FORECAST MODELS AND HIERARCHICAL COMBINED DISCRETE-RATE/DISCRETE-EVENT SIMULATION MODELS FOR PARCEL SERVICE NETWORKS

Sebastian Lang[(a)], Tobias Reggelin[(b)], Horst Manner-Romberg[(c)]

[(a),(b)]Otto-von-Guericke-University, Magdeburg
[(c)]MRU GmbH

[(a)]sebastian.lang@ovgu.de, [(b)]tobias.reggelin@ovgu.de, [(c)]info@m-r-u.de

ABSTRACT
Parcel service providers act in a fast changing market. The annual number of dispatch orders increased continuously in the past years, because of the tremendous popularity of e-commerce. At the same time, customers are expecting shorter delivery periods and lower prices for shipment services caused by the entrance of new competitors, the intersection of potential customers of courier, express and parcel delivery service providers and the increasing service quality advertised by e-commerce market leaders. In the consequence, parcel service providers need efficient tools to keep in pace with this development. This paper presents two simulation models, which enable the user to forecast future dispatch quantities and to evaluate the performance of their delivery network in consideration of different levels of detail.

Keywords: parcel service providers, forecasting, delivery networks, regression analysis, continuous simulation, discrete simulation, hierarchical simulation

1. INTRODUCTION

Driven by the increasing popularity of e-commerce, the German courier, express, and parcel (CEP) industry grows rapidly. From the year 2000 until 2015, the number of dispatch orders increased by 74 %. In the same period of time, the revenue of the CEP industry grew by 73 %. Parcel service companies benefit the most from this development. With a revenue of EUR 9.4 billion in 2015 and a share of 54 % in the revenue of the German CEP industry, the parcel service providers are the most significant participants of the CEP market. (BIEK 2016)
A decline of this development is not expected in the near future. The current trend even indicates an increasing growth of the demand for parcel shipments, due to the further expected strong growth of e-commerce. Figure 1 shows the impact of e-commerce on the annual number of parcel shipments in Germany. As illustrated, business-to-customer (B2C) shipments generate more than a half of the revenue of parcel dispatches and are mainly represented by e-commerce sales. Compared to the year 2014, the number of B2C shipments in 2015 increased by 10.1 %. (BIEK 2016, Bevh 2016)
Overall, approximately 170 million additional parcels were shipped in 2015 (BIEK 2016).

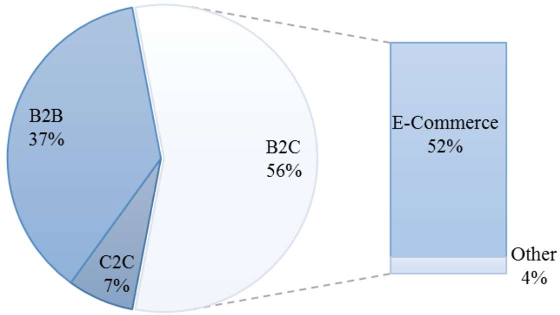

Figure 1: Distribution of the revenue by parcel dispatches according to the type of dispatch order

Parcel service companies are facing the challenge to maintain a high service level and to guarantee the lead time customers are used to, despite of rising shipment volumes and increasing utilization of their production systems. To cope with this challenge, the delivery service providers are forced to invest continuously in their supply network. Hereby, determining the correct amount and subject of investment is a difficult task. In terms of the amount of investment, parcel service companies should, on the one hand, pursue the goal to minimize their investments in order to avoid the waste of capital and the risk of opportunity costs. On the other hand, the parcel service companies are also facing the risk of under-investment which could result in an overload of their systems, in a decreasing delivery performance and in short-term investments which are commonly more cost-intensive than early planned investments. To avoid those risks, one solution approach is to forecast the future demand of parcel shipments to estimate the right point of time and the right amount of investment.
The necessary investment sum depends not only on the future system load, but also on the current capacities of the delivery network. A detailed knowledge about the capabilities of the resources inside a logistics network is essential to identify future bottlenecks and therefore potential subjects of investment. Compared to analytical or static models, discrete simulation models obtain great benefits for analyzing parcel service networks, because

they are able to consider the high complexity and dynamic behavior of such systems by implementing them on any required level of detail.

This paper presents an example for a holistic solution concept to support parcel service providers in preparing their logistics networks for future requirements. The approach integrates a continuous regression model to forecast dispatch quantities and a hierarchical discrete simulation model to evaluate the performance of an exemplary parcel delivery network.

2. RELATED WORK

The following research has been done on modeling and simulation related to the CEP industry.

BIEK (2016) publishes a forecast of dispatch orders in Germany until the year 2020. In contrast to the mathematical approach of the forecast model presented in this paper, the authors based their estimations mainly on surveys and expectations of industry insiders.

Clausen et al (2015) describe a discrete event simulation model of a transshipment terminal, which is linked to a mathematical optimization. The optimization algorithm improve the parcel transshipment operations by searching the best allocation of resources.

