access to the right facility at the time required to participate in scheduled activities at this facility (Sjöstedt, 2001). It has to be noted that both supply chain management and mobility management are large and not very coherent concepts that encompass more dimensions than shown in the figure. The model is here used as a convenient way to show the different aspects of supply chain management and mobility management, their respective heritage and their common goal.

Transportation and logistics systems that are the basis for goods transports are quite complex with different modes of transports and interdependencies between buyers, sellers, forwarders, etc. Figure 3 gives a good survey of the different qualities of transportation and logistics systems and why they, on a larger scale, are so hard to model and understand.

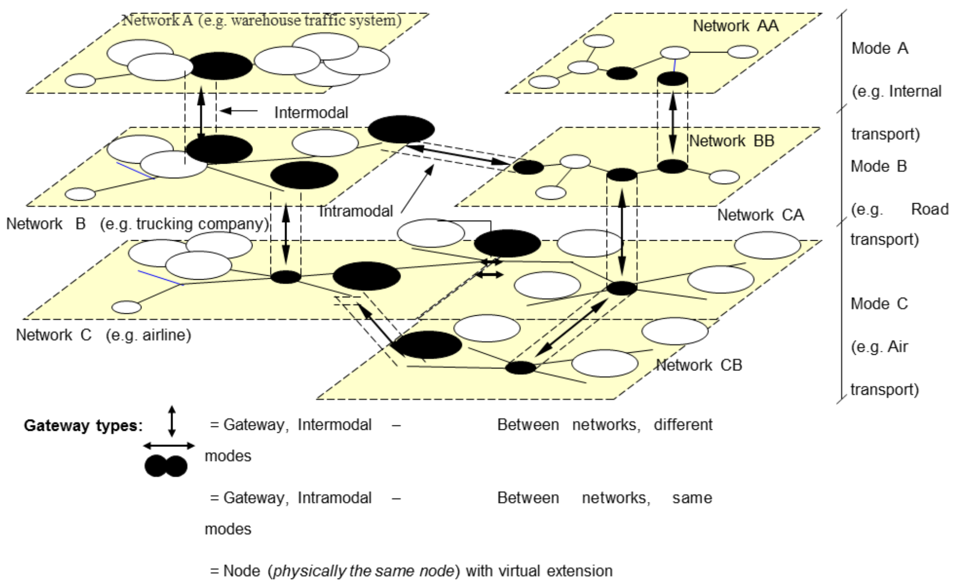

Figure 3: The transportation and logistics system (Waidringer, 1999)

The links can represent a road, rail, air or sea and if combined a multimodal network. The nodes are any place where there is an interconnection, be it unimodal as for example road-to-road, or multimodal, such as warehouses, airports, terminals, etc.

In the figure above, Network A represents the internal flow within a factory, warehouse or other entity. It is normally some kind of assembly if it is a factory and in a warehouse, the two main activities are to break goods into smaller shipments and to consolidate small shipments into larger ones.

Network B is a road transport network that in theory is only limited to where there are roads; in practice the limitation is rather the extension of the network that the trucking company in question is operating. The gateway between the networks is marked with a dark circle and a double arrow indicating that the flow can go in both directions.

Network C is an air transport network, which, as is the road network, only limited to what destinations the airline company operates. Here the gateway, as for the other networks is a specific node where the two networks meet.

The other networks denoted AA, BB, CA and CB respectively represent other chains and networks, unimodal or multimodal, in order to show a more comprehensive and complex picture of what an entire systems actually looks like.

This is a network representation of the transportation and logistics system but of course, there are processes taking place on these different networks and stakeholders who execute them. In the network, we discuss nodes, links, and different superposed or interconnected networks.

Transportation and logistics systems should be regarded as heterogeneous sociotechnical systems with a large number of stakeholders. The systems are influenced by a large number of variables that can have values within a great interval and often show a stochastic and emergent behavior. The character of these systems makes them inherently complex, the combinatory challenges makes them hard to analyze and the knowledge about the causal relations that define them is insufficient.

Nonetheless, currently, firms as well as authorities put lot of money, time, and resources into approaches, methods and models that are based on Newtonian assumptions and beliefs of certainty and mechanistic principles i.e. perfect rationality, determinism, and linear causality (e.g. spread sheet tools, linear programming, etc.). While, the reality logistics processes in supply networks, is mostly perceived as uncertain, nonlinear, and increasingly complex. Furthermore, with increased competition and changing demands, the marketplace will be even more turbulent. Hence, as stated by Robertson (2003);

"*if the business world is viewed as being complex, it is inappropriate to consider models developed under paradigms of equilibrium, stability, and linearity to produce an analysis of a turbulent environment"* (1 p.61).

However, Axelrod and Cohen (2000) provide a good explanation for the dominance of reductionist approaches when they state,

"No doubt, machines and hierarchies provide easier metaphors to use than markets and gene pools. So it is no wonder that most people are still more comfortable thinking about organizations in fixed, mechanical terms rather than in adaptive, decentralized terms" (18 p.29).

Another important feature of transportation and logistics systems, especially if viewed from a governmental and policy perspective, is that these systems are open[3]. This means that studying them and attempting to make predictions always includes an environmental factor that is unknown and constantly changing.

Consequently, the approaches, methods, and models provided for governmental agencies such as the Swedish Transport Administration as well as logistics managers, must be able to consider and treat constellations that are more complex. They should also be able to include interactions and behaviours, within and among agencies, firms and regions.

3.2.2 Freight transport modelling

Freight transport is the consequence of economic activities in terms of production and consumption of goods and the trade that connects those actors. The type of commodities that are traded affects the volume and characteristics of the generated traffic (with respect to e.g. mode choice, sensitivity to transport time, shipment size). Further, the conditions for conducting freight transport are defined by the infrastructure and the other types of traffic that are using it, together with regulations and availability and cost for transport resources. Finally, the volume and characteristics of the freight transport in a region affects other traffic in the infrastructure, the environment and the population, through e.g. contributions to congestion, air pollution and noise. The conclusion is that freight transport cannot be analyzed in isolation of all these other aspects of society and environment. In order to make useful forecasts and impact assessments, a freight model (or system of models) should be able to take into account changes in

- economic activity in the studied region
- infrastructure
- regulations, policies and taxes
- other traffic using the same infrastructure
- technology, business models and behavioral patterns
- varying time sensitivity among sectors
- freight transport volumes and patterns on the national and international level
- future prediction of freight types and volumes

Some of these effect relations go both ways, which will require feedback loops and iterations. This means that the model or model system needs either to include all these aspects, or be implemented in a framework where it could be connected to other models representing them, through e.g. input data and boundary constraints.

Freight transport involves a multitude of shipments of different sizes, characteristics and requirements. It involves everything from a 5 000 tonnes slow moving iron ore train to a 100 gram express parcel. The purpose of the shipment could be to deliver a vital spare part that stops the production in an

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[3] Ludwig von Bertalanffy (1969) describes two types of systems: open systems and closed systems. The open systems are systems that allow interactions between their internal elements and the environment. An open system is defined as a “system in exchange of matter with its environment, presenting import and export, building-up and breaking-down of its material components. Closed systems, on the other hand, are held to be isolated from their environment. Equilibrium thermodynamics, for example, is a field of study that applies to closed systems (Wikipedia)

entire factory at huge costs or it could be a load of gravel that just is supposed to be dumped somewhere. This highlights the challenges in modelling different aspects of freight transport. The effects of changing various parameters or real-life conditions are very contextual. Sometimes a 1 hour late delivery of a single screw can cost millions while in other cases a 1 day late delivery of a shipload of screws can have negligible consequences.

Several studies in the literature review which will be presented in a later chapter (e.g. Doustmohammadi et al 2016, Alho 2011) conclude that the modeling of freight transport is less explored and developed than that of passenger transport, in both theory and practice. The reasons for this are mainly that

- the freight transport system is more complex in the sense that it involves many stakeholders and decision-makers with different and sometimes conflicting needs and includes a large variety of commodities and shipments
- there is no standardized modeling framework
- there are inherent limitations of data access on a detailed level, as it is often proprietary or non-existent
- in order to capture effects of various policy changes and regulations, a large number of metrics are needed, such as number of trips, mode of transportation, travel distance, tons of goods transported, fill rate, vehicle types, transport costs, etc.

Chow et al (2010) state in the beginning of their study – with the purpose to suggest a model development path for the state of California – than an ideal freight demand model has “a strong behavioral foundation; a multimodal scope; incorporating freight and passenger interactions; and capable of handling policy changes”, but that not many efforts succeed in meeting these objectives. Doustmohammadi et al (2016) conclude their study with stating that: “the state of the art in true goods movement modeling is not yet sufficiently developed to the point where it is easily adoptable by most urban travel forecasters”. Alho (2011) points out a “lack of studies revealing a throughout analysis of the context for which an urban freight model is developed”.

In order for a model to be useful in the planning process, it must meet several requirements. Some of the requirements have been formalized in a set of official guidelines for the generation of traffic forecasts (The Swedish Transport Administration, 2012a). If one or more of these requirements are not fulfilled, it will lead to that the model either cannot be applied in practice or that the results are not used.

- The *model will only be applied* in practice if
  - the necessary input data is available
  - the model is user friendly enough for the staff that are supposed to handle it
  - the model can be applied for a reasonable cost and time use, and
  - the output contains the desired contents at a sufficient detail level
- The *model results* will come into use only if the model earns credibility by the actors that demand the results, and that requires that

- the input data is quality audited and up to date
- the model is transparent, and
- the outputs are reliable and clear

In addition, in order to fill its purpose, the model must be able to capture the dynamics of the system it is supposed to represent well enough (i.e. it is valid) and flexible enough to represent the different scenarios it will be used to analyze. Otherwise, there is a risk of basing important decisions on invalid assessments.

