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Master's thesis
Daily plan (schedule) adaptation in MATSim

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1. **ABSTRACT**

Schedule adaptation is the process of optimizing the daily schedules to maximize utilization of time and money. The difference in the perceived utility of all available alternatives (route, mode) leads to make adaptations in the daily schedule while having limited information about the network and the daily schedule plans. In this research, the trend of utility maximization is measured by the microscopic simulation software MATSim and a new customized module for replanning the daily schedule is introduced. MATSim can adapt the individuals’ schedules based on the network information and the experienced travel times. In order to validate the understanding of the MATSim software structure, a small network and a spatially distributed population are created in such a way that the changes in the MATSim results after the introduction of the new replanning module are easily predictable. A new replanning module associated with the personal choices of individuals is used for the simulation configuration. The individuals who used the newly added replanning modules for relocation of their work location are rewarded with an additional score by a new customized scoring function. The modified MATSim settings are applied to the synthetic network and showed that the resulting effects cannot be produced by a standard MATSim setup.

*Keywords: Travel behavior, daily schedule, replanning, MATSim.*
2. INTRODUCTION

Schedule adaptation is the process of optimizing daily schedules by maximizing the utility of time and money. Apart from the execution of the activities, the individuals (agents) need to travel between different activity locations. People normally select the route, they perceive as the shortest route (in terms of time and distance) under current traffic condition (1). It is quite rare that the most efficient route would be chosen by individuals, due to the following reasons: (1) limited knowledge of the available routes to the destination and plans of other individuals (2) limited information about the network conditions (3) plans of other people sharing the same infrastructure.

In this research, MATSim (Multi Agent Transport Simulation) is used for demand modeling and schedule replanning of multiple agents. Traffic flow micro simulations are important due to high temporal and spatial resolution (2). Microscopic simulation provides an opportunity to take each individual’s attributes into account for modeling travel demand management (TDM) measures (3). MATSim adapts the agents’ plans through an iterative process based on the network information (available routes, respective capacities, available modes etc.) and the experienced travel times by simulating plans of all the agents. After each iteration, a scoring function counts the utility of each plan. At the end of simulation, plans with the best score are regarded as the most efficient plan for each agent. MATSim functionality can be extended by introducing new modules. This research presents a framework by plugging in a customized module based on the agent’s behavior and also by proposing a new scoring algorithm.

In this research, a detailed study of MATSim functionality is carried out through literature review and programming code research. The objective is to find answers for the following questions: (1) how plan scoring is done in MATSim? (2) Which modules of MATSim are involved in the replanning process (3) How can a new behavioral module be integrated in MATSim. In order to answer these questions, we designed a new behavioral module and a customized scoring function. In order to validate the understanding of the MATSim software structure, a small network and a spatially distributed population are created in such a way that the change in MATSim results after introducing the new replanning module is easily predictable. The modified MATSim settings are applied to the synthetic network and showed that the resulting effects cannot be produced by a standard MATSim setup.

In this paper literature review is followed by an detailed explanation of MATSim in Section 4. The technical details of ‘Customized Replanning Strategy’ and ‘Customized Scoring Function’ are discussed in Sections 5 and 6 respectively. The simulation experiment and results are explained in Section 7. Finally, the conclusion is presented in Section 8.
3. RELATED WORK

Recent studies in transport research show a shift of interest from the analysis and modeling of activity-travel patterns to the dynamics of transport systems and the traveler behavior (4). In dynamic transport systems, some individuals react immediately and some take time before changing their behavior. An aggregation of all the responses causes an overall change in the travel patterns at any time. The literature works on agent-based applications, activity-based modeling (ABM) and the replanning in the daily schedules of the individuals are presented:

Agent-based Transport Application
The use of micro level data makes agent-based models to capture interdependency of agents and presents more realistic behavior of the travel demand (5). There are many agent-based transport platforms available for transport modelling and simulations, some of transportation related platforms are listed below:

