THE TECHNICAL OPPORTUNITIES AND SEMIOTIC PITFALLS OF MULTI-ACTOR SYSTEMS

Support, Planning and Communication between Marketing, Dispatchers and Passengers within the Netherlands Railways

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Abstract: In innovating its planning processes, passenger involvement in dispatching is one of the directions the Netherlands Railways is exploring. Multi-agent systems provide a way to study organizational aspects of such a change in the dispatching task that aims to bridge cultural differences between passenger and dispatcher. In this study, the cognitive, coordination and semiotic implications are investigated. Two versions of a multi-agent system have been constructed: NS-MAS 1 and NS-MAS 2. The involvement of active passengers as is realized in NS-MAS 1 provides the organizational specifications of realizing dispatcher-passenger communication. Furthermore, this implementation provides indications for bridging the cultural differences between passengers and dispatchers. NS-MAS 2 operates with passive passengers, simulated based on statistical data on passenger movements, and indicates the coordination possibilities involved with passenger involvement in dispatching.

1 INTRODUCTION

The realization and support of planning and dispatching in the Netherlands Railways (Nederlandse Spoorwegen, NS) requires problem solving, technical and communication skills of various stakeholders. The stakeholders are diverse. They include planners and dispatchers who plan, re-plan and communicate, the marketing department that wants to maximize customer satisfaction and the passengers who want to travel from A to B as convenient as possible. Essential in balancing the various parties in planning is the determination and valuation of constraints and goal functions. Planning is a coordination task and "is the attunement or assignment of multiple object types (such as carriages, ticket collectors, engine drivers and arrival and departure times), taking into account constraints and goal functions" (van Wezel et al., 2006). As long as only planners and dispatchers make the plans, the choices and priorities of constraints and goal functions are reasonably coherent and unanimous. However, as soon as other parties enter the problem solving space, conflict constraints and contradictions may arise. For example, if reduction of travelling time of a passenger in case of a detour after an incident is taken into account by a dispatcher - and this is not the normal situation - other than the usual plans have to be generated and other constraints become relevant. For planners, who only think in terms of "replacing carriages over time and place", the concrete goal function of minimizing detour time and communicating these goals with non-planners, is new and therefore different. Then besides technological and algorithmic skills, cultural backgrounds affect the interaction between people in the planning situation (Daft, 2001). A group's rituals, norms, and symbols result in a collection of beliefs that is specific to that group. This collection of beliefs governs the behaviours of the individuals within the group. Because the rituals, norms, and symbols are group specific, they are often a cause for misunderstanding within group interactions.

The case that is presented here resides within the context of the NS. The NS daily transports one million passengers. Transportation takes place with the help of 2,700 railroad carriages, which approximately run 5,000 train services per day. The

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trains run between 384 stations in the Netherlands. Within the NS, five kinds of planning divisions exist. The first concerns timetables and other plans. The second concerns the partitioning in planning rolling stock and planning rolling staff. The third concerns the partitioning in local planning and central planning (of stock and staff). The fourth concerns the distinction in year plan (long term) and day plan (short term), again of stock and staff and the last is dispatching, meaning solving problems at the day of execution because of accidents, delays and detours. Overall approximately 400 planners are continuously involved in making plans and schedules.

Our study only concerns dispatchers. Until recently, planning within the NS was only a matter for planners and dispatchers. Because of the increasing technological possibilities of planning support, advanced telephone communications, AI and agent software, and Internet, the NS is studying the influence of the marketing department and of preferences of active and passive passengers. We will explain the details later. This changing perspective and its complicated consequences is studied with the help of Multi-Actor Systems (NS-MAS). As the term MAS already indicates various (kinds) of actors are then involved jointly solving the re-planning or dispatching puzzle. Kinds of actors are of course the human dispatchers, but also software agents with different levels intelligence. Apart from its technical implementation, a MAS requires attention for and decisions about a) what kind of information is relevant for whom at what time and who understands this information, b) how the coordination between actors is realized, who is responsible for what and c) which minimal requirements regarding signs and symbols are relevant for meaningful communication. The first question requires a cognitive answer or perspective, the second an organizational answer and the third a semiotic answer (Klos, 2000; van den Broek, 2001; Helmhout; 2006). We will come back to this.