Those requirements give the framework illustrated in Figure 4 and the further analysis in this study is based on that framework.

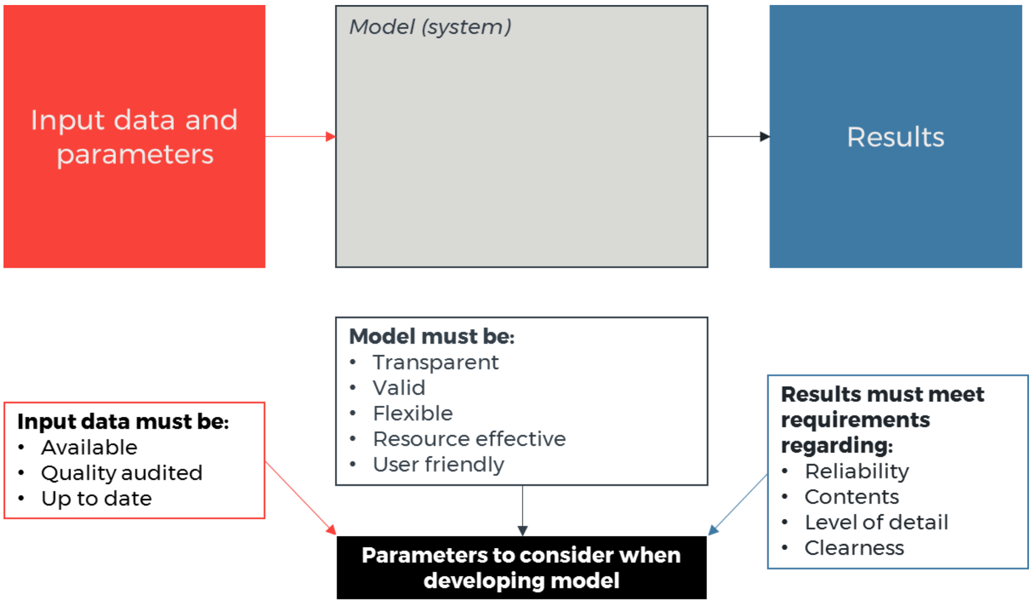

Figure 4: Requirements of model (systems) used in the Swedish Transport Administration's planning process. Adapted from Sweco & WSP (2017)

3.3 SCOPE

Since a complete regional freight and/or commercial vehicle model system is lacking in Sweden, the study is limited to describe approaches within those fields that could fill this gap (entirely or partially). Thus, model approaches that focus on or include the regional[4], metropolitan or urban scale are in the focus of the study.

Further, modeling of freight and/or commercial vehicles is within the scope of the study. That means that models that include freight traffic – that is, the transport of goods – by heavy or light trucks (and possibly other modes), and/or other commercial vehicle traffic such as service trips in cars and vans are of interest for the study. As described later in this report, freight flows and vehicle movements are modeled in different ways, and the models require different types of input data. However, the analysis needs of the agencies are not completely defined and therefore this study aims to include both.

In order to limit the information gathering process and provide an updated description of model approaches, the study is centered on model approaches

[4] The national scale in Sweden is comparable to the statewide scale in North America, where many transport models are developed and applied. The regional models discussed in this study thus concern a more detailed geographical level than in some other studies.

and initiatives that either have reached the stage of actual application in the agencies' planning process, or are new and especially promising. The literature study has been limited to publications from the last decade.

3.4 PURPOSE

The overall purpose of this study is to lay the foundation for the Swedish Transport Administration to set up an urban or regional freight model meeting the needs and requirements of the Swedish planning process by:

1. Describing state of the art for urban/regional freight transport modeling or model approaches in other fields of application with similar conditions to it
2. Giving recommendations on which path to choose for developing a Swedish model and how to make use of the insights from this study in the development of the existing model systems

A secondary purpose is to establish contact with other Nordic actors involved in urban or regional freight modeling or related fields in order to facilitate future knowledge sharing and, if desirable, cooperate in development of future models.

3.5 RESEARCH QUESTIONS

In order to meet the purpose of the study, the work took off from the following research questions:

- What types of regional or urban freight and commercial vehicle models exist in the Nordic and other countries?
- Are there models or model techniques, developed for other fields of application, which could be adapted for modeling urban or regional freight transport?

Models or categories of models found were regarded from the perspective of suitability for modeling Swedish urban or regional freight transport, meeting the needs and requirements present, with respect to

- The scope of the model(s) (e.g., geographically, regarding field of application or types of transport included)
- The purposes of the model(s), to what extent they are applied in practice, how the results come into use
- Briefly: conceptual model and implementation

The results from these research questions were used to analyze the overall question of

- What are the recommended actions for Swedish agencies (especially the Swedish Transport Administration) in order to enable future high-quality analyses and forecasts of regional and urban freight and commercial transport?

3.6 METHOD

In order to answer the research questions, a literature review has been conducted, which was complemented and facilitated by a number of interviews with model experts in Sweden, Norway and Denmark.

The interview questionnaire was adapted to each respondent's background, but was related to the questions:

- How do the agencies in your country currently model and forecast freight and commercial transport on the urban or regional scale?
- Are there aspects that would be beneficial to model but that are not included in current models? Are there other shortcomings?
- Are there any relevant ongoing development projects or suggestions for future models?

The focus of the literature review was on model reviews, descriptions of models that are implemented and applied as part of the agencies' planning process and especially promising approaches made in a research context. These considerations are motivated by the relevance for model implementation in the near[5] future.

However, since the demand for model analyses in Sweden is rather vaguely formulated in terms of exactly what needs to be modelled, and there is no formulated strategy for e.g. data collection efforts, the recommendations for Swedish model development must be broadly formulated. Therefore, effort was put into describing the considerations needed to take decisions for the model development and the need for a strategy or road map. This part is presented in the Discussion chapter.

[5] Starting within the next 3 years

4 LITERATURE REVIEW

The broad information gathering process conducted in this study resulted in a large number of studies and descriptions of individual model approaches as well as state-of-the-art studies. Found approaches are described in this chapter, while they are discussed in the next (chapter 5). The descriptions are made without going into detail, due to the large area covered combined with the early stage of the model development process. First, the findings of the literature review on freight modelling in general are summarized. Then, State of the art in the Nordic countries and internationally are described. Finally, a number of novel approaches in other fields are described, that could be useful for the topic of freight transport modelling.

4.1 FREIGHT MODELLING - GENERAL

In order to limit the scope and to capture the current situation, the review part of the literature study has been limited to the last decade, starting with 2007. A number of international reviews of freight and commercial vehicles modeling have been conducted during this period. In these studies, the model approaches present have been classified according to different systems. As Donnelly et al (2013) point out; there is no perfect classification system, since the boundaries between some approaches are fuzzy. In this section, we describe model classes that are used in several studies and that are based on the models' methodological approach. Anand et al (2012) argue that it is useful to classify models rather according to other factors in the model selection process, e.g. stakeholder involvement, the objective for the model and the model perspective.

This chapter describes the status of regional freight and commercial vehicle modeling in the various categories, without going into detail in any existing models. Instead, brief descriptions of a couple of interesting examples of implemented models are given in a subchapter below. Useful references that describe freight models used in different cities and states around the world are Chow et al (2010) and Donnelly et al (2013). Some of the reviews focus on urban transport or city logistics, but most take the broader perspective of freight modeling in general.

A common reference in the reviews is the *Forecasting Statewide Freight Toolkit* by Cohen et al (2008), which suggests that traditional freight forecasting approaches are classified in five classes (A-E). Later studies have built further on the classification, adding two groups of more recent model approaches (classes F and G), as described by e.g. Chow et al (2010) and Doustmohammadi et al (2016). They use this framework based on methodology in their reviews and describe freight forecast models in the following categories:

A. Direct facility flow factoring method: Growth rates are estimated from historic vehicle counts and applied to observed traffic volumes. This method is mostly used for short-term forecasts on individual links.
B. O-D factoring method: Same principle as class A, but instead of observed flows on individual links, the base for the forecast is O/D matrices for the base year.
C. Truck models: Vehicle-based models that generate trips with different truck types within and between zones, using the trip distribution and network assignment steps from the four-step

approach (see below). Often combined with passenger transport modeling.

D. Four-step commodity models: Freight version of the traditional passenger transport modeling approach. Forecast of commodity flows: amount of goods generated in sources/production units and consumed in sinks/consumption units (generation step) and matching of origin and destination (distribution step), is followed by conversion to daily trip numbers by mode (mode choice step) and then assignment to the network (route assignment step).
E. Economic activity models: Models that connect freight demand modeling to an economic or land use model, including feedback mechanisms with freight transport costs.
F. Logistics chain models: Modeling of commodity flows through the entire supply chain, meaning that transshipments and intermodal transports could be included. Enables models to include more dimensions of policy and decision-making.
G. Vehicle touring models: instead of trips, vehicle tours are generated within the model. The purpose is to capture vehicle movements and to include distribution and consolidated transports. Suitable for impacts assessments of typical city logistics policies, such as pricing strategies and restricted lanes.

