Towards Extending USEfUL-ness for Urban Logistics with Service-orientation

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***Abstract*—In this paper the workflow of the project 'Untersuchungs-, Simulations- und Evaluationstool für Urbane Logistik' (USEfUL) is presented. Aiming to create a web-based decision support tool for urban logistics, the project needed to integrate multiple steps into a single workflow, which in turn needed to be executed multiple times. While a service-oriented system could not be created, the principles of service orientation was utilized to increase workflow efficiency and flexibility, allowing the workflow to be easily adapted to new concepts or research areas.**

***Index Terms*—Service Orientation; Urban Logistics; Decision Support Tool.**

I. Introduction

Urban logistic processes are currently transformed in many ways to reduce emissions, increase efficiency and follow new political guidelines. This creates a complex environment for urban planners when making decisions. Since many novel concepts can be utilized to achieve different objectives within the planning area. To support urban planners in their decision making process, the project USEfUL created a web-based decision support tool that provides important information in an easy to comprehend way. One of the main goals of the project was to create an application that can easily be used while in discussion with other planners and decision makers.

A Workflow was devised to generate the data utilized in the web-based decision support tool, as many different domains had to be combined. First, data about the city Hannover was collected to select representative areas that could be used for the evaluation of novel logistic concepts. In the next step, simulation models were built that utilized the data to simulate the selected novel concepts within the representative areas, producing new data about the populations behavior and traffic. The newly created data was then analyzed using purpose built evaluation models, which derived simple tendencies that could be presented to the end user. As the last step, data had to be ingested into a web-based decision support tool.

The general workflow fits well with the application of a service-oriented software system, in which each domain team develops their own services, connected by a common service bus. Creating a complete service oriented system was however not possible due to constraints to time, budget and software development expertise. This leads to our research question: How can the principles of service oriented software development be applied to partially automated workflows?

In the following sections we will further implore the workflow as well as the application of service-orientation in a manual process. To this end Section II will discuss related work, before Section III will present the utilized service principles. The acquisition of data will be shown in Section IV, while simulations are discussed in Section V. Analysis of data and presentation within the web-based decision support tool are shown in Sections VI and VII respectively. Section VIII contains the conclusion.

II. Related work

Few other tools have been created to publicly present the impacts of different logistic concepts on urban areas.

As one of the earlier projects, BestUFS [1] analyzed different urban logistic solutions in general, providing rough advantages and disadvantages of concepts. The effects of concepts were analyzed through living labs, implementing pilot projects and evaluating impacts. While rough guidelines are also provided by the web based decision tool developed in USEfUL, no pilot projects were utilized in the project, relying on simulations instead. Furthermore, BestUFS does not present the results in the form of a web-based tool, but as simple documents, reducing the user experience.

The most important tool is the urban-transport-road maps shown by De Stasio et al. [2]. While the road maps show similar key performance indicators to the user, the results are simulated in real time. To achieve real time simulations, a very rough grained simulation was utilized instead of concrete agent based transport simulations as used in USEfUL. Furthermore the urban-transport-road maps-tool is a single system integrating different modules instead of a workflow consisting of multiple different tools.

Bozzo et al. [3] present a literature survey and a theoretical ex-ante-framework for the evaluation of logistic concepts created in the project SIPLUS. However, no simulations were utilized and no concrete evaluation of logistical concepts are presented in the paper. Furthermore, the authors remain with a theoretical model, not implementing a concrete decision support tool.

Overall, very little works concentrate on creating and managing a workflow to evaluate novel logistic concepts and presenting evaluation results to a user. Other works often focus on single issues within a possible workflow, while holistic views are uncommon.

III. PRINCIPLES OF SERVICE-ORIENTATION

As previously mentioned, filling the web-based decision support tool with data required a multi-step process that contained data collection, simulation, analysis and data ingest. All these steps had to be followed for many different logistic concepts that had to be evaluated in different research areas in respect to multiple key performance indicators. A fully automated approach was therefor likely to reduce overall project run time and increase productivity.