- Transportation Analysis and Simulation System (TRANSIMS) (6) is designed to assist transportation planners in analyzing information on traffic impacts, congestion, and pollution accurately. The Agent-based Dynamic Activity Planning and Travel Scheduling (ADAPTS) model (7) is an ABM which has been developed to determine the through integration of travel demand modeling with traffic assignment. The dynamic interaction effects are allowed within the demand model and network simulator. A Learning-Based, Transportation-Oriented Simulation System (ALBATROSS) (8) is derived from theories of choices which are used by the consumers while making decisions in complex situations. It predicts which activities are conducted when, where, for how long, and with whom, and the transport mode involved. Multi-Agent Transport Simulation (MATSim) (9) adopts the activity-based approach to generate and simulate individuals’ activities. MATSim has the ability to model interactions of public and private transport. As my prime task is to integrate the replanning module in MATSim, it is discussed in more detail in the methodology section (see Section 4).

Activity-based Modeling
Activity-based modeling (ABM) has been popular and used for establishing new transportation policies. ABM can predict the traffic demand on a network by inducing a daily activity-trip schedule for individuals from the observed data. The agent-based techniques are being used to support the activity-based traffic demand model in order to assess the effects of decision-making by the individuals.

Simulation of travel/activity responses to complex household interactive logistic decisions (STARCHILD) (10), is a policy sensitive methodology to model travel behavior based on activity pattern investigation and it also takes into account the theory of complex travel behavior based on a number of parameters associated with individual's travel decisions in a constrained environment. The Coordinated Travel - Regional Activity Modeling Platform (CT-RAMP) (11) models are categorized based on features, comprising a simulation of travel decisions for separate households and persons and explicitly modelled intra-household interactions through a range of activity and travel choices. Forecasting Evolutionary Activity-Travel of Households and their Environmental Repercussions (FEATHERS) (12) framework suggested a four stage development trajectory for a level transition from the four-step models
to the static activity based models (short term) and dynamic activity based models (longer term).

**Replanning and Schedule Adaptation**

A daily schedule is a sequence of activities that an individual wants to perform at different locations (hence the activities are separated by trips) \((13,14)\). Individuals develop a plan and keep adapting choice rules continuously while interacting with the environment\((4)\). In dynamic transport systems with limited and biased information, an individual tries to maximize his/her time utility by organizing his activities in space and time.

The impact of behavioral parameters were studied in \((15)\) by using the income based valuation of travel times at the individual level. This work applies an activity-based and agent-based simulation framework MATSim in the presence of user heterogeneity in travel time valuations and trip characteristics. The authors studied the effects of optimal congestion and the public transport pricing on the social and consumer welfare in a multi-modal context.

The implementation of two Within Day Replanning modules in the multi agent micro-simulation framework MATSim-T is described in \((16)\). These modules provide an opportunity to the simulated agents to replan the routes independently while traveling. They can also take the real time traffic information into account which is required for scenarios which may have unpredictable incidents, i.e. road accidents.
4. METHODOLOGY

The main objective of this research is to integrate a new replanning module and also to introduce a customized scoring function in MATSim. MATSim is a micro simulation software implemented using Java. It implements the ABM approach to create and simulate the individual daily schedules. It has two-layer structure: the physical layer and the mental layer. The physical layer represents the simulation of activities on the network. The mental layer deals with the daily agenda and replanning process (decision making) which includes mode choice, route choice and activity performing timings. These layers keep sending feedbacks to each other iteratively in order to conduct an overall traffic simulation. The quality of the plan is measured by using a score which is the sum of the positive utilities of all performed activities and the negative utilities of the trips. The objective of this iterative process is to find a relaxed state of the system where an agent cannot improve its score by making more changes in the plan. The modular form of MATSim allows to integrate new modules.

This research is carried out to answer the following questions: (1) what kind of inputs are required for MATSim? (2) what kind of output MATSim produces to analyze the results? (3) how different modules of MATSim functions and the algorithms involved in the calculations to find the distance between two points and the scoring? Research started with a holistic understanding of the MATSim structure. The details of the replanning module are investigated to learn the available replanning strategies and devise a framework to integrate a new replanning module into MATSim.