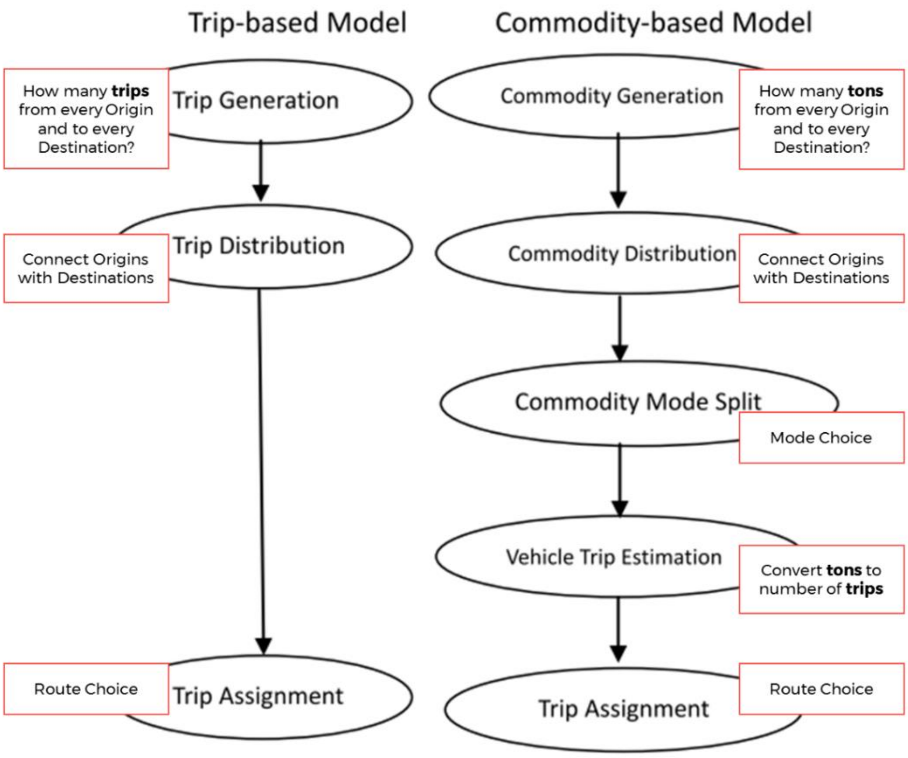

Figure 5: Illustration of model classes C and D, from Doustmohammadi et al (2016) with own comments added

Doustmohammadi et al (2016) conclude that none of the more traditional approaches in classes A-E alone is capable of addressing all analytical needs, but that the more recent approaches in classes F and G are more promising. Chow et al (2010) highlight which analytical needs gaps that are not met by model in classes A-E, of which policy studies are the most relevant for the urban or regional scope, and conclude that class F and G models fill many of the analysis gaps identified. However, the more advanced the models (going from A to G), the larger are the data requirements. Thus, except for the analytical needs that the model is intended to meet, the availability of data also need to be considered when deciding on which model approach to use.

Many of the models in categories A-G could also be more coarsely divided into commodity-based and vehicle-based models. Commodity-based models have the advantage to include more of the factors that generate the demand for freight transport, thus being able to model impacts of changes on a higher system level. On the other hand, vehicle-based models (trip-based or tour-based) can capture movement and activity patterns for the entity that is connected to most of the negative effects of freight transport and thus is subject to most evaluations and impact assessments (Doustmohammadi et al, 2016). Figure 5 above illustrates model classes C (which is an example of a vehicle-based model type) and D (which is commodity-based). However, the charts Figure 5 are not representative for *all* vehicle- and commodity-based models respectively, but more specifically for classes C and D.

The reviews also provide comparisons of the suitability of models in the different classes in other regards than those already mentioned. For example, the choice of model approach must also depend on whether it should include mode choice and on the geographical scope of the study. Doustmohammadi et al (2016) provide a table of advantages and disadvantages of models in classes A-G, taking data requirements and data availability in American conditions into consideration.

Donnelly et al (2013) make a review of best practices in freight and commercial vehicle modelling for the public sector, in order to give recommendations for the Ontario Ministry of Transportation. They list a number of emerging trends in freight modeling, namely

- Fully multimodal rather than truck trips
- Representation of complex truck tours
- Inclusion of distribution centers and their effect on freight flows
- Multi-level models (national, provincial, regional) rather than single geographic scale
- Linkages to macroeconomic models
- Focus on value of commodities carried, not just number of vehicles
- Looking at freight within supply chain context
- Agent-based simulation models
- Passive data collection instead of costly surveys
- Consideration of pricing and congestion effects

They also highlight the importance of identifying the functional requirements of the agency early in the model development process. Their study starts out with an overview of methodologies, including those mentioned above but using a slightly different classification. The descriptions of basic assumptions and usefulness for the purpose of their study are also more thorough. The study is focused on freight transport modelling but they highlight the usefulness to include all commercial vehicles in the forecast models. However, they conclude that very few implemented models succeed to do so.

Taniguchi et al (2014) review model approaches in city logistics focusing on three areas; emissions, healthcare and mega-cities, of which the first area is of most interest for this study. However, in order to successfully model emissions from city logistics, a broader perspective than just the transportation modeling and forecasting must be taken. The study summarizes a number of approaches that could be interesting extensions of a regional freight model, such as including upstream and downstream processes in life cycle analyses of freight transports, which has been shown to add 63 % compared to only considering tail-pipe emissions.

Anand et al (2012) analyze a number of different aspects in urban freight transport modeling. Firstly, they state that the models' stakeholder involvement must be considered. Most models take the "administrator's"[6] perspective, and the administrator often has an interest of the overall social cost. They have the interest of facilitating the transportation of goods in common with the various private stakeholders (shippers, carriers and receivers), but other individual interests often conflict between different actors. Secondly, they provide an analysis of different reasons or objectives for modeling. Thirdly, the descriptors used to quantify urban transport must be considered. Finally, one must be aware of the model perspective – the aspects of the system that are selected for representation in the model. They depend on the model user, objectives of modeling and the means available to achieve the objectives. The study reviews city logistics modeling efforts using this framework.

Representing an additional category of transport models, Shepherd (2014) provides a review of system dynamics models applied in transport during 1994-2014. System dynamics models are often illustrated by casual loop diagrams, which show the qualitative connections between the different entities modelled. The loops are either self-reinforcing or self-correcting (Shepherd, 2014). The models can be made quantitative by formalizing the connections by mathematical expressions. System dynamics models are used to describe complex, dynamics systems and their development over time (Thaller et al, 2016).

As Shepherd concludes, they cannot replace model tools for e.g. network assignment, since they usually are not representing the geographical dimension, but rather the time dimension of systems (even though exceptions exist). However, the strengths of system dynamics models make them useful for modeling dynamics that could not be easily captured by the traditional models, such as strategic policy issues that involve delays and feedbacks between different parts of the system. Such dynamics are sometimes outside the mental model of the decision maker. Other important benefits of the approach are

- the feasibility for a holistic view in the sense that it enables connection of transport to e.g. land use, economy, population and behavioral patterns and modeling of the coevolution of these systems
- the ability to provide knowledge of the dynamic behavior of the system rather than producing a static scenario
- that the underlying casual loop diagrams are easily communicated and developed in cooperation with different stakeholders (Shepherd, 2014)

Shepherd gives a review of 50 studies in the transportation area, divided in the categories after area of application, where the most relevant for this study is strategic policy at urban, regional and national levels. Most reviewed studies focus on passenger transport, with a few exceptions.

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[6] Public sector stakeholder's

Wang and Holguín-Veras (2009) developed an alternative freight distribution model using entropy maximization to assign truck volumes to tours. Unlike most models, this model uses aggregate data only. The benefit to this type of model is the reduced data required compared to the data-intensive models normally, while still providing realistic touring elements in a freight demand model. It is based on the same methodology and approach as the new model for Stockholm developed by Atkins and Chalmers, see below.

Giuliano et al. (2006) addressed the issue of data insufficiency by using secondary data sources to estimate commodity freight flows at a resolution from which a singular data source is not available. The resolution of existing public data such as the Commodity Flow Survey only goes down to the level of the aggregate metropolitan area. Using secondary data sources, Giuliano et al. were able to estimate the inter-county flows for the five counties in the Los Angeles metropolitan area. Reconciliation between multiple conflicting data sources for different years is conducted by using one source as the control.

4.2 STATE OF THE ART – NORDIC COUNTRIES

There are a number of previous approaches in Sweden to model regional freight transport, including the NÄTRA model for the Stockholm region and the GORM model for the Öresund region. These are described below. Further, the status of Norwegian and Danish regional freight modeling has been investigated.

4.2.1 NÄTRA

The *NÄTRA* system includes a database and a model system. The model system relies on input data from the database. Except from providing input data to the model, the database has also been used to extract statistics to describe commercial transports in Stockholm. The scope of NÄTRA is road traffic generated by the deliveries of goods and services in the county of Stockholm.

The database consists of the findings of a major survey conducted in 1998, addressed to a large number of workplaces in Stockholm and covering data such as the number of visits from service and delivery/pickup vehicles, routes conducted by the workplaces' own vehicles, etc.

The model system uses data from the database as boundary conditions to derive O/D matrices for different kind of road vehicles, which also can be inserted to a traffic assignment module to estimate traffic flows on individual links in the road network. Other input data includes a description of the road network, traffic counts and estimated O/D matrices of other road traffic (private travels, etc.), as well as an extended version of the official lorry traffic statistics. The later set of input data is crucial – the official lorry traffic statistics are normally only broken down to the county-to-county-level, which is not sufficient to estimate the O/D matrices for NÄTRA. However, for a number of years in the 80's and 90's, the statistics have been broken down to the municipality level, which enables the estimation of O/D-matrices for county border crossing heavy transport in the model system.

O/D matrices are generated separately for transport by different vehicle types and transport within the county and to/from the county. First, a set of á priori matrices are generated, that meet the boundary constraints from the input data. The matrices are then iterated between a network assignment module (to obtain link flows and to get transport times and distances using volume delay functions) and module that calibrates the O/D matrices with respect to observed traffic (traffic counts).