Figure 1 shows the workflow as well as the different models utilized in the project.

Unfortunately, due to budgetary constraints, the project team consisted mostly of domain experts, firm enough in computer science to develop and maintain domain specific models but not firm enough to create an inter-domain system. Therefor, a manual approach utilizing applicable principles of service-orientation was developed.

In service-orientation, the following principles for service design are often listed (e.g., by Rosen et al. [4] or Huns and Singh [5]):

- Isolation of responsibilities - a service is responsible for a specific task and is the only service responsible for that task.
- Loose coupling - services are as independent as possible of each other.
- Encapsulation - the interface of a service is strictly decoupled from the implementation.
- Modularity - services are self-contained and can be combined to create new workflows.
- Autonomy - a services lifecycle is independent of other services.
- Statelessness - services are without state.

Following these principles allows for high flexibility in software architectures. By applying principles of service orientation to a manual workflow, changes (which often are necessary within a research context) to each step of the workflow should be able without impacting the project at large.

In the following sections, it will be shown how the principles were applied to the design of the different tasks needed to create data for the decision support tool and evaluate whether the application of the principles improved the workflow flexibility.

IV. DATA ACQUISITION

The first step in the workflow is the acquisition of data necessary for simulations. To simulate inhabitant behavior, and in turn traffic resulting from the behavior, exhaustive data about geography (i.e. roads, buildings, etc.), inhabitant distribution, and other structural information (distribution of living spaces vs. office buildings/other industries, logistical points of interest, etc.) was needed, as shown in Table I.

TABLE I. KEY DATA FOR SIMULATION OF URBAN LOGISTIC BEHAVIOR.

Categories	Key data
Traffic	1. road maps, 2. velocity limits, 3. number of vehicles, 4. level of service, 5. modal split
Area usage	1. public, living, industrial, retail areas, 2. coordinates
Public transport	1. network, 2. coordinates
Districts	1. Borders, 2. number of buildings, 3. number of inhabitants, 4. demographics

While most of the data were provided by the city administration of Hannover, further studies and statistics have been analyzed to complete the necessary database. The database provides the information to other parts of the workflow.

V. SIMULATION MODELS

The second step in the workflow is the simulation of novel logistics concepts utilizing the previously described data as inputs. Since multiple logistics concepts needed simulation (the number of which was not pre-defined), the simulations were designed with common inputs and outputs as to flexibly interchange different models within the same workflow. The models were created using AnyLogic, a proprietary, java-based simulation tool, which provides extensive libraries and multi-method-simulation. A combination of discrete event simulation (DES) and Agent-Based Simulation (ABS) was chosen as the development methodology [6]. The combination allows the development of flexible models, enabling the simulation of different logistics concepts using the same base model.

TABLE II. SCENARIOS SIMULATED VIA ANYLOGIC MODELS.

Scenario	Description
Micro-Hub	The population is supplied by micro-hubs in the inner city area. A supply chain is created across different logistics levels.
White Label	The population of the CEP population is supplied by bundling orders from several CEP service providers in a common distribution center on the outskirts of the city.
City Hub	A stationary, inner-city transshipment point will be built, which will be used by several CEP service providers for last-mile distribution.
Parcel Pickup Locations	CEP service providers now only deliver via unattended services, in which orders are delivered to customers exclusively at stations/stores or via a drop-off location.
Online Grocery Shopping	Customers order consumer goods such as food and drugstore items from a local supplier with a specific delivery window to their desired location.
Neighborhood Logistics	Neighborhoods organize their mobility-triggering activities by linking and optimizing their routes through division of labor. Preferably, one neighbor does several activities for another neighbor (e.g. shopping activities).