Fedorko, Weiszer and Borzecky (2012) present a simulation model of the process of package sorting at a courier service.

Larsen (2003) creates a discrete-event simulation model for the postal industry to analyze the performance of postal networks. He presents an extensive tool to evaluate a postal logistic chain. The modeling of the postal processes with the discrete-event paradigm is not clearly described.

White et al. (2001) present an object-oriented paradigm for simulating postal distribution centers. They describe how discrete-event simulation is an established tool for the design and management of large-scale mail sortation and distribution systems.

Cornett and Miller (1996) describe a model of the aircraft operations at the United Parcel Service Louisville Air Park, which allows the user to evaluate the processes in dependence on flexible input data.

Dowlaty and Loo (1996) applies Monte-Carlo simulation to calculate the number of bags needed to operate a large package delivery.

Swip and Lee (1991) present the application of an integrated modeling tool on the reload process of a United Parcel Service.

Tuan and Nee (1969) present a simulation tool, which evaluates the relative merits of alternative nonpriority mail processing, handling, and transportation plans.

Most of the papers only describe isolated simulation models that focus on a single transfer point of a parcel or postal network.

3. FORECAST MODEL FOR DISPATCH QUANTITIES

The forecast model presented in this paper estimates the future demand of parcel shipments based on linear and nonlinear regression. To do so, the model is connected to a linear regression algorithm and to a Gauß-Newton algorithm for nonlinear regression. The algorithms generate and update the formulas in the model, in dependence on the given input data. Additionally, the model offers the possibility to analyze different development scenarios and to perform sensitivity analyzes. The forecast model was created in three steps:

1. Investigation of potential influencing variables for the annual dispatch quantity
2. Performing of multiple regression analyzes to quantify the influence of each variable
3. Implementation of the continuous simulation model

The following sections contain detailed descriptions to every work package.

3.1. Identification of Influential Variables for the Dispatch Quantity

In the first step, the authors identified economic figures, for which they suspect a potentially influence on the development of the annual demand for parcel shipments. The investigated datasets are also evaluated according to their:

- Reliability – the used datasets should originate from a objective source
- Quantity – the greater the amount of data in each set is, the meaningful results can be achieved
- Resolution – the regression analyzes can only be applied for datasets, which are completely associable with each other

In consequence of the research, the author team selected the history datasets of the economical figures illustrated in figure 2 for a further regression analysis. The chosen datasets fulfill all requirements, set up at the beginning of this section.

In terms of the postulated influence on the dispatch quantity, it is reasonable to assume a relation between the population development and the annual number of shipped parcels, expecting that every inhabitant could be

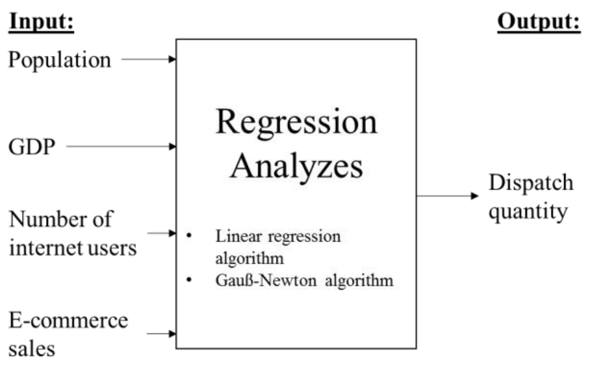

Figure 2: Economical figures with an assumed influence on the dispatch quantity

a potential customer for a delivery service provider. It is also obvious to consider an impact of the GDP on the dispatch quantity, because the GDP is a good indicator for the purchasing power of an economy. For both, the number of internet users and the e-commerce sales, an influence on the dispatch quantity is undeniable, knowing that e-commerce is the main driver of the fast growing parcel market.

To ensure the reliability of each dataset, the authors only consulted data from trustworthy sources. The history data about the German population and GDP come from Destatis (2017), further known as the federal statistical office of Germany. The forecast of the population development until the year 2060 originates from Destatis (2015). The author team referred to a study of PwC (2017) to receive forecast data about the GDP. The number of internet users in the years of 2001 until 2015 were calculated based on the surveys of Destatis (2017) and Initiative D21 (2016). Since no appropriate estimation for the development of the number of internet users in Germany could be found, it was necessary to generate the needed forecast data with a regression analysis, which is further described in the next section. The historical data of e-commerce sales were provides by MRU (2015) – a management consultancy firm with a strong focus on the CEP industry. The corresponding forecast data are based on trend scenarios of GfK (2015) and IFH (2014).

The data quantities of the sets are very disparate. While the population data extend back to the year of 1950, historical data about the GDP are only available until 1970. For the number of internet users and the e-commerce sales, the amount of data points is even smaller, because the internet is a comparatively new technology. Past data of the number of internet users in Germany exists only until 1997 and data about e-commerce sales could be only detected for the years since 2006. Meeting the requirement of an equal resolution and size of all datasets, the authors decided to consider only data since 2006 to determine the influence of the chosen economical figures on the dispatch quantity.