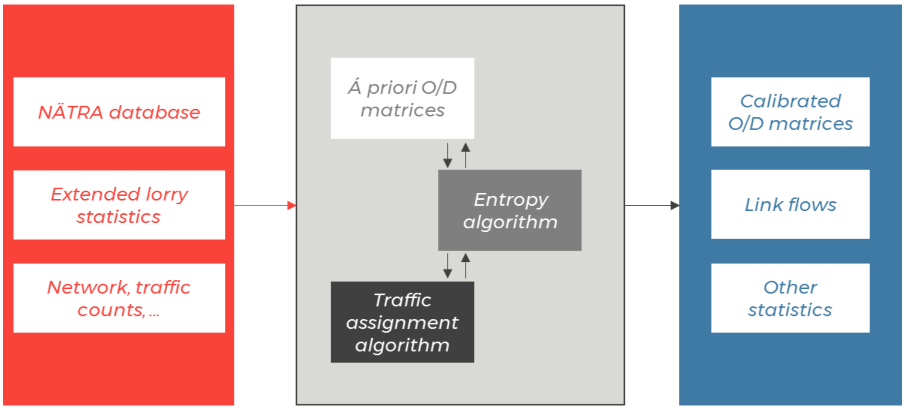

Figure 6: Schematic illustration of the NÄTRA model

The database has been partially updated from 1998 to 2005, by connecting it to new registers, which means that the number of workplaces per stratum was updated but the old scale factors (to estimate total amount of transports per stratum) were kept. This update was based on the presumption that a change of the number of workplaces in each stratum would explain the changes in transport volumes (Sweco, 2015a). However, Sweco state a number of facts that imply that patterns and behavior of urban freight and vehicle transports in Sweden have changed since the first survey in 1998.

Currently, a new update is conducted by Sweco (Edwards & Ramstedt, 2017). This update includes a survey related to two of the tables in the database; concerning the number of visits depending on vehicle type and workplace type and certain route information (number of stops, travel distance, etc.).[7] This probably accounts for part of the changed patterns and behaviors mentioned above.

During its lifetime, the database and model have been used to analyze freight and commercial transports in the county of Stockholm. Further, the database constitutes an important input data set for constructing lorry matrices for use in the regional passenger travel models (SAMPERS). In order to account for all traffic in the volume delay functions for passenger travel by road, the regional SAMPERS models require O/D matrices for lorries and commercial transport as an input. The zonal level of the regional SAMPERS models is more detailed than that of the national freight model (SAMGODS). Further, SAMGODS does not include e.g. distribution and service vehicles. Therefore, additional data must be added in order to estimate the matrices. The matrices are thus generated using disaggregated results from SAMGODS (freight transport between municipalities) together with data from the NÄTRA database (local and regional transports regarding e.g. distribution, construction and waste transport) and some complementary purpose-specific surveys and traffic counts. The local and regional transports in the O/D matrices are estimated using a model inspired by the NÄTRA model but adjusted to the available forecast data (Sweco, 2015b & 2015c).

[7] Information from Linda Ramstedt, Sweco, by e-mail 2017-05-17.

As a tool for constructing the lorry matrices for regional passenger models, the NÄTRA *database* plays an important role in the planning model system. It is a unique set of data regarding regional freight and service transports in Sweden. However, the original database is over 20 years old, and although it is being updated, it relies on costly surveys. Regarding the NÄTRA *model*, it has been used to analyze transports in Stockholm a couple of times, but there are no reports it has been applied in the planning process recently.

4.2.2 GORM

During 2007-2008, a freight transport model was developed for the Öresund region by the Technical University of Denmark, focusing on the county of Skåne in Sweden and the island of Sjælland in Denmark. The purpose was to improve the available strategic planning tools and the first version aimed at being able to analyze the concurrence between different modes of transport, effects of road taxes, environmental effects and terminal structure on an overall level. The model takes exogenously given growth rates and current transport demand matrices in tons, per commodity type and mode of transport, and computes the number of vehicles, routes and network flows for different scenarios (Vägverket Region Skåne, 2008).

Some developments of the model were carried out the following years, and the model was applied to make forecasts for 2020 and 2030 during 2010 (Ramböll & Tetraplan, 2010). Thereafter, the model has not been updated or applied.

4.2.3 New Stockholm model

On behalf of the City of Stockholm, Atkins and Chalmers University of Technology have developed a model to quantify the amount of transport that businesses in the city generate. It is an Excel model that will be applied in the city´s planning process starting this fall.[8] The model will assist the city administration to identify delivery needs and delivery types, assessing potential solutions to problems (e.g. traffic management, parking regulations), planning future infrastructure and policy measures (e.g. off-peak deliveries, consolidation) as well as being a tool for planning new areas.

The studied area comprises parts of Stockholm's inner city and the district of Hammarby Sjöstad, which is comprised of 160 postcodes in the inner city and 15 postcodes in Hammarby Sjöstad. In order to meet the design purposes and to enable future supplementary analyses, the activities are classified according to Swedish Standard for Swedish Industry Classification (SNI).

The most important model variables are the generation of freight deliveries (to the business) and, to a lesser extent, the generation of deliveries from the business. The explanatory variables covered by the study are mainly the number of employees, the area of establishment, the area of activity (measured in square meters) and the sector in which the business operates. These variables enable the use of the model for planning new areas and for policy changes.

In order to validate the developed model, control measurements have been made in two separate locations, Zenit and Skrapan, in Stockholm. The

[8] Information from Märta Brolinsson, The Traffic Administration Office of the City of Stockholm, 2017-06-13

amount of freight deliveries (FTG) were calculated on two separate occasions. The observed values for FTG were compared with the estimated value generated by the calculation tool. The calculation tool has a margin of error of 14.8% and -14.3% for Zenit and 3.3% and 3.9% for Skrapan. (Atkins, 2017)

Freight generation and freight trip-generation models for urban freight, such as the new Stockholm model, can be used by themselves to assess policy, assess parking needs, analyze local freight traffic impact, planning, etc. However, they are also the first step of an overall network model, as the root of the demand for freight are commercial establishments (with households gaining more importance lately). Following the classic 4-step approach, the next steps after trip generation is trip distribution, mode choice and route choice. Trip distribution requires a tour structure, and can be done using simulations or analytical models such as entropy-based models. Mode choice is primarily between road modes (truck classes), and route choice is based on routing and shortest path algorithms. There is a consensus that urban freight models require more behavioral models to complement statistical models and routing-based algorithms. (Sanchez-Diaz, 2017)

4.2.4 TAPAS

An agent-based simulation tool for transport chains, called *TAPAS* (*Transportation And Production Agent-based Simulator*), has been developed at Blekinge Institute of Technology in Sweden. Currently, the tool can only be used for case studies for individual transport chains, as it does not cover all transports in a given area (Sweco, 2015a). Thus, the scope is not geographical but organizational. Input data are case specific and not given in the model.

However, recent developments of TAPAS, TAPAS-Z and the extended TAPAS-Z, are steps towards more of a macro-modeling feature, i.e. to capture the transports within a geographical area. This is done by stochastically generate shipments from and to different locations in specific areas, either based on a theoretical probability distribution (TAPAS-Z) or by sampling from historical shipment data for the area (extended TAPAS-Z) (Holmgren & Ramstedt, 2017).

The purpose of the TAPAS model is primarily "quantitative impact assessment of, e.g., different types of transport-related policy and infrastructure measures" (Holmgren et al 2012). It simulates the behavior of the different actors involved in a transport chain on a micro-level, including decision-making and interactions, as well as physical activities such as production and transportation.

TAPAS is built using a two-tier architecture, with a physical simulator and a decision-making simulator, which are connected in a way that the production and transport activities that appear in the physical simulator are initiated by decisions taken in the decision-making simulator. The physical simulator includes links and nodes, and it models product types, transport infrastructure, vehicles, terminals, and production facilities.

The cost components that are included are production costs, reloading costs, inventory holding costs, as well as transport costs, which consist of:

- Time-based costs (e.g., driver, capital and administrative).

- Distance-based costs (e.g., fuel, vehicle wear, and kilometer tax).
- Link-based cost (e.g., road tolls).
- Fixed operator-based ordering costs (e.g., administration).

The types of agents that are included in TAPAS are customer, transport chain coordinator, transport buyer, transport planner, product buyer, and production planner, which are assumed cost-minimizers. In order to satisfy a customer's demand for products, the agents participate in an ordering process that involves selection of which transport and production resources and infrastructure to use, as well as planning of how to use resources and infrastructure.

Since the TAPAS model is centered on an individual transport chain and not a geographical region, it cannot be used for all the purposes of public planning in its current state. However, in a study from 2017, Holmgren & Ramstedt present a case study that has been used as an input by the authorities to evaluate effects of a changed Eurovignettte system in Sweden.

4.2.5 Norwegian approach

There is no official regional or urban freight model in Norway that is used in the planning process. Similar to the Swedish system, the idea is to generate fixed truck O/D matrices from the national freight model (*Nasjonal Godstransportmodell, NGM*) as an input to the passenger transport model. However, this is rarely done and more often, the previous truck matrices (i.e. existing from previous planning rounds) are used, with adjustments to correspond the current year or forecast.

Since the latest Norwegian commodity flow survey contains shipment data on a detailed level, geographically as well as regarding industry sector classification for senders, there are discussions about using this data for more detailed models on the regional, metropolitan or urban level. In doing that, there is a risk to expose sensitive business information when using disaggregates data, which has to be considered. (Hovi et al, 2017)

4.2.6 Danish model

In Denmark, there is a national transport model including both passenger and freight land transport (*Landtransportmodellen*) and a number of regional models for passenger transport. However, there are no regional or urban freight models in use at the present. Around 10 years ago, a regional freight model for the Öresund region, *GORM*, was developed and used in a number of analyses (see separate section above). However, it has not been updated since then. (Anker Nielsen et al, 2017).