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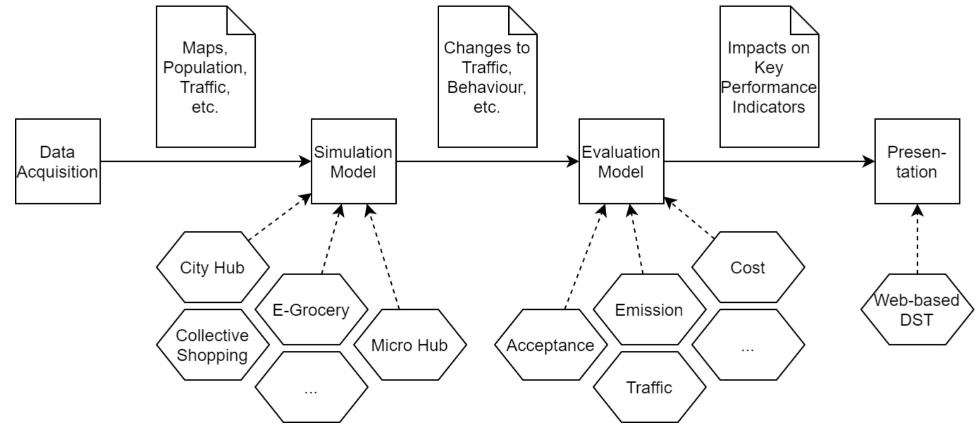

Fig. 1. Workflow of the project USEfUL.

In total, two base models were developed which can be configured to simulate six logistics concepts. While breaking with the principle of Isolation of responsibilities, since a single model may simulate different concepts, this choice was made due to software inflexibility within the simulation toolkit. The first model, CEP, simulates courier, express and parcel delivery services and provides the base for four of the concepts. The second model, E-Grocery, simulates food delivery in the research area via food fulfillment centers (DCenter) or traditional supermarket shopping. Both simulation models utilize the same database, containing information about roads, buildings, inhabitants, etc. about the research areas.

In the following section, the E-Grocery model will be presented, which comprises the most comprehensive tool in particular with regard to the logistical complexity (time window routing).

A. E-Grocery model

This simulation model is a consideration of the real world problem of last mile grocery delivery. Within the e-grocery base model, the basic logic of the food delivery process (e-grocery) was mapped and contrasted with the classical purchasing process. This delivery concept was chosen because it is one of the most common in Germany and is used by our partner company. The delivery module of the simulation model shows accruing routes through grocery deliveries to the pilot neighborhoods from a distribution center (DCenter). The deliveries were route-optimized to achieve the highest possible degree of realism.

The inputs for the simulation model utilize publicly available data such as OpenStreetMap locations or anonymized data from the city of Hannover, municipalities or other external partners. All simulation models utilize the same base model of the research areas as well as the population living in the research areas. The simulation of different logistic scenarios is achieved by configuring the simulation model via parameters such as participation rate, consolidation of orders or delivery locations. Important input parameters such as the size of the delivery fleet, the order volume, the type of purchase (bulk purchase or small purchase), time window of the order (depending on the customer type) as well as the shopping behavior, the travel speed and the route guidance were parameterized in order to be able to analyze the model flexibly depending on different behavior and circumstance scenarios and to produce results that are as realistic as possible.

The classic shopping model is based on data on shopping and mobility behavior from the MID study [7] and provides reference values and logics for comparison between classic shopping and grocery deliveries. A more detailed description of our model can be found in [6]. In the publications [8] and [9], supplementary, later extensions of our model are shown, which consider the neighborhood types of the pilot area and the downstream supply chain of the eGrocery scenario in more depth.

Since influences of e-grocery on traffic are mainly determined by shopping behavior, different, behavior-oriented comparison scenarios were defined (see Figure 2).