3.2. Quantification of the Influences using Regression Analyzes

Before a functional correlation could be evaluated between the selected input datasets and the dispatch quantity, it was essential to visual assess the datasets, which kind of correlations are worthwhile to check. This was done by comparing each dataset with the dispatch quantity one by one in a scatterplot. As an example, figure 3 shows the scatterplot of the comparison between the past dispatch quantity data and the corresponding past GDP data.

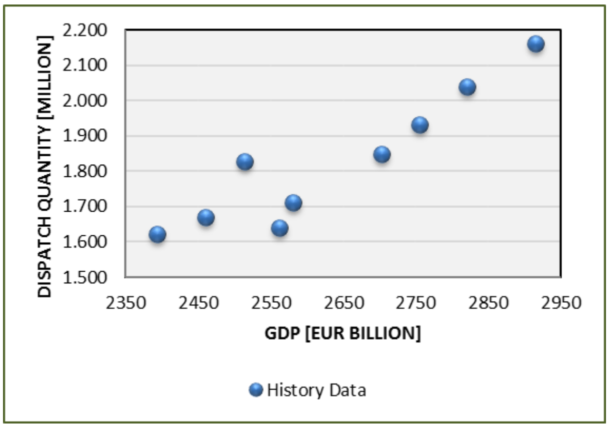

Figure 3: Pre-analysis for functional correlation between dispatch quantity and GDP history data

Based on the optical evaluation, several parameterized objective function were modeled to describe the influence of each dataset on the dispatch quantity. Remaining with the example illustrated in figure 3, the modelers assumed a linear or quadratic correlation between the annual dispatch quantity and the GDP.

To verify the assumptions, two regression algorithm were developed in C#. The linear regression algorithm fits a polynomial function for datasets, for which a linear, quadratic or cubical correlation is assumed. To do so, the algorithm tries to find the (polynomial) function, which obtains the minimal sum of squared distances to the data points. Detailed descriptions of this method are, for instance, given in Bingham and Fry (2010), Weisberg (2005) and Yan and Gang Su (2009). Besides the sum of the square distances, the algorithm also considers the mean forecast error to indicate data-overfitting. The mean forecast error is defined as the sum of distances between each history data point and the corresponding value from the regression (Andres and Spiwoks 2000). For the compared dispatch quantity and GDP data in figure 3, the linear regression algorithm approximate a polynomial function of the 2nd degree, which can be interpreted as a combined linear and quadratic correlation between both sets.

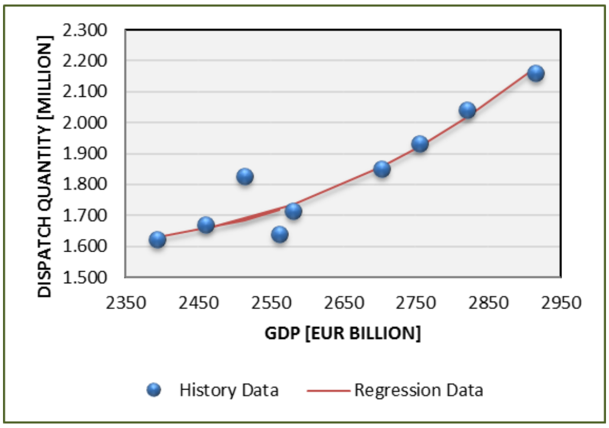

Figure 4: Fitted function of the linear regression algorithm for dispatch quantity and GDP data