4.2.7 IHOP

Another model currently under development is the IHOP model system that is included in this section because it has interesting implications also for freight modelling purposes, although the model itself is a passenger transport model.

The Swedish Transport Administration's model development plan states as one of eight expected results (The Swedish Transport Administration, 2017):

"A new generation of passenger transport model systems, with a dynamic model for urban areas implemented".

The IHOP project series aims at building Sweden's next generation strategic transportation model system. IHOP1 investigated the feasibility of deploying a dynamic and disaggregate network simulation package. IHOP2 developed a technical framework for integrating travel demand models and network assignment packages through the MATSim technology. IHOP3 moves on to ensure an economically consistent analysis of the travel behavior simulated in such a system.

The concrete challenge addressed by IHOP3 was as follows. Sweden's national travel demand model SAMPERS is static (i.e. it does not model time-of-day) and aggregate (i.e. it models representative person groups but no individual travelers). The person/network simulation system MATSim is, on the other hand, dynamic (full days are simulated second-by-second) and disaggregate (individual synthetic travelers interact in a simulated network environment).

Given these different resolutions of time and travel demand, different utility functions are used in SAMPERS and MATSim, which in turn leads to different models of travel experience, leading ultimately to different cost-benefit analysis results. The objective of IHOP3 was to devise a simulation method that allows for the economically consistent integration of SAMPERS and MATSim, resulting in the specification of a common, fully dynamic and person-centric, utility function in both SAMPERS and MATSim. The proposed solution, which is already partially implemented in SAMPERS/MATSim, is demonstrated in a small simulation setting, with the objective to indicate its scalability and readiness for implementation in a production version of the IHOP system.

4.3 STATE OF THE ART – INTERNATIONAL

Many model approaches within the various classes described in the Freight modelling - general section above have been suggested and developed by researchers around the world, often using a specific region or city as case studies. Further, a quite large number of states, especially in USA and Canada but also in Europe, have taken the approaches further and implemented freight forecast models and made the necessary data collection efforts. However, these implemented models are usually on the national (in Europe) or statewide (in North America) level, a scale that is more similar to that of SAMGODS than the regional or urban scale. A few exceptions have been found, and the most interesting approaches are described here. Only approaches going further than those made in Stockholm (NÄTRA and the new model) are described, since corresponding models are already represented in Sweden.

4.3.1 Calgary Commercial Vehicle Model and similar approaches

The City of Calgary has developed a commercial vehicle model, that includes all commercial vehicles and not only freight. The development is based on a major survey conducted in 2001, where more than 3.100 transport business establishments were interviewed about the travel patterns of their fleets. The information includes origin, destination, purpose, fleet, and commodity type of the truck tours. The resulting database describes more than 64.000 tours.

The model was developed in the following years (Donnelly et al 2013, Chow et al 2010).

Three types of commercial vehicle traffic are modeled using different approaches. External-internal trips were modeled using a gravity model. For vehicles that cover a certain area (such as newspaper delivery, garbage pickup, mail service, police cars), aggregate trip generation and gravity distribution models were used. Finally, tour-based movements, which accounts for two thirds of commercial vehicle movements in Calgary, were simulated microscopically.

The tour-based model includes simulation of tour purpose, vehicle type, next stop purpose, next stop location and stop duration. Decision-making for each vehicle is simulated while travelling, on what will be the next step (another stop or return home). These assignments are made using Monte Carlo techniques, with probabilities derived using a number of logit models estimated from the survey data.

The draft of Stefan et al (2005), who developed the model, states, "It is a novel application of an agent-based microsimulation framework that uses a tour-based approach and emphasizes important elements of urban commercial movement, including the role of service delivery, light commercial vehicles, and trip chaining."

Anand et al (2012) state that the model could be used to test wide variety of responses to network changes and possible scenarios related to traffic, policy and employment. Chow et al (2010) say that the model is capable of analyzing truck policies such as "increasing the cost per distance of operating vehicles (gas prices); increasing the travel time for all vehicles (congestion); changing truck route restrictions (accessibility); or cordon toll pricing for particular zones".

Similar approaches (truck tour-based microsimulation models) have been implemented in e.g. Chicago and in the states of Ohio and Oregon.

4.3.2 Combining System Dynamics with MATSim

Thaller et al (2016) develop a system dynamics model for urban freight transport that is linked to the MATSim simulation tool, thus enabling forecasts also on a disaggregated infrastructure level. The approach is currently being calibrated and validated, using Berlin as a case study. The model focuses on the courier- express- and package services (CEP) for households and businesses on the urban level.

The System Dynamics model includes submodules for population, household structure, freight demand, freight transport demand (including volume, performance and fuel consumption), fleet development, tour characteristics and transport lead time, transport costs and environmental effects. The system is used for the forecast of a number of parameters that define the MATSim world. Then the MATSim model is run for one day, using the parameters from the forecast, to simulate the traffic on the infrastructure level. Thereafter, certain results are fed back to the system dynamics model for further iterations.

MATSim (Multi-Agent Transport Simulation toolkit, www.matsim.org) is the same open-source platform that is currently being used for a dynamic passenger travel model for Stockholm; see separate section on IHOP above.

According to the documentation available on the MATSim webpage (Horni et al, 2017), MATSim includes:

- "Microscopic modeling of traffic: MATSim performs integral microscopic simulation of resulting traffic flows and the congestion they produce.
- Microscopic behavioral modeling of demand/agent-based modeling: MATSim uses a microscopic description of demand by tracing the daily schedule and the synthetic travelers' decisions. In retrospect, this can be called 'agent-based'.
- Computational physics: MATSim performs fast microscopic simulations with 10^7 or more 'particles'.
- Complex adaptive systems/co-evolutionary algorithms: MATSim optimizes the experienced utilities of the whole schedule through the co-evolutionary search for the resulting equilibrium or steady state."

The project by Thaller et al is using a previously developed freight extension to MATSim called JSprit (Thaller & Clausen, 2015).

4.4 AN ALTERNATIVE MODELING PERSPECTIVE

The traditional way to describe and model large complex systems such as biological systems, international currency trading, transportation and logistics, is to go from top to bottom, as shown below in Figure 7. This requires extensive knowledge of the system and all its components in the form of input about values, choices, etc.

Another way is to start from the bottom and from there aggregate results. Then it is sufficient to be able to create so-called agents, which can be organizations, people, machines, etc. that have a function, such as an intermodal crane in an intermodal terminal. Objective functions are then set up for the intermodal terminal, such as cost, service time, etc.

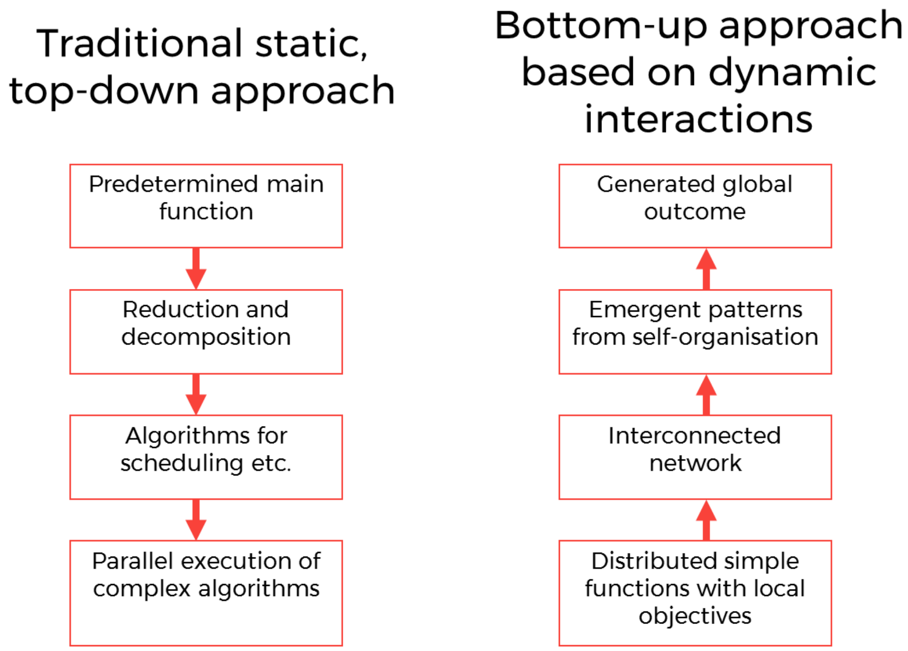

Figure 7: A comparison of conventional top-down oriented methodologies and agent-based bottom-up ones (Source: Reaidy et al, 2003)

Reaidy et al (2003) provide a comparison of conventional top-down oriented methodologies and agent-based bottom-up ones. The top-down methodologies are based on the presumption that knowledge is outside the "system" and someone can measure and analyze the observable phenomenon of interest and from that decompose correctly to different subunits where the sub-problems are solved separately. Then, as Kreipl and Pinedo (2004 p.83) state, *"at the end, the partial solutions are put together in a single overall solution."* Models that are constructed by global performance measures (also called observables (Parunak et al 1998)), cannot cope with the dynamics of their constituent parts since the observables are constructed of aggregated behaviors of the whole system (Swaminathan et al 1998). This top-down assumption is inherited from the positivistic paradigm built on mechanistic assumptions and reductionism. In this regard, Kauffman (1995 p.VII) states that *"the past three centuries of science have been predominantly reductionist, attempting to break complex systems into simple parts, and those parts, in turn, into simpler parts."*

Bottom-up methodologies are based instead of a synthesizing philosophy, where the user presumes that he/she cannot understand the whole phenomenon of interest but can observe different activities and processes, and try to understand their behavior and their objectives. These agents (the processes or activities) interact and communicate with other agents and they join to form a coherent whole (Luck & d'Inverno, 2001). Global patterns emerge from these interacting and interrelated networks of agents i.e. a generated global outcome from more or less self-organizing agents.