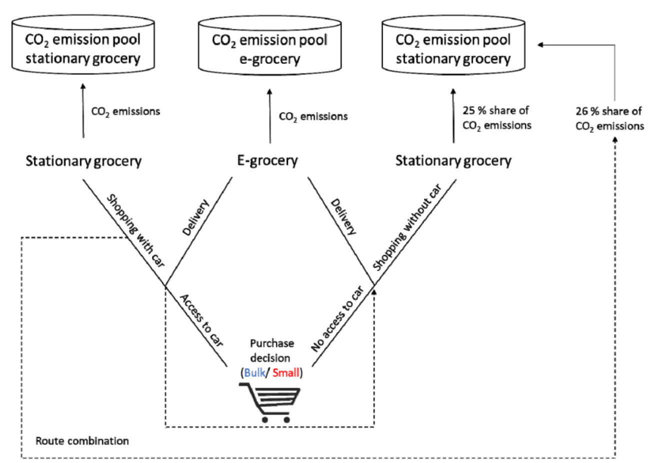

Fig. 2. Comparison of CO_2 emissions for e-grocery and normal grocery shopping [6].

Depending on their characteristics, these lead to different kilometers driven, a different number of start/stop operations, a different working time, and different emissions after interface transfer.

The simulation output is realised trough the creation of Excel-files which contain information common to all simulation models as well as some scenario-specific information like the success rate of delivering within specified time windows. A wide variety of simulation experiments were conducted for each scenario and over 1000 simulation iterations were performed.

The final Excel spreadsheet contains all iteration results for each scenario, shown in Table III.

TABLE III. OUTPUT VALUES OF THE E-GROCERY MODEL.

Data	origin	Measured variable
Mileage	AnyLogic	Total kilometers driven per agent type
Process times	AnyLogic	Duration tour / per vehicle type Utilization of vehicles or buildings Start/stop ratios
Number of tours	AnyLogic	Number of tours per vehicle type Deliveries made Returns (false acceptances)
Scenarios Information	AnyLogic	Scenario no. Iteration run & Simulation timestamp

Within the simulation model loose coupling as well as modularity is achieved through the definition of inputs and outputs. While some modifications needed to be made to accommodate each scenario, file structure is mostly identical between the models. This allows some interchangeability of simulation models in respect to data im-/export, reducing development time of interfaces in the database or the following evaluation models. In the context of the larger project, defining clear interfaces supported the parallel development of multiple simulation models as well as the database and the evaluation models, reducing overall communication workload. After common interfaces were defined only big changes had to be coordinated between all project teams, while small changes between two teams did not cause issues for other teams.

VI. ANALYSIS OF THE SIMULATION DATA

The next step within the workflow is the evaluation of the effects of logistics concepts on key performance indicators such as emissions, area use, costs and traffic behavior. The evaluation was done by comparison with the current traffic situation within the research areas, as logistics concepts influence multiple key performance indicators at once (Allen et al. [1]). For that a base case was defined and simulated to give a detailed overview about the actual situation.

Every evaluation comprised of multiple steps as shown in Figure 3. Firstly, requirements have to be defined to figure out the main results of the analysis and the structure of the evaluation model. With the knowledge and simulation base a data base is created to collect specific data and structure them. The results of the data base are one part of the definition of the target figures. They are roughly defined before the execution of the AnyLogic simulation and specified with the knowledge

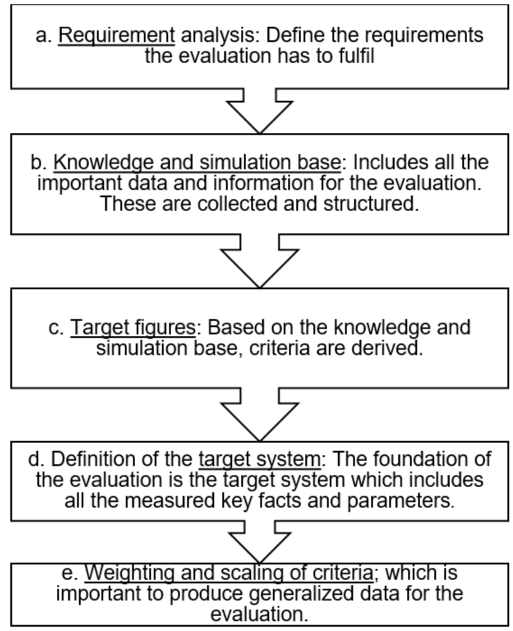

Fig. 3. Evaluation procedure modified from Drews and Hildebrand [10].

base. The other part of the data base is the input for the target systems. The target systems are built to work up the simulation input. Each target figure gets its own system. At last, all the scenarios and models are summed up and scaled to make them comparable.