The dispatching task involves a series of actions performed by a dispatcher that are intended to recover from a disruption in the railways network, with the objective to restore the original train timetable as quickly as possible. Disruptions are delays, train or railway breakdowns, or other causes for the train service to deviate from the planning, which are the cause for imbalance of available material (i.e. trains and wagons) and personnel (i.e. engine drivers and ticket collectors). The objective of the dispatcher's task is re-planning for certain periods of time (e.g. 4 hours). This objective narrows the dispatcher's task down to a problem solving activity (Newell & Simon, 1972; Simon, 1977; Laird et al., 1986), in which material, personnel, and timetable comprise the problem space. From this perspective, the dispatcher is concerned solely with the components that relate to the Netherlands Railways transport service. Until now, dispatchers do not take into account actual (individual or aggregated) passengers, their preferences, or marketing goals.

For most transport situations of the Netherlands Railways, the load consists of passengers who use train service as a means to get from A to B. Unlike cargo, passengers are actors that behave intelligently. They are able to deal with delays in their planning, by choosing the exact train they will use taking into account some slack. Delays that exceed this slack time result in passengers unable to complete their journeys as planned. The specific solution the dispatcher implements to overcome a disruption does not explicitly include the desires of affected passengers. The chosen solution might benefit a particular passenger. However, because neither passengers nor their desires are considered when a dispatch action is devised, no certainty about the effects of a dispatching action exists for passengers.

This research wants to bridge the distinct cultures of dispatchers, marketers and passengers, constructing a multi-actor system that connects dispatchers' practices to passenger experiences and preferences. Such inclusion of passengers in dispatching changes the original problem space. Where in the original situation the problem space only contains non-cognitive elements (i.e. timetable and trains) and few cognitive elements (i.e. personnel), the new problem space will contain many intelligent agents (i.e. passengers and AI software). The purpose of the multi-actor system (NS-MAS) is threefold.

First, the system's objective is to provide insights into the required communication and possible coordination structures between dispatcher and passengers. Currently, dispatcher and passenger only communicate indirectly and one-way through the measures taken by the dispatcher. In order to take into consideration passenger preferences in developing a dispatching measure, two-way communication between dispatcher and passenger is required. How such two-way communication should be organized needs to be determined. Coordination in dispatching is absent in the current situation: the dispatcher decides which dispatching measure is taken; passengers play no role. Actively involving passengers in dispatching opens new coordination possibilities, for then an additional deciding actor, the passenger, becomes part of the dispatching task.

The second objective of the study is to investigate the role of knowledge in passenger involvement in the dispatching task. This objective links to two complementary sorts of knowledge. The first sort concerns the knowledge that needs to be included about passengers in order to realize passenger involvement. For perspectives are different between dispatcher and passengers, knowledge about passengers will be needed to bridge the difference and facilitate knowledge exchange. The second sort concerns the question what knowledge a passenger should provide in case s/he is assigned an active role in dispatching.

The third, more practice oriented objective of the multi-actor system is to provide insights into the effects of alternative dispatching measures on passenger opinions. Alternative measures might result in equally suitable solutions from the traditional perspective (i.e. balancing material and personnel, and restoring the original timetable as quickly as possible) but render different responses from affected passengers. This is interesting for the marketing department of the NS