It might seem to the reader that agents and objects are similar in nature, which they are; however, there are differences in both their construction and execution. Jennings, Sycara and Wooldridge (1998) provide a number of differences between the concepts. The first relates to the degree of autonomy, where an agent embodies a stronger notion of autonomy (Wooldridge 2002). Jennings, Sycara and Wooldridge (1998) define it as "*objects do it for free; agents do it for money."* Another distinction between object and agent systems is with respect to the notion of flexible (reactive, pro-active, social) autonomous behavior. In general, objects are passive i.e. they need to receive a message or similar in order to become active; agents have their internal mechanism for that (Jennings & Bussmann 2003). A third distinction lies on the model level, where the agents in agent based models are each considered to have their own thread of control whereas in the standard object model, there is a single thread of control in the system (Jennings, Sycara, & Wooldridge 1998).

4.4.1 Implemented models in other fields

Electricity Market Complex Adaptive System (EMCAS) (Macal et al, 2004)

While planning and operation of traditional electric utility systems used to be strongly driven by least-cost and reliability concerns, recent trends toward restructuring and unbundling are creating opportunities for new participants with new business models to enter the markets and are creating diverse and dynamic markets. Centralized, monopolistic decision-making organizations are giving way to heterogeneous, decentralized decision structures. The "single" decision-maker is replaced by a host of decision entities each with their own, unique business strategies, risk preferences, and decision models.

The implicit assumption of a centralized decision-making process built into many of the global optimization and equilibrium-based power systems analysis tools developed over the last two decades limits their ability to analyze the forces prevalent in today's emerging markets in an adequate way. This is amplified by recent experiences that have shown the difficulties of understanding the operation of these markets.

The Center for Energy, Environmental, and Economic Systems Analysis (CEEESA) has been developing EMCAS, the Electricity Market Complex Adaptive System model, in which the diverse participants in the electricity market are represented as "agents." All agents have their own set of objectives, decision-making rules, and behavioral patterns. Further, agents can draw on an array of historical information (e.g., past power prices) and projected data (e.g., next-day load) to support their unique decision process.

The Virtual Market Learning Lab (North et al. 2010)

It is a large-scale, Repast Simphony[9] model of consumer markets and is co-developed by Argonne National Laboratory and Procter & Gamble (P&G). It represents the shopping behavior of consumer households and the business behavior of retailers and manufacturers in a simulated national consumer market. Argonne and P&G successfully calibrated, verified, and validated the resulting agent-based model using several independent, real-world data sets for multiple consumer product categories with more than 60 comparison tests per data set. The model has been successfully applied by Procter & Gamble to several challenging business problems

The Hydrogen Economy Model (Mahalik et al. 2007)

This is an agent-based model running that describes how a personal transportation system might transition from petroleum to hydrogen. It is a Repast Simphony representation of the Los Angeles, California, metropolitan area, with 5,000 square miles of detailed and geographic information system (GIS)-sourced interstate highways and omnipresent local roads. The model has driver and investor agents. Driver agents use their cars to move between their demographically assigned home neighborhoods and their jobs. Drivers have a variety of characteristics including income levels, environmental concerns, risk aversion, and car type preferences (e.g., wanting conventional fuel cars versus hydrogen cars). Investor agents build, own, and operate hydrogen fuel stations based on the investor's estimates of the potential for profits at each available geo-located site.

[9] The Repast Suite is a family of advanced, free, and open source agent-based modeling and simulation platforms that have collectively been under continuous development for over 15 years. It is supported by University of Michigan, Procter & Gamble and the Department of Defense and is developed and maintained at the Argonne National Laboratories, USA

5 DISCUSSION

In this chapter, the findings of the previous chapters are analyzed and a number of conclusions for a feasible way forward in the Swedish context are formulated. First, we describe the model gap, i.e. what desirable analyses that cannot be made using available models. Then, the need for a long-term strategy regarding model development is discussed, and what such a strategy should include. Four crucial aspects that define the current needs and opportunities are described more in detail:

- Data supply – available data and novel conditions
- A widened view of scenarios at the planning horizon
- Communication of model employment and inclusion of stakeholders
- Modern model development techniques

A structure for model development decisions at different levels is presented. Finally, conclusions are summarized and recommendations given.

5.1 THE MODEL GAP

As described in earlier chapters, there are a number of models already present in the Swedish planning system. Those models can be used to perform certain types of analyses, but do not fill all analysis needs stated by the agencies[10]. However, since the analysis needs of the agencies have not been precisely defined, they cannot be thoroughly described here. Instead, they have been broadly divided as in Figure 8:

1. Quantification of current state of the system – to answer questions of traffic levels etc. as they are right now, or were in the past, and to visualize this in different ways
2. Forecast, business as usual – to answer the same questions as in 1, but for a future year, given that the system continues to evolve as it has done historically, but with respect to a number of agreed changes to exogenous factors
3. Scenario analyses – here meaning evaluation of entities in different future scenarios with respect to related systems such as population, economic development, land use, mobility and consumption patterns, travel behavior, etc.
4. Impact assessment, network changes – estimation of the effects of infrastructure investments
5. Impact assessment, policy/regulations/taxes - estimation of the effects of other measures such as regulations, taxes and charges and other policy changes or initiatives

The other dimension in Figure 8 is the entities that are being modeled. Different entities are of interest depending on the desired analysis and stakeholder. For example, the new Stockholm model quantifies the generation of commercial vehicle trips to different kinds of establishments, but not the amount of goods transported or the flows in the network. The Samgods models and its PWC matrices estimate the production and consumption of goods per municipality and the origins and destinations of these flows. However, the flows are on the municipality level, which is too

[10] By ”agencies” we mean all types of administrations (national, regional, local) with an interest to perform freight transport forecasts

aggregated for an urban or regional analysis. Further, the model is calibrated with respect to ton-kilometers and not vehicle-kilometers, which makes the quality of the traffic estimations to/from the region uncertain.

As can be seen in Figure 8, available models cover most of the analysis needs for quantifying the current situation. In many cases, already a visualization of this is valuable for different stakeholders. A framework for merging the results from these models and visualizing them would provide useful information for decision-makers.

Further, some of the models are also feasible to generate results for a forecast year; given that it is a business as usual scenario as described above. This applies to the outputs from the Samgods model, the new Stockholm model and the Lorry O/D matrix model[11]. However, for alternative scenario analyses and impact assessments (on the regional or urban level), the agencies currently only have the options to evaluate the effects from commercial transport using the passenger transport models. Here, the commercial transport demand is fixed, an only the network assignment step will be affected between different scenarios.

Depending on how the analysis needs of the agencies are formulated more precisely, the model gap is given by the blank areas in Figure 8. Please note that Figure 8 does not include quality in its dimensions, but only if the entities and types of analyses are within the scope of the models. The existing models should be further developed (or replaced) in case their quality is regarded too low[12]. New models, or extensions of existing models, should be placed in a common framework with the mentioned models (as well as any other relevant models, see chapter 5.3 below).

[11] but not the NÄTRA model

[12] "Quality" could be defined as the fulfillment of the parameters in Figure 4.

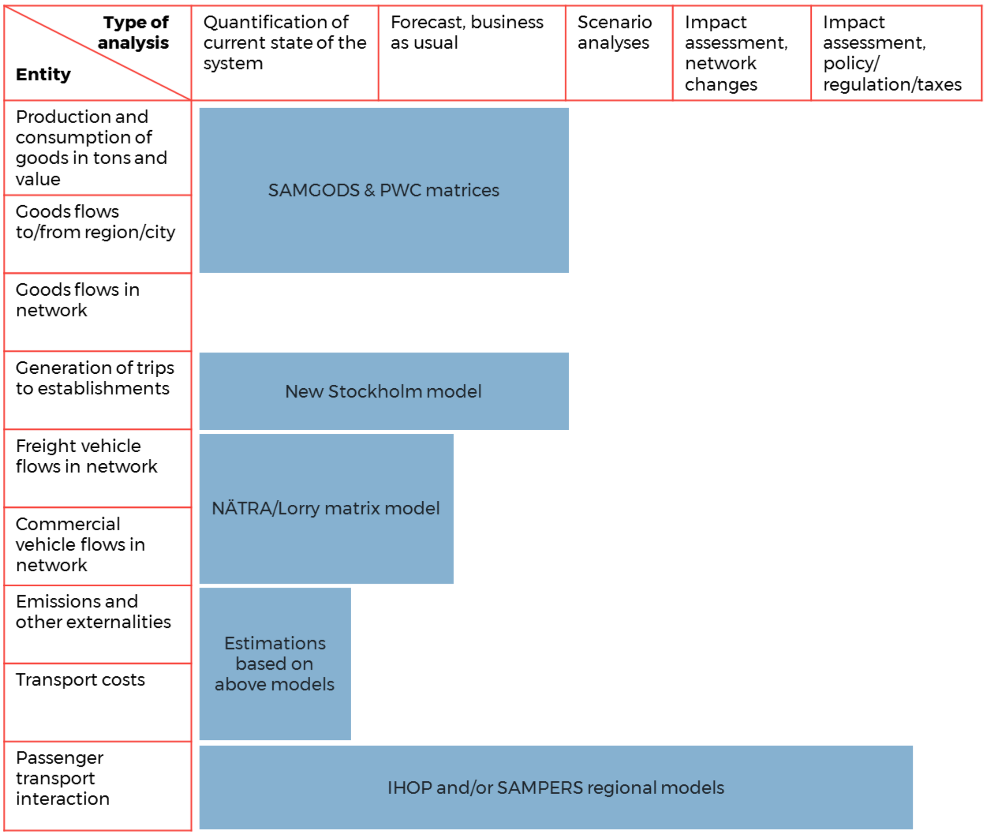

Figure 8: Illustration of what is feasible to model with existing models, with regard to modeled entities and types of analyses. "Network" is here equivalent to the infrastructure at the detail level of interest

5.2 THE NEED FOR A LONG-TERM STRATEGY

The kinds of models discussed in this study do not exist for their own sake, but to fill a purpose in the in the agencies' planning of the transport system and to provide knowledge to be used in decision-making. Therefore, before making, often costly, model development efforts it is important for the responsible agency to have a long-term strategy for all decision-making and actions related to the model. Such a strategy should define and describe

- The analysis needs that the model should respond to, i.e. the model's raison d'être, and how this relates to other parts of the agency's operations and goals
- The resources allocated for model development, data collection, model management and evaluation, in terms of staff and financial budget
- Which stakeholders that contribute to and/or use the model, how they will participate in the different phases in the model's lifespan and how communication with them will be upheld
- An action plan regarding development (including the sub-steps of design, implementation, calibration, validation, documentation), evaluation and updates of the model
- Criteria for minimum quality of the model in order to be used for decision-making, e.g. for all parameters in Figure 4.