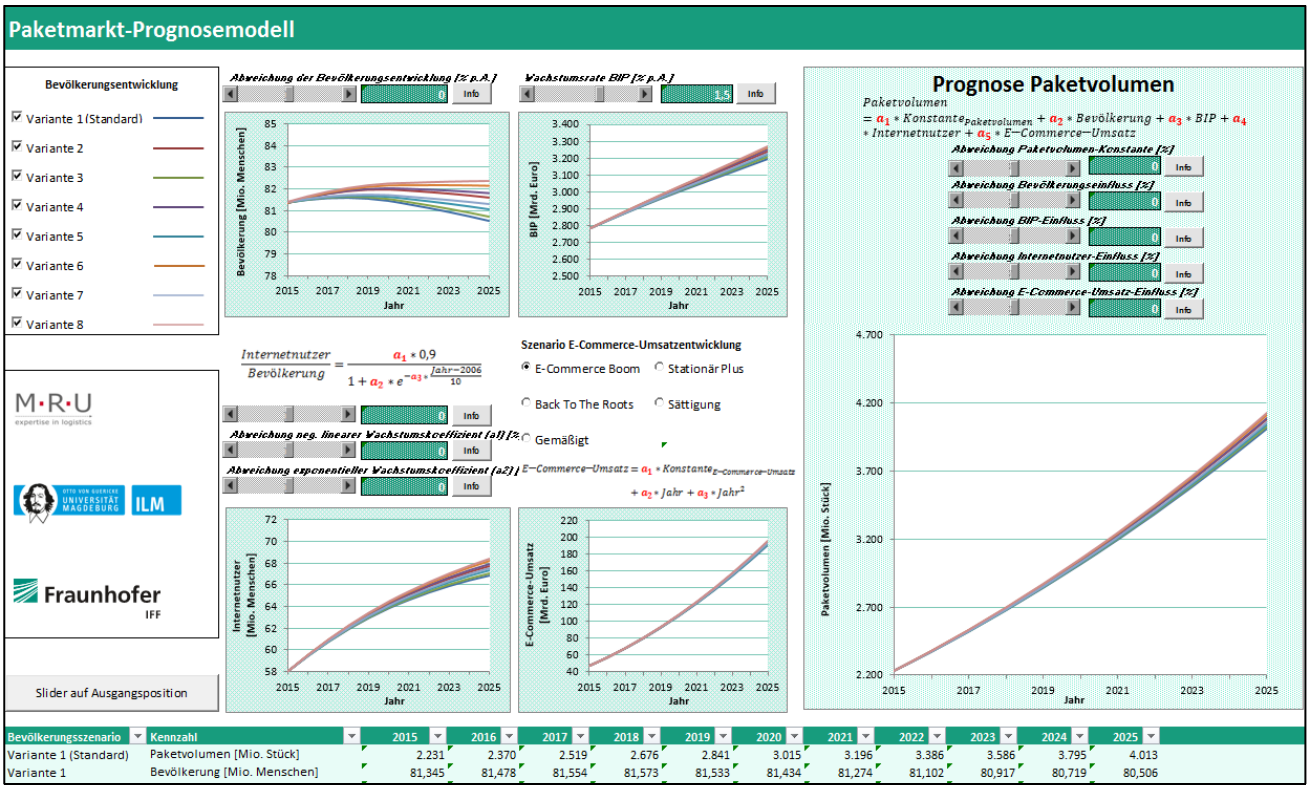

Figure 5: Screenshot of the implemented forecast model in Microsoft Excel

The second regression algorithm which was implemented is the Gauß-Newton algorithm. This method was applied if a nonlinear correlation between datasets were supposed. Hereby, the nonlinear problem is approximated by a finite number of linear problems using Taylor expansion. More precisely, similar to the linear regression the Gauß-Newton algorithm searches the coefficients of a nonlinear function, in order to minimize the sum of square distances of each data point to consider. For further information about this method, please refer to Argyros and Hilout (2013), Damen and Reusken (2008) and Deuflhard (2004). Like for the linear regression algorithm the mean forecast error is additionally calculated to identify data-overfitting.

As discussed in section 2.1, it was necessary to generate forecast data for the number of internet users. In a preceding analysis, the history data of the number of internet users were also inspected for a potential correlation within the values. The authors assumed for this dataset a dependence to the population, which correlates to a sigmoid function in. As illustrated in figure 5, the authors used the history data of the internet users within the Gauß-Newton algorithm to fit a sigmoid function, which considers also a forward projection for forecasting. In general, sigmoid functions have an upper bound, to which they converge. It is clear that the number of internet users is limited by the number of inhabitants in Germany. For the presented function in figure 5, the authors assumed, that the number of internet users can not exceed 95 % of the population.

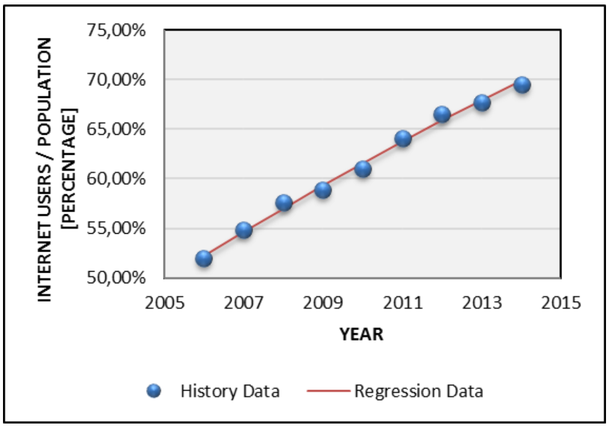

Figure 6: Fitted sigmoid function of the Gauß-Newton algorithm for the number of internet users

In the end of the regression analysis, the quantified influences of the four economical figures were summarized in one forecasting function:

$$Q_D = a_1 * C_D + a_2 * P + a_3 * GDP + a_4 * IN + a_5 * ECS \quad (1)$$

Whereby the variables are declared as followed:

- Q_D: Dispatch quantity
- C_D: Constant of dispatch quantity
- P: Population
- GDP: Gross domestic product
- IN: Number of internet users
- ECS: E-commerce sales

- $a_1,\ldots,a_4$: Parameters of the influence variables from the regression analysis

3.3. Implementation of the Forecast Model

The resulting forecast model is a VBA based tool, implemented in Microsoft Excel. The tool visualizes forecasts of future dispatch quantities until the year 2025. The model enables to incorporate in-depth knowledge, by manipulating the parameters of the influence variables with scrollbars and edit fields. Furthermore, the user is able to choose between eight scenarios of population development as well between five scenarios of e-commerce sales to improve the accuracy of the forecast results. Beside a graphical output in plot charts, the user can achieve a deeper insight into the forecast by analyzing the numerical result values in tables. Figure 5 on the previous page gives an impression of the implemented model.