In this paper, we discuss the developed multi-actor system in more detail, focusing specifically on its functionality and the effect on the dispatching task. The MAS has been developed in two versions (1 and 2). Each version has its specific functionality. The first version (NS-MAS 1) focuses on realizing communication between dispatcher and real, active passengers, through for instance a mobile device. The second version (NS-MAS 2) concerns an extension of the first version, enabling communication between dispatcher and simulated, passive passengers, and enabling the use of more complex dispatching measures. In the second version, statistical data was used to initialize these passive passengers. We first provide an overview of the functionality that was realised in NS-MAS 1. Second, the functionality of the second version is discussed in detail. Both versions of the multi-actor system have been implemented in the Java Agent DEvelopment Framework (Jade, 2007; JADE; Bellifemine et al., 2007). The Prometheus Design Tool and methodology (Prometheus, 2007; Padgham & Winikoff, 2004) have been used to design the multi-actor system.

2 NS-MAS WITH ACTIVE PASSENGERS (NS-MAS 1)

In a MAS, humans and software agents collaborate to solve the problem at hand and construct a solution that combines logistics and passenger preferences (Gazendam, 1990; 2003). Besides humans (dispatchers and passengers), two types of software agents are used. First, relatively autonomous agents are part of a MAS. These agents ensure the internal functioning of the MAS, primarily relaying messages. Second, NS-MAS 1 consists of intelligent assistants. Identified passengers are represented as intelligent assistants. If a passenger identifies himself to the MAS, an intelligent assistant is constructed to represent him. In addition, a dispatcher is assigned an intelligent assistant. The agents differ in terms of cognitive complexity and cognitive possibilities. The questions in the research are threefold. First, to what extend should intelligent software assistants have search and decision authority. Second, what kind of coordination mechanism is suitable to combine humans and various kinds of software agents, and third what does communication entail in terms of signs and symbols.

The objective of the system has been to enable the incorporation of passenger preferences in dispatching, such that dispatchers would consider passengers in the solutions they develop. In NS-MAS 1, passengers register themselves with the multi-actor system and specify their travel plans for the journey(s) they will make at a specific time and date. These passengers are called active passengers, for they are able to actively communicate with the dispatcher by means of intermediary software agents.

Taking passenger preferences into consideration demands that dispatchers and passengers are able to communicate. Version one of the multi-actor system realizes two-way communication between dispatcher and active passengers; a dispatcher communicates timetable information to passengers (i.e. the effect of a disruption on the timetable, and of the dispatching measure s/he suggests on the timetable), and passengers are able to react and respond to these. Dispatching measures, devised by the dispatcher, are communicated to the multi-actor system, which forwards these towards passengers' mobile devices. After being informed about a planned dispatching measure, a passenger can respond by assigning it a grade from 1 (undesirable) to 10 (very desirable). All passenger responses are gathered and presented back to the dispatcher. The dispatcher can then decide whether the suggested dispatching measure is implemented or an alternative solution needs to be developed.

Though presented as a straightforward process, communication between dispatcher and passengers concerns a complex interaction involving fundamental differences in culture and language. Dispatchers are concerned with restoring timetable functioning, and think in terms of timetable information. The solution that restores the original timetable as quickly as possible is regarded as the best solution. In contrast, passengers only care about the journey for which they use the train service. For the NS-MAS passengers are modeled such that they use the concepts travel time, train changes, and comfort in relation to their journey. Any disruption or delay that hinders them to finish their journey in the planned time is undesirable. Organizing communication between dispatcher and passengers has been the main functionality that was implemented the first version of the system. Realizing this function required two main elements. First, the communication channel needed to be built. Second, the language difference that exists between dispatcher and passengers needed to be bridged.