Before the modeling of the evaluation system some goals have to be set and defined. In the following sections each step is described in further detail.

A. Requirements

To model a significant evaluation system some core requirements have been set. The aspects shall guarantee a structured modeling process and an easy way to extend it once new logistic concepts should be implemented. In addition, the linking of the parameters and scenarios is desirable to release a comparable output.

The following aspects have to be taken into account while executing this evaluation modeling:

- transparent and replicable evaluation
- generalized assessment
- automation possible
- cross-district valuation based on the different criteria

B. Simulation and knowledge base

As seen in Figure 4 two different input types are used for the evaluation model: the research input and the simulation input. The research input provides information about the logistic concepts and the variation of data needed to evaluate them. The sources of the research input have been the data described in Section IV. Also, data from logistic companies were taken into account. The simulation output of the AnyLogic workflow and the research have been combined to build the basic structure of the target system. In addition, some of the research input also influences the specific definition of the target figures. Some of the most important inputs and outputs are listed in Figure 4.

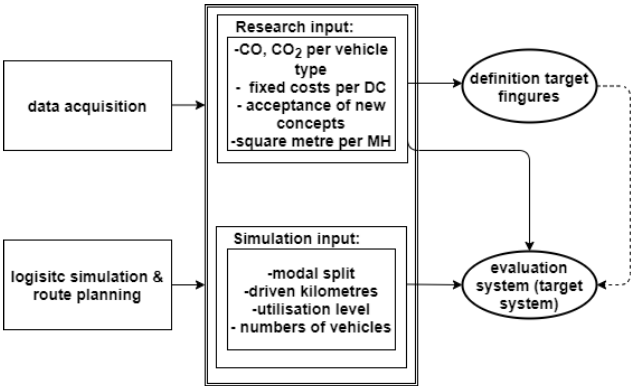

Fig. 4. Simulation output analysis.

C. Target figures

As shown in Table IV, the target figures are categorized into core targets and derivation targets. The core targets are emissions, costs, traffic and area savings.

TABLE IV. TARGET FIGURE CATEGORIES.

Core [unit]	Derivation 1^{st} [dependence]	Derivation 2^{nd} [dependence]
emissions [CO_2 equivalent]	ecologic BEP [CO_2 equivalent per €]	implementation potential [{CO_2/€;€;m^2;∅ km/h}]
costs [€ per day]	economic efficiency [profit (€) per day]	acceptance [{CO_2/€;€;m^2;∅ km/h}]
area savings [m^2]		
traffic [∅ km/h]		

Emissions Goal of the target figure is the reduction of CO_2 emissions and noise.

Costs For the last mile delivery a cost model is created. The balances are measured to the base case which provides information about the economic effects.

Traffic The overall intention is to reduce the traffic activity and congestion. One idea is to substitute individual traffic to commercial transport.

Area savings This target figure deals with the reduction of exploited economically used areas in the urban surrounding.

Due to the mutual influences (proportional, neutral, reciprocal) the core target values are connected. The derived target figures are deduced out of the core targets. Whereas the ecologic BEP (Break-even point) and the economic efficiency are calculated out of the core target figures directly, the acceptance and the implementation potential needed qualitative input which is challenging to evaluate.

1) Target system: Each target figure has got its' own analysis system. In this case the cost model is presented more detailed:

$$K_{total} = k_{fleet} + k_{DC} + k_{log}$$

The shown formula describes the three main modules of the cost model. The parts "fleet costs" (k_{fleet}) and "distribution center costs" (k_{DC}) are essential for all presented concepts. Due to changes in the supply chain in some concepts the third part "logistic costs" (k_{log}) is adapted, especially in the CEP delivery services.