Since the reality is not static, but conditions change unexpectedly, this strategy should be reviewed and revised regularly, for example every year. Further, the strategy should be approved by the necessary stakeholders. All future decisions regarding the model, in different stages, could then be related to the strategy and contribute to a continuous improvement of the decision-making basis.

It is not rare that this kind of framework is lacking connected to model development. As a useful example, the National Academy of Sciences (2007) provide recommendations for the U.S. Environmental Protection Agency on model evaluation, principles for model development, selection and application and model management, for models used in environmental regulatory decision making.

When constructing this strategy, we suggest that the following general aspects are regarded, as they are characteristic of the current environment for models for public planning.

5.2.1 Data supply – available data and novel conditions

Another possibility or opportunity that exists today, that did not exist when the models currently in use were built, is a wide variety of data sources that are available and can be combined in what is popularly named Big Data Analysis.

There are projects currently ongoing that are using tracking data from vehicles (trains, trucks, ships and airplanes) in order to collect data for modelling purposes. There are also projects using passive data from cell phones in order to get travel patterns, and or use active data through collaborative efforts, such as Waze to name one such application.

All these methods of data collection are possible to use and integrate in platforms combining them with for example geospatial data. One challenge though is how to address the issue of integrity especially for personal data.

Along with these new opportunities, the traditional data sources remain, such as different kinds of registers (of vehicles and commercial establishments, employment, etc.), all estimations that have been made for the SAMGODS model, the CFS and other surveys, e.g. those conducted for the NÄTRA model and possibly other similar models for cities around the world, if available. Those should be assessed with regard to their usefulness for new models.

5.2.2 A widened view of scenarios at the planning horizon

Society, technology and climate are changing at an accelerating pace and in an increasingly global and interconnected world, we can expect sudden regime shifts and rapid changes in behavior. Still, the time perspective in the agencies' planning for e.g. infrastructure spans over 15-25 years (forecasts) and investment calculations are made using a calculation period of 40 years.

Currently available forecast models allow the user to define future scenarios through a set of parameters, while the dynamics of the system that the model represents are pre-defined. This corresponds to a linear development of the system over time.

However, given the uncertainty of future trajectories, models that can represent a wider range of future scenarios and changed behavior are useful, or even necessary.

Even if existing models could reproduce the behavior of the future system in an adequate way, it brings high expectations on the model user to set the parameters in a way that reflects different credible future scenarios.

Rather, it is useful to employ models that simulate the system's trajectory from today until the future year of interest, so that the user can see the evolvement of different indicators and how the dynamics work under different conditions. There are classes of models (such as the System Dynamics models described earlier) that allow for these types of analyses and thus will help the user to define future scenarios that are more or less likely to happen. Such analyses could give useful insights in e.g. thresholds and changes of equilibrium in complex systems such as the transportation system or the infrastructure of a city.

5.2.3 Modern model development techniques

Finally, the way we are able to build models currently is quite different from what was the case in the late 90's and early 00's when the models used today were built.

There are developments also in computer capacity, where clusters of computers online can be used instead of having to invest in expensive supercomputers.

Coupled to this, most modern models are either built in a cloud-based environment and "old" models are migrated into this more flexible environment. This is popularly called Software as a service (SAAS) and has changed the business model for example in the Warehouse software market as wells as for traditional Route optimizing software.

Another example of development in this field is that most modern software architectures allow for module-based approaches with modular model systems where the sub-models can be replaced and revised as superior techniques and data sources emerge.

All this makes it possible to build more agile module models that are not locked into hardware or software solutions that over time will be rendered obsolete. Over time, this will reduce the costs for building models and make it easier to keep them up to date.

5.2.4 Communication of model employment and inclusion of stakeholders

Models are, by definition, simplified images of real life phenomena. When constructing models of complex systems, the simplifications sometimes make it hard for many stakeholders to recognize or approve of their own reality the way it is represented in the model. As a simple example, aggregate freight models often require average values as input parameters, such as costs for the transport or transshipments different types of goods, or the weight of a container. However, most shipments taking place in the real world are characterized by values that are far from the average and therefore stakeholders cannot recognize themselves in the model representation.

However, increased computational capacity and new model approaches enable the employment of models with a lower degree of simplification. Except from the obvious advantage of giving more accurate results, such models could increase the credibility and acceptance of the model among different stakeholders. If the model is more similar to reality, it facilitates the communication and use of the model results and enable decision-makers to feel more secure when referring to the model results. Other means to the same goal is to enable more visualization of model dynamics and results.

5.3 MODEL DEVELOPMENT FRAMEWORK

Many decisions need to be taken when deciding to develop a new model. It is not always straightforward to distinguish different concepts, approaches and techniques. In this section, we provide a structure that is intended to facilitate the discussions about model development decisions for different levels. Three levels have been defined and described here. However, decisions need not to be taken in the described order; the process will presumably be iterative. The process is tightly linked to the strategy described in the previous chapter. The three levels are illustrated in Figure 9. Strategies and ambition levels for data supply will affect decisions on all three levels.

Decisions on all levels need to take the parameters in Figure 4 into consideration, although not all parameters are necessarily relevant for all levels.

5.3.1 Model landscape

On the highest level, the new model must be places in the model landscape. This includes defining the scope of the model as well as how to connect it to other models.

5.3.2 Model architecture

On the next level, the model architecture is decided. This includes what entities that are modeled and how they are assumed to relate to each other. Here, the structure of the model is sketched, for example if it will be built up by independent modules. Most descriptions in the literature focus on this level, as it describes the functionality of the model. Model developers also tend to focus on the next level.

5.3.3 Model techniques

On the most detailed level, different model techniques are compared and evaluated. By model techniques, we mean the methods used to solve the mathematical problems posed by the chosen model architecture.

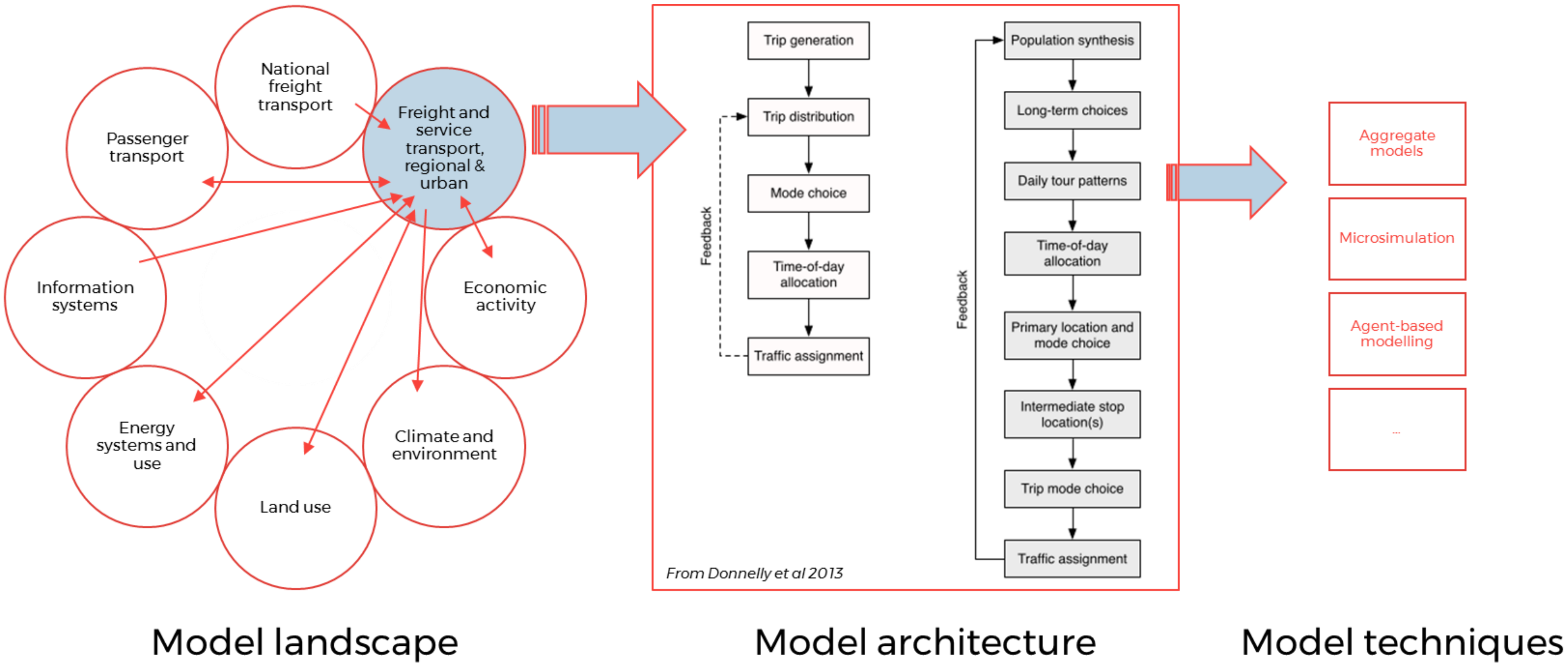

Figure 9: Illustration of different levels to consider in model development. The flow chart serving as an example of model architecture is from Donnelly et al (2013)

5.4 CONCLUSIONS

In this study, we have described the state of the art in regional and urban freight and commercial vehicle modeling. Some successful and some promising approaches have been identified, but most approaches in the literature have not evolved past the research context into actual implementation. Further, most implemented models are on the national or statewide level, which is too aggregated with respect to the scope of this study.