Communication between dispatcher and passenger is realized through three main software agents, namely the Planner, TravelManager, and TravelCoach agents. The Planner and TravelCoach agents are intelligent assistants and form interfaces between human actors and the NS-MAS. The Planner agent interfaces between (human) dispatcher and NS-MAS. The Planner agent receives inputs regarding delays and disruptions (see Figure 1), and dispatching measures from the dispatcher, and forwards these to the TravelManager agent. Reversely, the Planner agent transmits passenger response information it receives from the TravelManager to the dispatcher. The TravelCoach agent is the interface between the system and one passenger, and interacts with the passenger regarding travel information, i.e. delay and disruption information, and dispatching measures. The TravelManager agent connects the Planner and TravelCoach agents, and facilitates internal communication within the multi-actor system. Figure 2 shows the graphical user interface of the TravelManager agent, used to monitor and control the agent's behavior.

The content of the communication has been conceptualized in one ontological model, integrating dispatcher, passengers and various software agents. The main distinction between concepts used by dispatcher or passenger lies in the level of

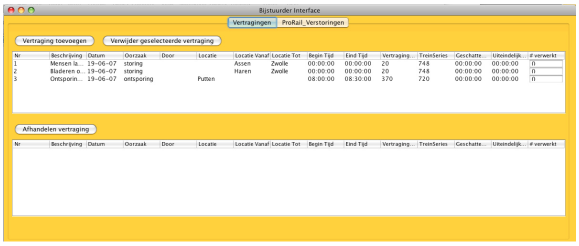

Figure 1: Planner user interface.

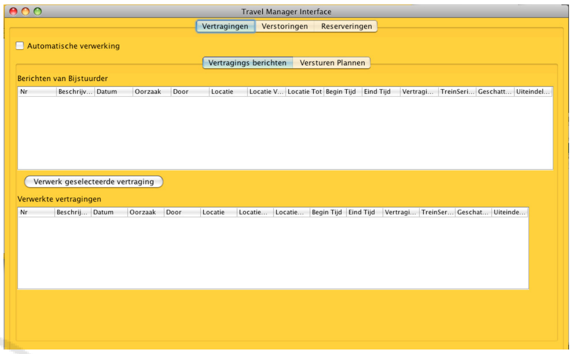

Figure 2: TravelManager user interface.

aggregation and abstraction. Due to his task, a dispatcher considers the railroad network as a whole, especially the train services using the railroad network in the region he is responsible for. A dispatcher's knowledge of the railroad network consists of start and end station of the line, intermediate stations, the line's timetable, and other parts of the railroad network the line passes. Passengers consider the same railroad network from the perspective of their individual journeys, which translates to one specific route that is taken by the passenger from his / her place of departure to his / her destination, stations where s/he needs to change trains and particular times involving the actions of boarding and alighting.

Dispatchers formulate dispatching measures in terms of adaptations of lines, speeding up or slowing down a line at specific points of its path, removing or adding stops to its path, shortening the line's path by making the line return before reaching its final station, or taking the line out of service completely. Such dispatching measures need to be translated to the route that the individual passenger travels. Within the NS-MAS, the first step is to identify those passengers that are affected by the dispatching measure. This is the responsibility of the TravelManager agent. Because active passengers have registered themselves and the travel plans of the journeys they make, the TravelManager is able to lookup the affected active passengers. After having determined which passengers are affected, the TravelManager determines the effect of the dispatching measure on the travel plan of the affected agents. This agent subsequently constructs new travel plans for each individual active passenger and communicates these plans to these passengers' TravelCoach agents. The TravelCoach agents show the new travel plans to their connected active passenger and ask for a response. The passenger responds by assigning a grade between 1 and 10 to the new travel plan. All grades from affected passengers are communicated back by their TravelCoach agents to the TravelManager. Once all responses have been gathered, the TravelManager aggregates and categorizes the responses of the affected active passengers into five categories, reaching from "dissatisfied" to "satisfied". Frequencies per category are communicated to the Planner agent, which in its turn informs the (human) dispatcher about the outcome.

From a cognitive perspective, the characteristics of the software agents are poor. They are communication and ordering agents with the help of simple algorithms. From an organizational view, the leading coordination mechanism is authority and hierarchy. The dispatcher is the boss and the ultimate decision maker. The semiotically interesting points are that dispatcher and passenger use a different semantics whereas software agent can only exchange meaningful information by means of the human actors (Jorna, 2009; Helmhout et al., 2009).