To validate the functionality of the integrated module, an experiment is designed by considering a synthetic network and population. In the first experiment, the newly coded replanning module is evaluated by using the synthetic network and population. The same network and population are further run by the built-in replanning module of MATSim independently. At the end, both the built-in MATSim modules and the customized integrated module are used to run the simulation and the respective results are compared.
4.1. MATSIM

4.1.1. Structure
MATSim has a closed loop modular structure (Figure 1). The “Initial Demand” module consists of the agendas of each agent. These plans are simulated in the “Execution” module and the “Scoring” module counts the utility of the simulated plans. The “Replanning” module replans the agenda by changing the starting time, duration for the activities and routes to be followed based on the utility of last simulated plan. The iterative process runs for a configurable number of iterations.

![MATSim Structure Diagram]

FIGURE 1: MATSim Structure (17)

4.1.2. Process
MATSim has an iterative process where initial plans of the agents are optimized based on the co-evolutionary algorithm considering network constraints. The optimization process does not only include route choice but also incorporates time choice (18) and mode choice (19).

The process starts by selecting a plan for each individual (agent) out of the set of plans of an agent. The number of plans in each set is fixed and defined in the configuration file. The changes in the selected plan are made using a randomly selected strategy out of the replanning strategies defined in the configuration file. Then the simulator simultaneously simulates the new plans of all the agents on the network. After each simulation, each plan is scored. The new plan is added to the set of plans. The set of plans have a fixed size, if the number of plans in the set is already equal to the set size, then the plan with the lowest score is eliminated. Keeping plans with the highest scores gradually increases the overall average scores of individuals as well as the average score of the whole population.

4.1.3. Input Data
The minimum required data to run a simulation are stored in the following files:
- **Config**: Simulation parameters i.e. number of iterations etc. are defined in this file.
- **Network**: It contains details about the available road infrastructure for the simulation. It consists of two elements, named as nodes and links. Nodes are defined as x-y coordinates whereas links connect the nodes.

- **Population**: This file contains agents’ ids and a set of plans for every agent. A plan contains details about activities to be performed and about the travel to reach the activity locations.

### 4.1.4. Mobility Simulators (MobSim)

The Multi-Threaded QSim is the default MobSim used in MATSim. QSim is a queue-based simulation in which traffic dynamics are modeled with waiting queues (2). The Queue based approach is adopted due to its computational efficiency as MATSim has to deal with large scenarios. Other details of multi-threaded QSim are explained in (20).

### 4.1.5. Scoring

Once the simulation has been completed, the score is calculated for each plan. Scoring is the customizable procedure in MATSim. The Charypar-Nagel scoring algorithm is the default scoring function in MATSim.

#### 4.1.5.1. Default Scoring Function - Charypar-Nagel

Figure 2 (17) shows the graphical representation of the Charypar-Nagel scoring algorithm. The x-axis represents the time and the y-axis shows utility(score). According to algorithm, when an activity is performed, a positive utility is added to the agent’s score. Furthermore, a negative utility is added to the score for travelling. No utility is added for being idle i.e. waiting time before start time of an activity.

![Graphical representation of Charypar-Nagel Scoring Algorithm](image)

**FIGURE 2: Charypar-Nagel Scoring Algorithm**

The mathematical formula for calculating the utility is given in equation (1)

\[
Score = V = \sum_i (V_i^{\text{perf}} + V_i^{\text{late}}) + \sum_j V_j^{\text{leg}}
\]  

(1)

The total score is the sum of the score of each activity to be performed and of each trip to reach the activity location. The score of each activity “i” is the sum of three terms. The terms are
specified as follows:

- **\( V_{i}^{\text{perf}} \) = Reward (positive utility) for performing on activity**

Equation (2) shows the positive utility associated with performing an activity that is related to the actual time spent on performing the activity (\( t_{\text{perf}} \)) and the typical time duration for performing the activity (\( t_{\text{typ}i} \)). There is a slope constant (\( \beta_{\text{dur}} \)) which defines marginal utility of time (same for every activity). Usually it is positive because performing an activity for a long time adds more positive utility. By default, it is set as +6. \( t_{0,i} \) is the offset at which utility starts to become positive (executing the activity for less than \( t_{0,i} \) is equivalent to drop the activity completely).