3.4. Validation of the Forecast Model

To evaluate the accuracy of the model results, the authors compared the fitted functions with the corresponding data sets from the past. Of particular importance is the fitting accuracy of the dispatch quantity, because the function is influenced by all other economical figures. Therefore, the dispatch quantity is the best indicator to evaluate briefly the fitting quality of all functions. Figure 7 compares the dispatch quantity data from the regression with the real dispatch quantities of the past years.

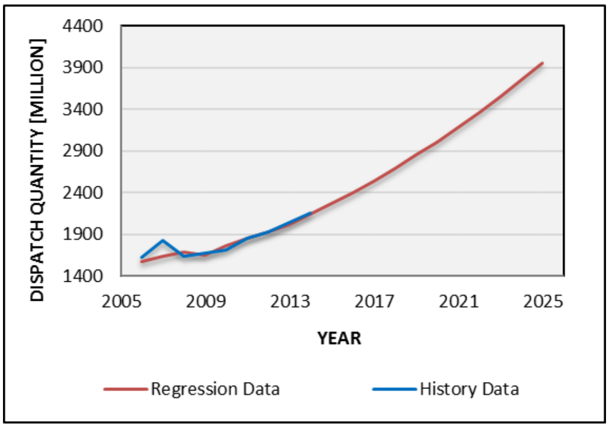

Figure 7: Comparison of dispatch quantity regression data and real history data

With a coefficient of determination of approximately 0.9, the fitting accuracy of the regression is more than satisfying.

4. IMPLEMENTATION OF A PARCEL SERVICE NETWORK AS HIERARCHICAL MESOSCOPIC SIMULATION MODEL

After the generation of forecast data, the user can check if its parcel service network is able to process the estimated dispatch quantities according to the customized service level requirements. To give an instance, the delivery network of a parcel service provider was implemented as simulation model.

Because of the plenty number of locations and their processes inside, it is a challenge to define the right level of detail for the simulation model. In General, the choice of the level of detail is a central question in modeling and simulation (Balci 1989). Finding the right level of detail is even for experienced simulation engineers not a trivial task. A high level of detail leads to a time consuming creating phase and a long simulation run time. A low level of detail involves the risk of modeling system components inaccurately, which can lead to invalid simulation results or reduce the adjustability of system parameters (Wenzel et al. 2008).

In order to resolve this problem, the parcel service network is implemented as hierarchical mesoscopic simulation model. The following descriptions summarize the previous work of Erichsen et al. (2015).

4.1. Mesoscopic Simulation

Primarily, the exemplary parcel service network is implemented as mesoscopic simulation model. The mesoscopic simulation approach detailed described by Reggelin (2011) and Reggelin and Tolujew (2011) is settled between continuous and discrete-event simulation in terms of level of detail, required modeling effort and computational time. Looking on the plenty number of locations within the parcel service network, the mesoscopic simulation approach represents a good compromise to consider, on the one hand, the operations within the network on an expedient level of detail and to receive, on the other hand, simulation results in a tolerable period of time. Hereby, a mesoscopic abstraction and aggregation is achived through the modeling of intra logistics processes as discrete flow rates, while transport processes are still modeled with flow objects.

Krahl (2009) as well as Damiron and Nastasi (2008) describe the simulation paradigm of modeling processes through piecewise constant flow rates as discrete-rate simulation. For instance, the simulation software ExtendSim 9 has a discrete-rate library to create these type of models. The authors use also this software to model the parcel service network.

No longer considering single parcels for processes within the locations of the network, the mesoscopic simulation model calculates experiments in a significant smaller computational time compared to purely object-based models. Furthermore, the mesoscopic simulation model depicts operations more accurate than continuous simulation models, because the control of processes and resources is event-driven, by which the point of times of necessary adjustments can be precise calculated.

4.2. Hierarchical Model Structure

In course of simulation experiments, the analyst may indicates a node of the network as bottleneck, but cannot exactly identify the cause of the underperformance, because the mesoscopic view limits the possibilities for analyzes. In this case, a microscopic view on the processes of the location would be desirable.

The model of Erichsen et al. (2015) meet exactly this requirement by implementing the parcel service network as a model with a hierarchical structure.

More precisely, locations to be analyzed in more detail are implemented another time as additional sub-models considering a higher level of detail. Through switches in the main model, the user is able to manually change the hierarchy and therefore the level of detail. For superficial experiments to receive quick impression of the network performance, the lower level of detail is used. That leads to a fast run time of the simulation model. Only for detailed analyses, the user applies the higher level of detail for simulation experiments. Figure 7 illustrates this concept on the example of a hub.