3 NS-MAS WITH PASSIVE PASSENGERS (NS-MAS 2)

The second version of the NS-MAS extends the initial version in two directions. First, the system is extended to be able to use statistical data about passenger movements through the railroad network to construct (aggregated) simulated passengers. To contrast them with active passengers, these simulated passengers are labeled passive passengers. Passenger movement data that has been gathered consist of data about the station of departure and destination, ticket type used for the journey, travel motive, and the frequency a passenger travels by train. These data are used to construct passive passenger agents in NS-MAS 2. The second extension concerns the handling of more complex dispatching measures. The initial version only is capable to process changes in times and stops of train lines. In NS-MAS 2, dispatchers are able to introduce detour scenarios to passengers. Whenever a part of the railroad network is out of service due to for instance a derailed train, a detour scenario provides dispatchers the addition to relay passengers around the blocked part of the network. Additionally, passengers are provided a solution to continue their journey with only a minimum delay. The two extensions that have been realized in NS-MAS 2 imply various changes to the initial prototype. The required changes are discussed subsequently, starting with the extension to incorporate statistical data to simulate passive passengers.

Three software agents have been added in NS-MAS 2 to implement the handling of statistical data to simulate passive passengers. First, the StatisticalManager agent manages all statistical data. Upon receiving a request to provide data about a specific line, this agent responds with the amount of passengers that make use of that particular line and their travel plans in terms of station of departure and destination. The CommunicationManager (Figure 3 shows its graphical user interface) is the intermediate between the TravelManager and the StatisticalManager and responsible for creating passive passenger agents. Finally, a StatisticalPassenger agent represents a passive passenger. The StatisticalPassenger agent provides a response to any dispatching measure it receives, similar to the response an active passenger provides (a grade between 1 and 10).

Communication between agents largely follows the same pattern as in NS-MAS 1. The TravelManager remains responsible for communication between the dispatcher (Planner agent) and the passengers (multiple StatisticalPassenger agents). The main difference between NS-MAS 1 and NS-MAS 2 relating to communication is associated with the creation of passenger agents. The communication that ensures correct passenger agent creation is displayed in Figure 4. Prior to starting communication with them, passive passenger need to be instantiated. Upon reception of delay or disruption information, the TravelManager agent forwards this information to the CommunicationManager, requesting the creation of affected StatisticalPassenger agents.

When receiving a message from the CommunicationManager that passenger creation has finished, the TravelManager forwards delay and disruption information to the StatisticalPassenger agents.

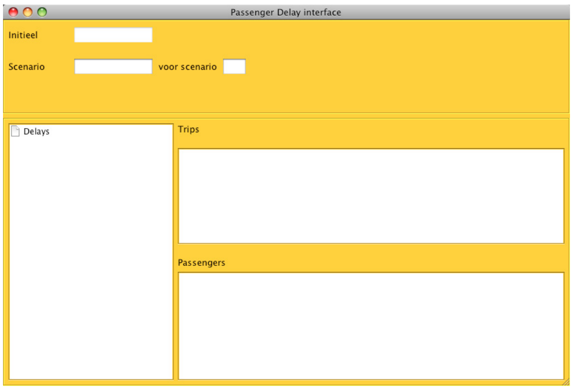

Figure 3: CommunicationManager user interface.

Communication between TravelManager and StatisticalPassenger agents about dispatching measures and passenger responses follows the same communication pattern that exists between TravelManager and TravelCoach agents as described in the previous section.