With the following formula of the distribution center costs (k_{DC}) the process and the handling of the data should be emphasized:

$$k_{DC} = ((n_{DC} * (k_{pbs} + k_{st})) * c) * l$$

where n_{DC} is the number of distribution centers-output of the simulation, k_{pbs} are the fixed asset costs to run the distribution center (defined via research input), k_{st} are staff costs (defined via research input), c is the factor to define the capacity of the DCs-output of the simulation and l is a location factor defining cost changes based on ground values (defined via research input). The total costs of the last mile delivery are all compared to the firmly defined base case (BC). In case of the different CEP concepts, all concepts are more expensive compared to the base case. As seen in Figure 5 the White-Label (WL) concept and the central pick-up stations (PS) are slightly higher positioned while the Micro Hub concept (MH) and the City-Hub concept (CH) doubled or rather tripled the costs. In this project the costs are spread on four different quarters of the city. This was clarified by the fixed numbers of parcels per quarter. With this output of the target system the overall scaling is possible.

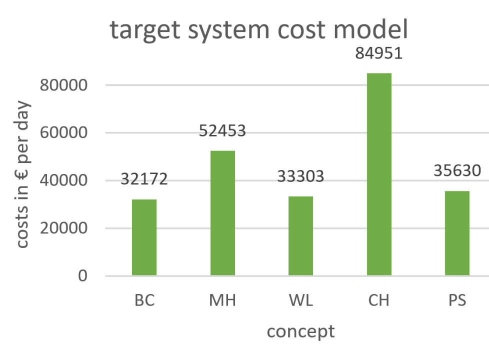

Fig. 5. CEP cost comparison.

2) Weighting and scaling of criteria: With the valuation of the simulation all the concepts have to be comparable to give a clear statement about the tendencies and the possible changes. All values for a target figure have been collected to scale the values. Another important point has been the possible negotiation of some of the target figures like emissions, costs, area savings, ecological BEP and acceptance. With the

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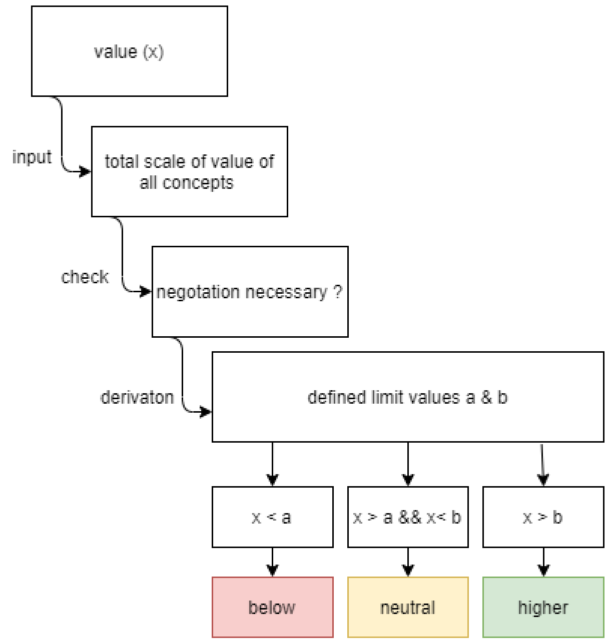

Fig. 6. Scaling system.

categorization with limit values a tendency is shown as a result of the analysis as shown in figure 6.

As the entire process of evaluation is inherently independent of previous evaluations, the application of statelessness was trivial. Furthermore, evaluations are modular, since the evaluation of a single key performance indicator is independent form the evaluations of other KPIs Different KPI-Evaluations can be easily combined to create a clearer picture about each logistic concept, as each concept might affect different KPIs.

VII. Web-based decision-support-tool

Lastly, evaluation data was made available to users in the form of a web-based decision support tool. The tool not only presents the evaluation data from the analysis, information about logistic concepts, research areas and the project itself are also made available.