\[
V_{i}^{\text{perf}} = \beta_{\text{dur}} \times t_{\text{typ}i} \times \ln\left(\frac{t_{\text{perf}}}{t_{0,i}}\right)
\]

For \( t_{\text{perf}} > t_{0,i} \)

- **\( V_{i}^{\text{late}} \) = Penalty (negative utility) for arriving late**

Equation (3) shows the negative utility associated with being late to reach an activity location. The negative utility is directly related to how late an agent has arrived (\( t_{\text{late}} \)) and a slope constant (\( \beta_{\text{late}} \)) which is by default set as “-18” in MATSim.

\[
V_{i}^{\text{late}} = \beta_{\text{late}} \times t_{\text{late}}
\]

- **\( V_{j}^{\text{leg}} \) = Penalty (negative utility) for travelling**

Equation (4) shows the negative utility associated with travelling from one activity location to another. The negative utility is sum of four parts: (1) the product of the travel time (\( t_{\text{trav}} \)) and a constant (\( \beta_{\text{travel,mode}} \)) associated with the specific transport (2) the money spent on travelling (\( m_{\text{trav}} \)) (normally in the form of toll or fare) and on the marginal utility of money (\( \beta_{m} \)) (3) the distance travelled (\( d_{\text{trav}} \)), its marginal utility (\( \beta_{\text{dist,mode}} \)), mode specific cost per unit distance (\( \gamma_{\text{dist,mode}} \)) and marginal utility of money (4) the transfer penalty (\( V_{\text{transfer}} \)) associated with the change of vehicle (normally used for public transport: e.g. taking a connecting train).

\[
V_{j}^{\text{leg}} = \beta_{\text{travel,mode}} \times t_{\text{trav}} + \beta_{m} \times m_{\text{trav}} + (\beta_{\text{dist,mode}} + \beta_{m} + \gamma_{\text{dist,mode}}) \times d_{\text{trav}} + V_{\text{transfer}}
\]

All \( \beta \)-values (constants) are taken from the mode choice logit model of a given case. If the mode choice logit model is not available, default values are used.

### 4.1.6. Replanning Strategies

There are a number of replanning modules available in MATSim that sometimes alternate some parts of the selected plan with the goal to improve overall utility of a plan. These replanning strategies are further divided into two types.
4.1.6.1. Selectors
These replanning modules do not make changes in a plan but choose a plan out of the set of all plans for an agent e.g. Best Score Selector

- **Best Plan:** This module selects the plan with the highest score out of set of all the plans for an agent.

- **Change Exp Beta:** This module changes the already selected plan with a plan having a sufficiently better score than that of selected plan.

- **Keep Last Selected:** This module just selects the last selected plan.

- **Select Exp Beta:** This module selects a plan out of existing plans using a logit model.

- **Select Random:** This module selects a plan randomly through uniform distribution.

4.1.6.2. Innovative Module
Following replanning modules make changes in the selected plan with a goal to improve utility.

- **Re Route:** This module recalculates all the routes of the selected plan by using routing algorithms available in the routing package of MATSim.

- **Time Allocation Mutator:** This module modifies the end time of the first activity of the plan randomly in the range of ±30 mins and activity duration of all the activities are changed except first and last activity with the goal to improve utility of the plan.

- **Change Leg Mode:** This module changes the transport mode for all the legs of the selected plan of an agent.

- **Change Single Leg Mode:** This module changes the transport mode of only one randomly chosen leg of the selected plan of an agent. Hence providing an opportunity to have more than one mode in a single plan and to check whether changing the transport mode for a single leg will improve the utility or not.

- **Sub Tour Mode Choice:** This module changes the mode of transport for a sub tour (trip).

The modular form of MATSim allows the independent use of every module i.e. replanning, scoring (21). The customized replanning and scoring module explained in the next sections are independent of each other (similar to the standard modules) and can also be used individually.