The found examples of implemented models are often only partially covering the analysis needs and similar models are already present in Sweden. Although such models are useful, a model gap remains. There are also examples of more complete models, but they are a result of dedicated efforts for data collection and model development during 10-20 years, which requires quite large resources and a long-term plan.

We have described the basics of a range of model approaches traditionally used for freight transport, as well as novel perspectives of modelling complex systems. Much progress has been made in the latter discipline during the last two decades and such approaches start to gain ground also in transport modeling (with the agent-based module of the Calgary model as an example), since they include perspectives and elements that are feasible for modeling the transport system. However, they have previously been applied primarily in other fields.

There are quite a lot of efforts ongoing both in Sweden, the Nordic countries as well as internationally, but unfortunately most of these efforts are made in isolation and often with a scarcity of resources. This makes the progress slow, stepwise and sensitive to the ideas and needs of single stakeholders.

The choice of model approach in the Swedish context will depend on the strategic plan and ambition of the agencies. In order to support those decisions, we have provided a framework and recommendations of necessary considerations in such a process. The first step of the process in to formulate a strategic plan, in which the analysis needs as well as necessary stakeholders to involve and available resources to meet these needs are defined and formulated. In that strategy, it is important to consider the rapidly developing conditions in terms of data supply, computational resources and techniques and an increasingly interconnected and complex surrounding world.

5.5 WORKSHOP FINDINGS

In this section, a summary is given of a workshop/seminar held on June 21, 2017 at the Swedish Transport Administration in Solna, Sweden.

The workshop had two purposes; an external assessment of the findings of the study and to discuss possibilities and challenges for future development.

The workshop opened with a presentation of the findings of this report and thereafter, short presentations from five invited speakers were given:

- Dan Andersson, Chalmers, Göteborg, Sweden
- Gunnar Flötteröd, KTH, Stockholm, Sweden
- Martin Nilsson Jacobi, Chalmers, Göteborg, Sweden
- Gunnar Johansson, IBM, Norway
- Fredrik Nilsson, Lund University, Sweden (not present, presentation sent beforehand)

The discussion was primarily focused on; the challenges connected to data sources and data quality, modelling issues and the usefulness of the models depending on different stakeholders' needs, such as the Swedish Transport Administration.

Dan Andersson pointed out the need to involve the end customers, which are paramount in the decision making for freight transport. A discussion followed that focused on the challenges of involving many different stakeholders with different needs. A most valid comment was that even within stakeholders such as a larger city, there are several stakeholders that have different missions, such as the Urban planning office, the Environmental office and the Transport administration to name a few. A comment to this is that we also have the different phases from design and planning to operations (real time) needs on models, which is important to have in mind when discussing the needs and possible results of a model for freight transportation (or any model).

This led to a discussion about the heterogeneity of needs and demands for what the models are supposed to deliver in terms of results. In combination with several different layers of infrastructure and transport modes as well as the combination of passenger- and freight transport, it was concluded that a model that encompasses all this complexity is probably not feasible. Instead, it was argued that several models have to be built and a special focus should be on the interface between the models, as well as how the results can be combined and interpreted. Finally, the inherent heterogeneity of freight, high valued, time sensitive, large volumes etc. was pointed out that makes freight transportation and hence modelling of it quite different from passenger transport modelling.

Gunnar Flötteröd pointed out that the development most certainly is a combination of top-down and bottom-up approaches and that a bottom-up approach is not a "silver bullet" when it comes to modelling. He also pointed out that there are limits for what we can do, even if we had unlimited access to perfect data, massive computer power and a clear view of what we wanted to achieve. He suggested that the limitations of modelling skills would hinder the predictive power before the limitations of data availability. Throughout the seminar, several speakers suggested that there might be large potential in exploiting already existing data with new techniques.

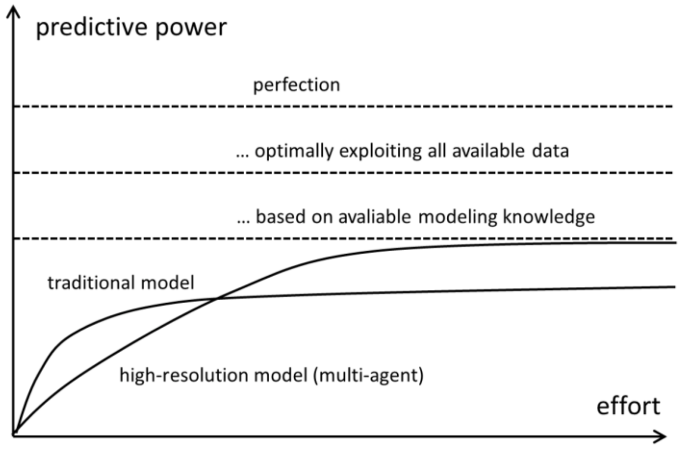

Figure 10 Conceptual limits of modelling (Flötteröd, G, 2017)

The figure shows the limits based on how good we are (knowledgeable) in modelling, the availability of data in relation to different modelling approaches as well as predictive power and effort necessary. It was pointed out that the limits are pushed upwards due to development, but we will never reach the boundaries. The figure also points out the relations between the powers of the model and how long time it takes to achieve the desired results. This is closely related to the time horizon discussion and the boundary between Research and Development.

Gunnar Johansson pointed out the challenge of fragmented ownership of the models, even if the Swedish Transport Administration always played a major part in Sweden. Among other things the GORM and NÄTRA models where brought up as examples of models where large resources were put in, but where the models have been used or developed only for a few years. The reason for this was suggested to be lack of resources for administration and maintenance of developed models. This led to a discussion about the need for a stable environment for the development of methods and models over time, related to the need for a long-term strategy and implementation plan. However, there was no immediate conclusion about how to proceed or which organization that could or should take on that responsibility. It was though concluded that this is a necessity to enable development and use methods and models over time. The Swedish Transport Administration and Transport Analysis pointed out that for passenger transport and CBA models (SAMPERS, SAMKALK etc.) they have had and taken the responsibility for many years. It was concluded that each stakeholder must identify their own needs and take responsibility for meeting them, and cooperate on the common areas.

Martin Nilsson Jacobi pointed out that the challenges pointed out in this study as well as in the workshop are not unique for transport. Rather these challenges are universal for all models related to complex systems. There are although somewhat different approaches to what the models are used for, e.g. regarding the detail level of predictions and the inclusion of individuals' choices. Further, he discussed the opportunities to employ developed statistical methods to overcome part of the challenges of sparse data sets and suggested that we can reach further using existing data. This was followed by a renewed discussion about the goal of models in the transport sector as well as what the value of more complex models is. The effort might not be related to the benefit, simpler models are sometimes sufficient. Often, simpler models on the system level can complement and validate detailed models. It was also pointed out that a model will never be finished, which relates to the above discussion about a stable environment that allows models to be developed and maintained over time. An important aspect is that it should be possible to update methods and models continuously in order to capitalize on improvements in for example computer capacity, data availability and modelling knowledge to mention a few and that the only way to achieve this is to build models in a stepwise fashion.

The workshop was concluded by the authors of this report with the following statement:

1. It is necessary to create a stable environment for the development and maintenance of methods and models for transport in general and for freight modelling in cities and regions specifically
2. A model framework needs to be established where both the Swedish Transport Administration and other stakeholders as the large cities can cooperate and invite others to co-develop models
3. Enough resources have to be allocated in order to not only develop, but also to maintain and update the models over time
4. Around 85 % of the Swedish population lives in urban areas due to the last centuries' urbanization which makes the cities and dense regions the most urgent need for modelling
5. The possibilities to make use of existing data in new ways should be exhausted, in parallel with exploration of the opportunities of existing big data sets from the internet of things, social media etc. together with novel data processing techniques
6. We are midst a paradigmatic change not only how we live our lives, but also data availability, computer capacity and modelling knowledge, which makes it paramount to initiate new approaches

5.6 RECOMMENDATIONS

Based on the findings of this report we suggest that the Swedish Transport Administration initiates a multi-disciplinary R&D program that focuses on the dimensions laid forward in this chapter. This R&D program should focus on:

7. Bring together the efforts already underway at the different governmental agencies, universities and consultant companies
8. The combination of available models for freight transportation that exist in Sweden, in order to maximize the utilization of efforts already made
9. The exploration of existing data from new and old sources, using novel techniques
10. A long-term flexible strategy, which includes;
    - clearly stated goals, needs and necessary resources - at the Swedish Transport Administration
    - a forum of other stakeholders
    - model framework where emphasis is put on defining the model landscape, architecture and available techniques in order to generate a road-map for model development, which should be regularly revised and include efforts to continuously evaluate the development
    - data supply, modern model development techniques, scenario generation and stakeholder involvement

It would also be beneficial to invite other stakeholders such as the larger cities in Sweden as well as our neighboring countries.

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