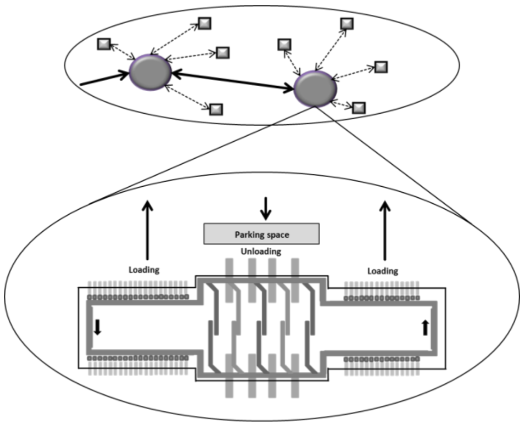

Figure 8: Hub hierarchies

To demonstrate the differences between the less detailed and high detailed sub-models, figure 8 and figure 9 presents the implemented processes of a hub in both sub-models.

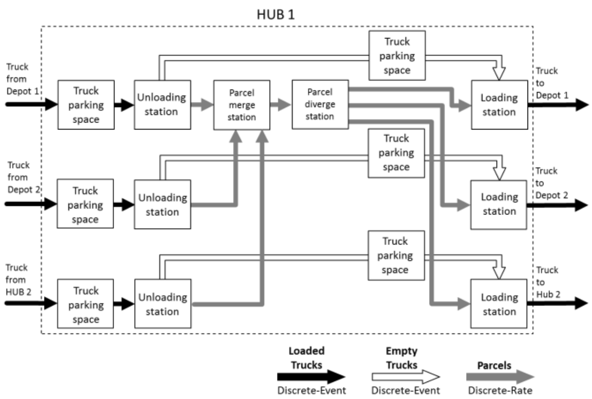

Figure 9: Conceptual model of the mesoscopic hub

Compared to the mesoscopic standard model, the most striking difference of the more detailed hub is the consideration of internal transports within the hub as single processes. Therefore, a more complex control is implemented, which navigates the parcels to the respective outputs of the hub. This allows, for instance, to identify congestions on conveyors or in buffer areas.

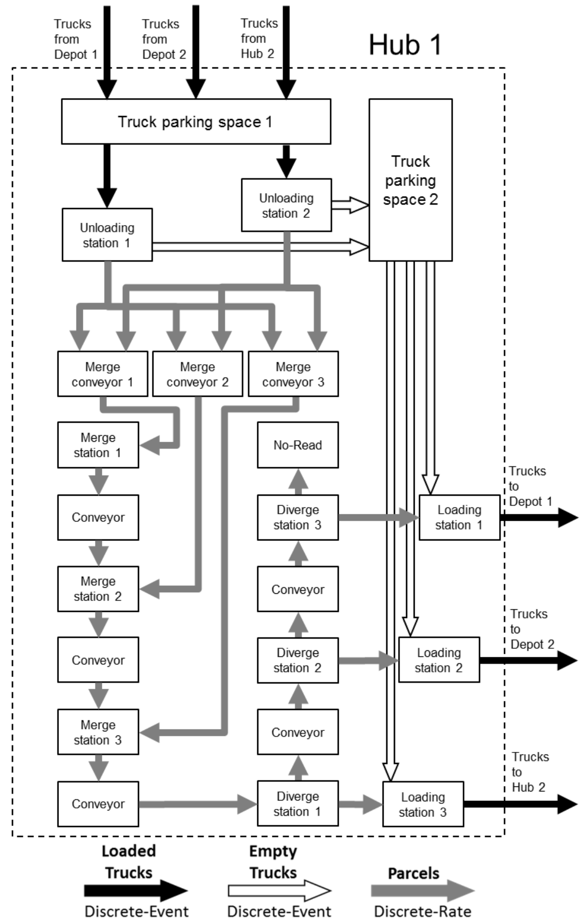

Figure 10: Conceptual model of the microscopic hub

In General, the model enables to determine for instance:

- The throughput time of single parcels
- The utilization of hubs and depots of the network
- The required number of trucks to ship the incoming parcels in time

The KPI's are calculated in order of several input parameters, which can be adjusted by the user. For instance, these are:

- Speed of parcel sorter
- Length of parcel sorter
- Capacity and speed of feeding lines
- Capacity of the trucks
- Speed of trucks
- Rate to load trucks
- Rate to unload trucks
- Quantity of trucks on transport relations
- Length of the transport relations

4.3. Validation of the Hierarchical Mesoscopic Simulation Model

The validation process consists of two steps. In the first step, the functionality of the microscopic submodels were evaluated by considering them as separate models. In simulation experiments, dispatch quantities labeled with specific destinations were sent to each model. By checking if all parcels has left the models through the expected sink and in the expected time, the hierarchical components of the simulation model were successful validated.

In the second step, the accuracy of the complete simulation model was evaluated, considering the mesoscopic parcel network and the microscopic submodels of some network nodes. Hereby, several simulation experiments has been done, in which parcel shipments has been processed on a pure mesoscopic level or in a mix of mesoscopic and microscopic processes. Like in the first step of the validation, the authors evaluated the quality of the results on the throughput time and on the accuracy of the routing of parcels through the network.