5. Customized Replanning Strategy
One of the main objectives of this research is to investigate the procedure to plug in a new replanning strategy in MATSim. A simple replanning strategy is designed to validate the proposed integration procedure to include a new replanning strategy. The designed replanning
strategy changes the work activity location of those agents according to specific preferences e.g. an agent works at location “A” but he prefers to work at location “B”. The work activity location is changed to the location of agent’s preference. It can be introduced as an attribute of each agent individually in the population file. We assume that if a person has some preferences regarding any aspect of the performing an activity and he performs the activity in his desired way, the perceived utility will be high. Hence the newly introduced replanning strategy changes the location of the activity to a new agent’s preferred location.

The procedure to integrate a new replanning module starts by defining a new strategy. A replanning strategy which is described above has been designed which makes changes in the selected plan. The customized strategy is coded by using a Java class which is an implementation of the MATSim class named “PlanStrategyModule”. The newly made “MyPlanStrategyModule” Java class makes all the changes in the selected plan but the MATSim controller does not use this class directly. We need some methods to link the replanning module class to the MATSim controller. It can be achieved by making a child class of the MATSim module “PlanStrategy”. It acts as an interface between the controller and the replanning function. This class is defined in the “Strategy” module of the config file. The “Strategy” module contains a set of replanning strategies and their respective probability to be used in a specific simulation. This module communicates to the controller to use one or more replanning strategies. The class “PlanStrategyModule” is implemented with the name “MyPlanStrategyModule” which contains our newly designed replanning strategy.

```java
public class MyPlanStrategyModule implements PlanStrategyModule
```

The flow chart in Figure 3 shows the replanning process which contains different steps that are discussed in detail below:

Step 1: A plan is selected for replanning by “MyPlanSelector” which is an implementation of the class “PlanSelector”. Firstly, the plan selector class checks if there is any plan in the set of plans which has not already been selected (known as unscored plan) for replanning. If there is an unscored plan, it selects the unscored plan. Otherwise a plan is selected randomly.

```java
class MyPlanSelector implements PlanSelector
```

Step 2: Person ID of the selected plan is checked in order to find the specific group of people (in our case, people having preferences regarding work location).

Step 3: The replanning function looks in the selected plan for “PlanElements” of the type “activity”.

Step 4: Checks whether the activity is of the type `work`.

Step 5: Change location

FIGURE 3: Customized Replanning Module
Step 5: If type of activity is “work”, the coordinates of activity “location” are changed to coordinates of new location which is supposed to be a preferred work location of an agent. As mentioned above, the MATSim controller does not directly use the replanning function. Hence we implemented the “PlanStrategy” module as “MyPlanStrategy”. The controller uses the “MyPlanStrategy” to link the new replanning function with the replanning strategy module.

public class MyPlanStrategy implements PlanStrategy

At the end, we need to set our config file to use the “MyPlanStrategy” as a replanning strategy; this is done by defining it in the “Strategy” module. The given code shows the strategy part of the config file where replanning strategies are defined. The config file snippet below shows that only the newly introduced replanning strategy is being used for the replanning process. The probability of the new replanning strategy is “1” which means that every plan will be replanned by using this replanning strategy.

6. Customized Scoring Function

The default scoring function of MATSim is already explained in detail in Section 4. The default scoring function scores all the agents in the same way for a specific simulation. In a simulation, the agents having different attributes are treated in the same way to assign a score due to constant scoring parameters (discussed in Section 4.1.5). This is not the case in the real life. Everyone has different attributes and perceived utility of performing the activity is different for each agent. Hence, a customized scoring function is required for scoring an activity with respect to special attributes of the agents or for scoring any special event happening in the simulation. Apart from the default MATSim calculations, each agent needs to create a customized scoring factory to receive persons or events as input and can give a score to them by using a new technique. We assumed that an agent’s perceived utility is high if it works at a location of his choice. We added an extra utility of 100 to the score of those agents who change work to their location of choice. This additional utility is added by plugging in a customized scoring function in MATSim. For the customized scoring calculation, a customized “ScoringFunctionFactory” is implemented. The controller is prompted to use the new scoring factory by using the following command;

controller.setScoringFunctionFactory(new ScoringFunctionFactory())