Enabling detour scenarios in the multi-actor system required a change in the content of communication between the TravelManager and StatisticalPassenger agents. The content of communication closely follows the implementation of the initial version. Again, an ontological model is used to bridge the different views of the railroad network that exist between dispatcher and passenger. Figure 5 shows the ontological model that has been constructed for NS-MAS 2, in UML (OMG, 2009) notation. However, in the initial version the Travel-Manager agent was responsible for translating dispatching measures to the travel plans of individual passengers. In NS-MAS 2, the TravelManager only communicates his dispatching measures in terms of changes he has made to the original timetable of lines to the StatisticalPassenger agents. The latter translates these changes to their own travel plans. Also, the TravelManager communicates replacing lines to passengers. If for instance, a passenger cannot complete his journey because s/he arrives too late to get onto a connecting train, the TravelManager provides the information about an alternative train in the same direction. In a similar fashion, the TravelManager agent is able to communicate detours to passengers, replacing lines within a passenger's travel plan with an alternative route. With NS-MAS 2, the TravelManager agent's routing and travel plan calculations have been distributed to the individual StatisticalPassenger agents. Additionally, StatisticalPassenger agents have been made more ontologically rich, for these agents are equipped with knowledge to understand and process changes to lines, in addition to knowledge about their own travel plan. The behavior of StatisticalPassenger agents however, has been implemented as a mathematical function that calculates a comfort grade. The comfort grade is calculated by comparing the original travel plan with the new travel plan that incorporates the suggested dispatching measure. The comfort grade is a function of the travel time of the original travel plan and of the new travel plan.

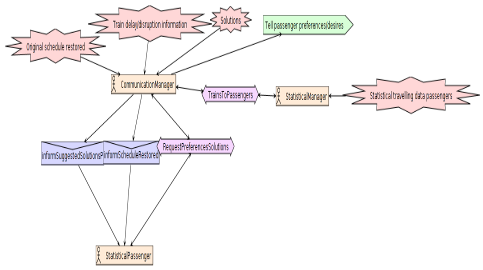

Figure 4: Communication specification NS-MAS 2.

From a cognitive point of view, the software agents are much richer than in NS-MAS 1. They combine, order, and integrate as if they were intelligent actors. They do more than just handle and exchange messages. From an organizational point of view, the dispatcher still is the boss, but he is working with intelligent software agents that take work out of his hands and that he has to trust. It is therefore still authority that is the coordination mechanism, but the question can now easily be formulated at what moment an in which circumstances can the software agents be autonomous? From a semiotic point, the communication is less rich than in NS-MAS 1. Semantic and pragmatic considerations are left out of NS-MAS 2.

4 THE OPPORTUNITIES AND PITFALLS OF NS-MAS

Traditionally, dispatching is a problem-solving task within a predefined problem space (Simon, 1977). A dispatcher is required to as quickly and efficiently as possible restore a train service according to the original timetable. Within this space of timetable, train lines, railroad network, personnel, and train material the dispatcher is able to devise any solution that meets a set of criteria. Passenger desires need not be considered in these kinds of solutions.