5. SUMMARY

This paper described a suggestion for a holistic solution approach to deal with the issues of a fast developing and high dynamic parcel service market. The approach consists of a continuous and a discrete simulation model. On the first level, the user applies the continuous simulation model to create a customized forecast of future shipment demands. Hereby, the model estimates dispatch quantities until the year 2025 based on linear and nonlinear regression.

On the second level, the forecast data are used in a hierarchical mesoscopic simulation model to evaluate the future reliability of a parcel service network. Despite of the large and complex structure of the network, the model enables fast analyses through a mesoscopic rate based implementation of intra logistics processes. Due to its hierarchical structure, the model allows also detailed analyzes by switching to a higher level of detail for specific locations within the network.

In this way, analysts are able to identify the correct point of time to invest and the right subject and amount of investment to ensure a sufficient capability of the delivery network for future shipment service demands.

REFERENCES

Andres P., Spiwoks M., 2000. Prognosegütemaße. State of the Art der statistischen Ex-post-Beurteilung von Prognosen. 1st ed. Darmstadt: Sonderforschung ökonomischen. und juristischen Institutionenanalyse.

Argyros I.K., Hilout S., 2013. Computational Methods in Nonlinear Analysis. Efficient Algorithms, Fixed Point Theory and Applications. 1st ed. Singapore: World Scientific Publishing Co. Pte. Ltd.

BIEK, 2016. Kurier-Express-Paketdienste. Wachstumsmarkt & Beschäftigungsmotor. KEP-Studie 2016. Berlin: Bundesverband Paket und Expresslogistik e. V. Available from: www.biek.de/index.php/studien.html?file=tl_files/biek/downloads/papiere/BIEK_KEP-Studie_2016.pdf [accessed 2 May 2017]

Balci O., 1989. How to assess the acceptability and credibility of simulation results. In: MacNair E.A., Musselmann K.J., Heidelberger P. (Hrsg) Proceedings of the 1989 Winter Simulation Conference, Washington (USA). IEE, Piscataway, pp. 62-72

Bingham N.H., Fry J.M., 2010. Regression. Linear Models in Statistics. 1st ed. London: Springer

Bevh, 2016. Interaktiver Handel in Deutschland. Ergebnisse 2016. Berlin: Bundesverband E-Commerce und Versandhandel e.V. Available from: https://www.bevh.org/uploads/media/Auszug_aus_der_bevh-Studie_Interaktiver_Handel__in_Deutschland_2016_.pdf [accessed 2 May 2017]

Clausen U, Dieckmann D., Baudach J., Kaffka, J., Pöting M, 2015. Improving Parcel Transshipment Operations – Impact of Different Objective Functions in a Combined Simulation and Optimization Approach. In: Yilmaz L., Chan W.K.V., Moon I., Roeder T.M.K., Macal C., Rossetti M.D. (Eds.) Proceedings of the 2015 Winter Simulation Conference

Cornett K., Miller A., 1996. An Aircraft Operations Simulation Model for the United Parcel Service Louisville Air Park. In: Charnes J.M., Morrice D.J., Brunner D.T., Swain J. J. (Eds.) Proceedings of the 1996 Winter Simulation Conference, pp. 1341–1346

Damen W, Reusken A., 2008. Numerik für Ingenieure und Naturwissenschaftler. 2nd ed. Berlin: Springer

Damiron C., Nastasi A., 2008. Discrete Rate Simulation Using Linear Programming. In: Mason S.J., Hill R.R., Moench L, Rose O., Jefferson T., Fowler J.W. (Eds.) Proceedings of the 2008 Winter Simulation Conference, pp. 333-338

Destatis, 2017. GENESIS-Online Datenbank. Wiesbaden: Statistisches Bundesamt. Available from: https://www-genesis.destatis.de/genesis/online [accessed 3 May 2017]

Destatis, 2015. Bevölkerung Deutschlands bis 2060. 13. koordinierte Bevölkerungsvorausberechnung. Wiesbaden: Statistisches Bundesamt. Available from: https://www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/VorausberechnungBevoelkerung/BevoelkerungDeutschland2060Presse5124204159004.pdf?__blob=publicationFile [accessed 3 May 2017]

Deuflhard P., 2011. Newton Methods for Nonlinear Problems. Affine Invariance and Adaptive Algorithms. 3rd ed. Berlin: Springer

Dowlaty Z., Loo C., 1996. Derivation of the Initial Stock of Bags – A Monte-Carlo Approach. In: Charnes J.M., Morrice D.J., Brunner D.T., Swain J. J. (Eds.) Proceedings of the 1996 Winter Simulation Conference, pp. 1479–1482

Erichsen B., Reggelin T., Lang S., Manner-Romberg H., 2015. Hierarchical Mesoscopic Simulation Models of Parcel Service Provider Networks. In: Merkuryev Y., Del Rio D., Bruzzone A. (Eds.) 17th International Conference on Harbor, Maritime and Multimodal Logistics Modelling and Simulation, HMS 2015, pp. 73–78.