The new scoring function is defined in the new scoring factory. The scoring function contains the list of algorithms to be used for scoring purpose. These algorithms use planned activities and trip-legs for scoring. The new scoring function receives the agent’s plan as input. The customized function reacts to the events, activities and the trip-legs. The scoring function assigns score to each activity and its associated trip-leg separately within the plan. After assigning score to all activities and trip-legs, the scoring function accumulates the overall score
of activities and the trip-legs. The sum of scores of all the activities is returned. The new scoring factory is created by using the following command.

```java
public ScoringFunction createNewScoringFunction(Person person)
```

In the “ScoringFunction” function, the basic MATSim scoring algorithm for the scoring normal activities and trips is used. An additional function is coded in the “ScoringFunction” to add an additional score of 100€ to the score of the agents who performed the work activity at a location of their choice. The “ScoringFunction” function checks if the agent belongs to group of people who have some preference regarding the work location. If the agent belongs to the mentioned group, the coordinates of the work location is compared with the coordinates of its preferred work location. If the coordinates match, an extra score of 100 is added to the score. The sum function adds all the scores, calculated by the basic algorithm and also by the newly embedded scoring function. The sum function returns the total calculated score of each agent.

![Diagram](image)

**FIGURE 4: Scoring Procedure**

### 7. Simulation Experiment and Results

An experiment was designed to validate the proper integration of the customized modules in MATSim. The details of the experiment are described in detail in the following section, starting from the input descriptions.

#### 7.1. Network Generation

A small network was designed which is shown in the Figure 5. There are four major nodes(corners) labeled as node 1, 5, 21 and 25. The agents have home and work locations near to the corner nodes. All the roads in the network are one way. All the links have a capacity of 100 vehicles per hour and free speed of 27.78 m/s.

#### 7.2. Population

A synthetic population of 1000 agents is created. 250 agents live near each corner node of the network shown in Figure 5. Each agent has a plan which contains the home and work type activities and the mode of travel is car. Following code shows an example of an agent’s plan.
7.3. Simulation Results and Discussion

Three simulations are conducted using following combinations of replanning strategies:

- New Replanning Strategy Only (explained in Section 5)
- Best Score, Re-Route and Time Allocation Mutator (MATSim Replanning Strategies)
- New Replanning Strategy, Best Score, Time Allocation Mutator

These combinations are selected in order to see the trend of utility without the new replanning module, the effect of new replanning strategy on utility when it is used alone and when it is used in combination with MATSim replanning strategies. For each simulation, the default “MobSim” is used for simulating the plans and the new customized scoring is used. The
number of iterations per simulation is 10 and an agent can hold maximum 5 plans. In the experiment only 250 agents out of the 1000 agents are rewarded with positive utility for relocating their work location to a place of their preference using the new integrated replanning module. This configuration is adopted to clearly explain the increasing trend of average utility of the whole system over the iterations by inclusion of agent’s attributes in the replanning process.

All the figures shown in this section are MATSim generated outputs. These figures show the average score of all the agents for each iteration. The blue line represents the average of the best plan scores of each agent. The green line shows the average score of all the plans of each agent while for the average worst plan score, the red line is used.

7.3.1. Simulation 1: Using New Replanning Strategy Only

In the first simulation, only the new customized replanning strategy is used for replanning purpose. The graph in the Figure 6 represents the results of the simulation. In the first iteration, the customized replanning strategy changes the work location of those agents who have a preferred location to their preferred location. Hence an additional score is added to utility of those agents who have the work location of their choice. All others agents follow their initial plans and does not get any additional utility. The overall average best score increases which can be seen by the slope of the blue line. For the remaining iterations, there is no change in the blue curve because the best available plan for every agent is already achieved in the first iteration. Before explaining the behavior of the red and the green curves, it would be better to recall some important information about MATSim. Each agent has a limited amount of plans to hold (e.g. 5 plans in this case). In each iteration, MATSim only selects one plan for each agent and change it by using the replanning strategy. For each agent the MATSim plan-selector takes the unscored plan (if any) first. If there is no unscored plan, a plan is chosen randomly. If we examine the red curve, it does not change till the 5th iteration. It is due to the unscored
plan in every agent’s set of plans. By the end of the 5th iteration, each plan is selected once and replanned. The red curve goes up to the maximum possible best score. The gradual slope of the green curve shows a continuous increase in overall average scores over the number of iterations. All the curves do not change after the 6th iteration because every plan of each agent is optimal now. More changes will not result in a better score.