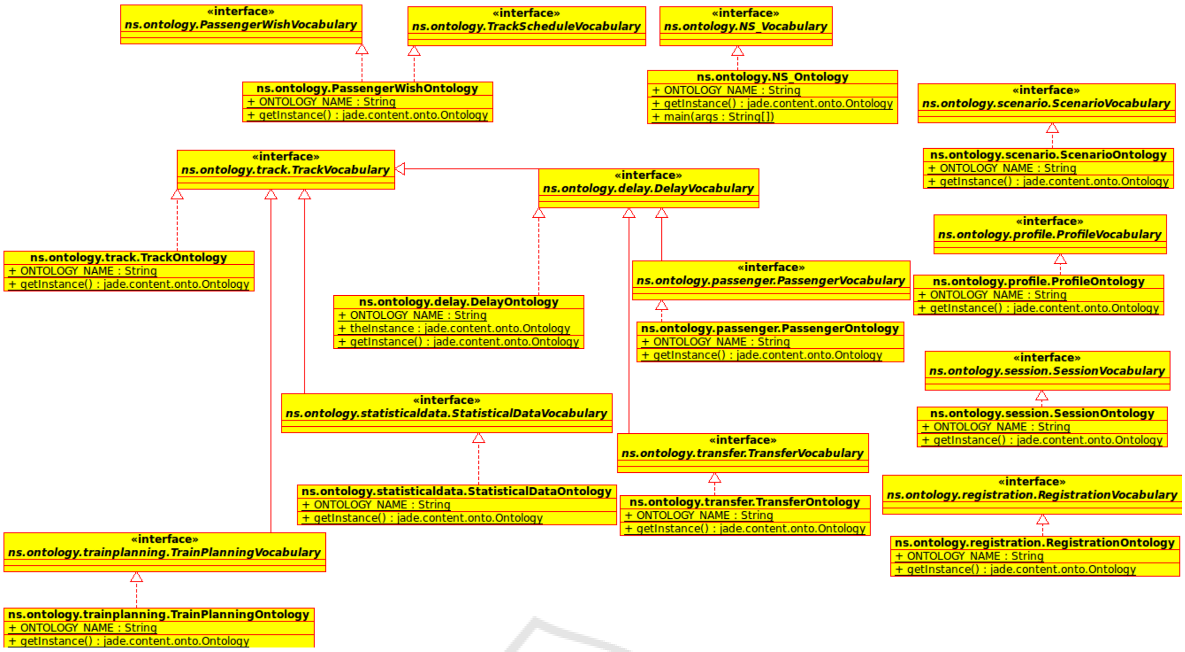

Figure 5: NS-MAS 2 ontology.

Dispatching in a new NS-MAS sense, however, develops towards a form of dispatching in which passengers, i.e., the customers, take a much more important position. No longer will dispatching involve problem solving in a complex, but clearly defined problem space. The incorporation of passenger desires into dispatching requires communication with these passengers at the moment dispatching is required (i.e., at the moment a delay or disruption occurs in train services). This extension of the problem-solving task of the dispatcher increases its complexity even further. The dispatcher needs to combine known, stable components from the original problem space with unpredictable, intelligent passengers; unpredictable regarding the specific journeys passengers make, their travel motives, and their positions towards changes in their travel plans. Summarizing, the dispatcher's task transforms from a reasonably well-structured into an ill-structured problem-solving task (Simon, 1973).

Prior to the start of this study for the NS, no clear idea had been developed of how to organize interaction between dispatcher and passenger, nor was clear what knowledge is involved in such interaction. The first version of our NS-MAS provides two main insights. First, it indicates how communication between dispatcher and passenger needs to be structured. Essentially, communication between dispatcher and passengers is a one to many, two-way communication pattern. A dispatching measure needs to be communicated to all affected passengers. Reversely, a dispatcher needs to receive one clear overview of passenger responses to a dispatching measure s/he suggests. In our NS-MAS, the TravelManager has been created as the pivot between dispatcher and passengers. The TravelManager sends a dispatching measure to all affected passengers and receives and aggregates passenger responses and sends this as one overview back to the dispatcher. Summarizing, this NS-MAS provides a structure to organize communication between dispatchers and passengers.

The second insight by the first version of our NS-MAS is the required knowledge that enables dispatcher-passenger interaction. Plainly communicating a dispatching measure to passengers will not. In such communication, knowledge of passengers and dispatcher regarding the railroad network and train services is too different. During the construction of NS-MAS 1, knowledge about the travel plans of each individual passenger has been identified as crucial in order to realize sensible interaction between dispatcher and passenger. Knowing the travel plans of individual passengers enables the translation of dispatching measures to the effect these measures have for passengers. Receiving the effect of a dispatching measure on their own travel plans enables passengers to understand the measure, and enables them to respond knowledgeably. Hence, incorporating knowledge about passenger travel plans is a

Table 1: Overview cognitive skills / coordination in NS-MAS 2.