Fedorko G., Weiszer M., Borzecky M., 2012. The Shipments Flow Simulation in Courier Company. Carpathian Logistics Congress 2012

GfK 2015: E-Commerce: Wachstum ohne Grenzen? Online-Anteile der Sortimente – heute und morgen. Bruchsal: GfK GeoMarketing GmbH. Available from: http://www.gfk-geomarketing.de/fileadmin/gfkgeomarketing/de/beratung/20150723_GfK-eCommerce-Studie_fin.pdf [accessed 3 May 2017]

IFH 2014: Branchenfokus PBS-Artikel. Köln: IFH Institut für Handelsforschung GmbH. Available from: https://www.ifhshop.de/studien/branchen-insights/42/branchenfokus-pbs-artikel?number=

Initiative D21, 2016. D21-Digital-Index. Jährliches Lagebild zur Digitalen Gesellschaft. Berlin: Initiative D21 e. V. Available from: http://initiatived21.de/app/uploads/2017/01/studie-d21-digital-index-2016.pdf [accessed 3 May 2017]

Krahl D., 2009. ExtendSim Advanced Technology: Discrete Rate Simulation. In: Rossetti M.D., Hill R.R., Johansson B., Dunkin A., Ingalls R.G. (Eds.) Proceedings of the 2009 Winter Simulation Conference, pp. 333-338

Larsen N.E., 2003. Simulation – A Key Tool to accelerate and add Confidence to Postal Network Configuration. In: Chick, S., Sanchez, P. J., Ferrin, D., Morrice, D. J. (Eds.) Proceedings of the 2003 Winter Simulation Conference, pp. 1585–1592

MRU, 2015, E-commerce sales data for the years 2006 until 2015. Hamburg: MRU. Data are not accessible to the public. Please send your request on: http://www.m-r-u.de/de/kontakt/ [accessed 3 May 2017]

PwC, 2017. The Long View. How will the global economic order change by 2050? London: PricewaterhouseCoopers LLP. Available from: https://www.pwc.com/gx/en/world-2050/assets/pwc-the-world-in-2050-full-report-feb-2017.pdf [accessed 3 May 2017]

Reggelin T., 2011. Mesoskopische Modellierung und Simulation logistischer Flusssysteme, Otto-von-Guericke-Universität Magdeburg

Reggelin T., Tolujew J., 2011. A Mesoscopic Approach to Modeling and Simulation of Logistics Processes. In: Jain S., Creasey R.R., Himmelspach J., White K.P., Fu M. (Eds.) Proceedings of the 2011 Winter Simulation Conference,IEEE, Piscataway, pp. 1513-1523

Swip, T. M., Heungsoon, F. L., 1991. Application of an integrated Modeling Tool. In: Nelson B.L., Kelton W.D., Gordon M.C. (Eds.) Proceedings of the 1991 Winter Simulation Conference, pp. 786–791

Tuan P.L., Nee D.S., 1969. MASS-A Mail Service Simulation. In: Proceedings of the 1969 Winter Simulation Conference, pp. 382–395

Wenzel P., Weiß M., Collisi-Böhmer S., Pitsch H., Rose O., 2011. Qualitätskriterien für die Simulation in Produktion und Logistik, Springer-Verlag Berlin Heidelberg

Weisberg S., 2005. Applied Linear Regression. 3rd ed. Hoboken, New Jersey: John Wiley & Sons, Inc.

White K.P., Barney B., Keller S., Schwieters R., Villasenor J., Terry W.S., Fairbrother R.G., Saxton R.D., 2001. An Object-Oriented Paradigm for Simulating Postal Distribution Centers. In: Peters B.A., Smith J.S., Medeiros D.J., Rohrer M.W. (Eds.) Proceedings of the 2001 Winter Simulation Conference, pp. 1007–1012

Yan X. and Gang Su X., 2009. Linear Regression Analysis. Theory and Computing. 1st ed. Singapore: World Scientific Publishing Co. Pte. Ltd.

AUTHORS BIOGRAPHY

Sebastian Lang is a student of the master's program industrial engineering and logistics at the Otto-von-Guericke University in Magdeburg. He holds a master's degree in mechanical engineering with focus on production technologies and a bachelor's degree in industrial engineering in logistics. His research interests include simulation modeling and mathematical optimization of production and logistics systems.

Tobias Reggelin is a research and project manager at Otto von Guericke University Magdeburg and the Fraunhofer Institute for Factory Operation and Automation IFF Magdeburg. He received a doctoral degree in engineering from Otto von Guericke University Magdeburg. He holds a diploma degree in industrial engineering in logistics from Otto von Guericke University Magdeburg and a master's degree in Engineering Management from Rose-Hulman Institute of Technology in Terre Haute, IN. His research interests include modeling and simulation of production and logistics systems, the development and application of new modeling and simulation methodologies and the development and use of logistics management games for teaching and training.