7.3.2. Simulation 2: Using Best Score, Re-Route and Time Allocation Mutator

The graph in Figure 7 shows the results of the simulation used by the built-in strategic replanning modules. The Best Score, Re-Route and Time Allocation Mutator strategies are used with respective probability of 0.1, 0.3 and 0.6. All the curves do not have a smooth increasing trend over all the iterations due to availability of a lot of replanning options. It can be observed from the graph that the rate of increase in average best score and average score is high. It shows that there is a great room for improvement in the initial plans of agents. After the first iteration, the increase is gradual. The downward slope of the red curve shows there is some kind of congestion or traffic jam. This trend continuous till the 5th iteration. After the 5th iteration, the average worse stars rising. It can be observed that peak values are not settled yet. It indicates that there is still scope for improvements in the plans and more iterations are required to reach a relaxed state.

![Score Statistics](image)

**FIGURE 7: Simulation Score (MATSim Replanning Modules Only)**

7.3.3. Simulation 3: Using New Replanning Strategy, Best Score, Time Allocation Mutator

The graph in Figure 8 shows the results of the simulation using the built-in strategic replanning strategies (Best Score & Time Allocation Mutator) as well as our customized replanning strategy. The probability of strategies to be used is 0.1 for Best Score, 0.6 for Time Allocation Mutator and 0.3 for our customized replanning strategy. The result(graph) of the third simulation is similar to the results of the second simulation. But the score values of the last simulation are higher than those of the other two simulations. The score is the highest in the simulation using both built-in and customized replanning strategies. As there are other replanning modules available in this simulation, the probability of the customized replanning module to be used was less than one. There would be fewer people who have used the customized replanning module and got the additional score. Still the average scores are higher.
than those of the simulation using only built-in MATSim replanning strategies. This shows that addition of personal attribute in replanning and scoring functions can lead to increased overall utility. The graph also shows that there is still some opportunity for improvement. It takes more iterations to come to a stable score level.

![Score Statistics](image)

**FIGURE 8: Simulation Score (Customized and MATSim Replanning Modules)**

### 7.3.4. Discussion

The procedure to integrate a new replanning module that includes the attributes and behaviors of person in MATSim simulations is convenient. The increase in the average of best scores supports the fact that including the personal choices of the agent does not only increase the utility of the agent individually but also increases the utility of the system. In the experiment, we assume people have high perceived utility for doing work at a location of their preference. The utility added to agent’s score for working at his preferred place is arbitrarily chosen constant (100). For the 2\textsuperscript{nd} and 3\textsuperscript{rd} simulations, more iterations are required to reach a relaxed state where agents are left with no option to improve the score.
8. **CONCLUSION**

The integration framework of a customized *replanning* module in MATSim is presented in this research study. It shows how to introduce new replanning techniques making use of personal attributes. The addition of personal attributes in the replanning process can be helpful to understand the individuals’ thinking about their time utility. The personal attributes can also have influence on the overall system utility and it can be studied by using this approach. A customized *scoring* function is also integrated in MATSim in accordance to the introduced replanning strategy. The customized scoring function can be used to score some special events or activities. It can also be used to score the effect of personal attributes in the replanning process. The inclusion of personal attributes can help in understanding the perceived utility behavior at individual level. In the study, an attribute regarding relocation of work activity is included. The simulation results also show the importance of the agent’s personal attributes in the replanning process.
REFERENCES


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**Daily plan (schedule) adaptation in MATSim**

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Voor akkoord,

**Ali, Sadaqat**

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