Agent	Dispat-cher	Planner	Travel-Manager	Active passenger	Passive passenger
Agent / actor	actor	agent	agent	actor	Agent
Cognitive skills	- Change problem space - Apply weights	- Search within problem space	- Pass through information	- Search problem space	- Calcul-ating
Coordina-tion role	Boss	Slave	None / combine	None	None

necessary step towards enabling dispatcher-passenger interaction.

NS-MAS 2 circumvents the largest disadvantage of the initial version, namely the requirement that passengers register their travel plans prior to starting their journey, and that passengers actively respond to suggested dispatching measures. We assume that only a minority of passengers will register their travel plan. This renders the NS-MAS of limited use to dispatchers. Incorporating statistical data about passenger movements, travel motives, travel frequency, and ticket types to create passive passengers removes the dependency on registration of travel plans by passengers. In this way, dispatchers are able to use the NS-MAS for simulation purposes, exploring the responses of passenger to dispatching measures.

In addition to removing the necessity to have passengers registering their travel plans, NS-MAS 2 provides the possibility to specify more complex dispatching measures, than are currently available to dispatchers. Currently, dispatching measures are formulated similar to dispatching in the initial version of the system. Dispatchers only are able to specify that a line is slowed down, or speeded up, or that a line stops at more or less stations than its normal service. Providing detours to passengers currently only is provided at an individual basis by ticket collectors, only in response to a passenger's request. NS-MAS 2 enables dispatchers to explore the effects of detours, thus enlarging the portfolio of dispatching measures they have at their disposal.

This initial version consists of agents that show no cognitive skills, and cannot behave autonomously. According to Wooldridge (2002), the agents in version one therefore are not agents. NS-MAS 2 in contrast, houses agents that are cognitively richer, and are able to respond autonomously to suggested dispatching measures from the dispatcher, namely the StatisticalPassenger agents. Furthermore, version two only deals with one human actor: the dispatcher.

summarizes the various agents existing the in the NS-MAS, their cognitive abilities, and their roles in coordination. The presented NS-MAS is a hybrid system; it connects human actors and software agents. Together, actors and agents participate in the problem-solving task of dispatching. However, the two versions of the NS-MAS facilitate this cooperative mode of problem solving in distinct ways. In NS-MAS 1, software agents only relay and transform messages between dispatcher and passengers.

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From an agent perspective, versions NS-MAS 1 and 2 show similarities from a coordination perspective. In both versions the initiative and decision making power lie with the human actor(s). Dispatchers take the initiative in communication. Eventually, they also decide what dispatching measure is brought into effect. Passengers, irrespective of being active or passive passengers, have the possibility to express their thoughts about a suggested dispatching measure. Their decision making space however is limited to assigning a grade to the suggested measure. Both versions show a hierarchical coordination mechanism, in which the dispatcher is the authority and holds decision power; passengers are subordinates without any authority or power. Passengers only provide their opinion about the devised dispatching measure to the dispatcher. The dispatcher still has the choice to consider these opinions when choosing what measure to implement.

Coordination within the multi-actor system however does not have to follow the pattern as described above, in which authority and power remain with the dispatcher. The provided description closely follows the current organization of the dispatching task within the Netherlands Railways. As indicated, the NS-MAS primarily facilitates communication between dispatcher and passengers. This communication is a necessary element in coordination between dispatcher and passenger, enabling a broader spectrum of coordination configurations than the mechanism just described. A possible scenario could be to distribute authority among the passengers that are affected by a disruption in train service, and let passengers together come up with a solution that i) restores the balance in material and personnel, ii) ensures train service to continue according to schedule as quickly as possible, and iii) aids affected passengers in continuing their journeys or relaying their journeys as comfortable as possible. Additionally, passengers could be granted the decision power to implement the suggested dispatching solution. In such a scenario the dispatcher's task shifts from a problem solving to a coordination and implementation task.

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