The main design goals of the web-based decision support tools was ease of use. A user should be able to utilize the tool quickly e.g. in a meeting with other decision makers to discuss the impacts of novel logistic concepts on a given area. Through expert workshops the following requirements were refined:

- Present Information about:
  1) the project USEfUL
  2) research areas (districts)
  3) novel logistic concepts
- Allow users to view and export the evaluations of the concepts.
- Allow the modulation of concepts through the selection of different parameters.
- Compare the evaluation results of multiple concepts within a research area/across research areas.

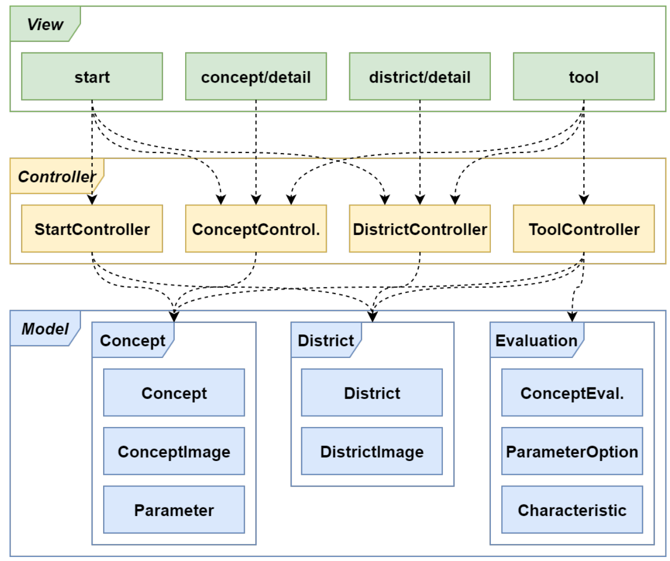

Fig. 7. Rough design of the web-based decision support tool.

The rough design of the web-based decision support tool is shown in Figure 7. Based on the industry standard model-view-controller-pattern, four different views present the user the most important information. The start page, showing rough overviews over logistics concepts, as well as research areas, serves as a landing page. From this page, the user can navigate to detail pages for concepts ans research areas (districts) or the decision support tool. Detail pages show images and in-depth information about concepts or districts and can be used to thoroughly understand the presented evaluations. The tool-page allows a user to select the combination of research area and logistic concepts, configure the concept with the parameters defined for the simulation models. After the user makes a selection, the evaluation results for the chosen combination are presented to the user.

The application was built utilizing the Laravel Framework which in turn required the use of php, javascript and a database (e.g. mysql). Docker was utilized to decrease setup times and increase productivity.

Data import is handled by manually converting Excel files from the evaluation into RFC-compliant comma-separated-values, which in turn are imported into the database of the tool. If the web-tool is viewed as a service, this results in a violation of the statelessness of services. However, as the workflow is not fully automated, storing the results in the web-tool is necessary, as the results can not be recreated on-the-fly. Furthermore, execution of simulations takes a long time, violating the design goal of quickly presenting a user with the desired information.

VIII. Conclusion and Future Work

In this paper the workflow of the project USEfUL was presented, which aims to create a web-based decision support tool for urban planners. It described the different steps within

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the workflow, beginning with the data acquisition and ending with the result presentation.

This process lent itself to the application of service principles, since each step was developed and managed by a different team consisting of domain experts. By clearly defining service-like endpoints and common data formats, the different steps of the process could be pipelined which reduced overall project run-time. I.E. after completing calculations or evaluations on one concept the simulation team could hand off the data to the analysts and start work on the next logistic concept.

However, not all the service principles, which are usually applied to services, could be applied to all steps of the workflow. While simulation and analysis were stateless steps, producing outputs only dependent on the inputs, data collection and presentation of results could not be implemented in a stateless manner.

Overall, the principles of service design could be utilized as guidelines for the steps of a non-digital workflow, which is most likely attributed due to the origin of the principles. In future work the construction of a fully automated service oriented system is the next logical step for the project USEfUL, since a fully automated system is often faster and more reliable than manual processes.

Acknowledgment

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