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Towards Agent-Based Scenario Development for Strategic Decision Support

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ABSTRACT

Scenario planning is a method for learning about the future by understanding the nature and impact of the most uncertain and important driving forces affecting that future. However, most scenarios, being mostly stories, lack validation, dynamism and fail to acknowledge all relations between actors, activities and resources. In this paper, we propose an agent-based model for scenario development that tackles these problems by specifying scenarios as agent organizations which makes possible the representation of the global organization strategy, and global goals together with the objectives and requirements of different stakeholders. As a concrete example of agent-based scenario planning, the OperA model for agent organizations is used to create a model scenario for NedTrain, a rolling stock maintenance provider in the Netherlands.

1. INTRODUCTION

The purpose of strategy is to create a good fit between the organization and its business environment. As organizations seek to adapt in a world of rapid change, strategic planning becomes increasingly dynamic and complex. This task takes place in situations that are uncertain and ambiguous, which means that there are multiple equally possible futures to be reckoned with. Strategic planning typically involves establishing or validating an organizational vision identifying corporate values, stake-holders and their goals, objectives and dependencies, and perhaps specifying critical success factors or tactics in support of the goals and objectives. It may also include identification of processes and value chain links or business processes for business process re-engineering [13].

Scenario planning is a method for learning about the future by understanding the nature and impact of the most uncertain and important driving forces affecting that future. It has been advocated as a suitable way to describe views of the future within the context of a business organization [17]. Scenario planning is a group process that encourages knowledge exchange and development of mutual deeper understanding of central issues important to the organization. The goal is to craft a number of diverging stories by extrapolating uncertain and heavily influencing driving forces. Scenarios are powerful planning tools precisely because the future is unpredictable. Unlike traditional forecasting or market research, scenarios present alternative images instead of extrapolating current trends from the present. Nevertheless, classical scenario planning suffers from some pitfalls, one of which being the fact that scenario planning lacks validation tools that enable the evaluation of the proposed scenario, and therefore it will be difficult to reach hard business decisions based solely on scenarios, unless the scenarios are underpinned by facts and sound analysis [5]. Furthermore, being mostly stories, scenarios often lack a clear internal logic (credibility), dynamism, and fail to acknowledge all relations between heterogenous actors, activities and resources [14].

Agent models offer an appropriate route for describing a complex system, by enabling its specification in terms of autonomous components and their interactions. Agent-based models are increasingly recognized as powerful tools for simulating social systems, as they can represent important information about the world not easily captured by traditional models [12]. Agent-based models enable to connect the (heterogeneous) micro behaviour of individual entities to different patterns of macro, or organizational, behaviour. In the same way as scenarios, agent models can be seen as support tools for decision making by proving powerful 'what-if' images of the future. Agent based modelling of organizations provides a natural framework for tuning the complexity of the organization and its components: roles, rules, interactions, individual behaviour, degree of rationality, ability to learn and evolve [1]. Furthermore, agent models enable the identification of unexpected or hidden complexity that would never be revealed by traditional scenario planning.

The development of organizational scenarios calls for models, languages and methodologies to represent interaction, roles and other concepts that characterize societies. That is, such models must depart from the global requirements and objectives, and an organizational view on the environment reflecting the organizational strategy [7]. Traditional agent models are mostly concerned with the individual agents' perspectives. Those models mostly assume an individualistic perspective in which agents are taken as autonomous entities pursuing their own individual goals based on their own beliefs and capabilities In this perspective, global behaviour emerges from individual interactions and cannot easily be managed or specified externally. However, in the case of scenario planning (as in the case of institutions and other formal organizations), the behaviour of the global system is leading, and structural characteristics of the domain must be considered and incorporated in the model. Furthermore, agent-based models have the capability to overcome some of the problems with scenario planning, due to the ability of agent models to represent dynamics and enable (formal) validation of systems. That is, the use of agent models enables the generation of meaningful insights and the evaluation of policies and strategies [3]. From the above considerations, we have identified the following requirements for agent-based scenario planning and organizational modelling systems [8]:

- Support and direct the analysis of the organizational structure of the domain in order to determine society norms and facilitation roles
- Include explicit formalisms for the description, construction and control of the organizational and normative elements of a society (roles, norms and goals) instead of agent beliefs and states.
- Provide mechanisms to describe the environment of the society and the interactions between agents and the society, and to formalize the expected outcome of roles in order to verify the overall animation of the society.
- Provide methods and tools to verify whether the design of an agent society satisfies its design requirements and objectives.

Although the OperA model for agent organizations has not been developed with a scenario planning application in mind, but it aims at generic organizational modelling, OperA meets the above requirements which have been the guidelines to its development [7]. OperA takes a collectivist view on agent societies that places the global characteristics of the domain in the first place. The framework consists of three models that make the conceptual separation between organizational and individual perspectives possible. The organizational model describes agents societies in terms of roles, constraints and interactions rules.

In this paper, we present a practical application of OperA as scenario planning tool to the development of strategy at NedTrain, a rolling stock maintenance provider in the Netherlands. OperA is used to develop a scenario for the organization of rolling stock maintenance and operational services for transportation along a decentralized, client-oriented view (trains are responsible to determine their status and request maintenance), replacing the current centralized view (planning based on centrally managed time tables). The agent-based scenario represents and evaluates the desired, possible future, situation and is used to guide the discussion around strategic decision making and adoption of change.

The paper is organized as follows: in section 2 we briefly introduce the OperA model for agent organizations, which is the basis for scenario development method proposed in section 3. Section 4 provides an overview of NedTrain and the goals this company has for the project. Section 5 presents the agent-based model for the rolling stock maintenance scenario. The evaluation of the model and its implications for the decision making process at Nedtrain are described in section 6. Finally, we conclude and present some directions for future work in section 7.

2. THE OPERA MODEL

Agent organization modelling differs from traditional MAS modelling by integrating organizational and individual perspectives into one model and enabling dynamic adaptation to organizational and environment changes [7]. We see agent organization models as having at least two description levels. At the *abstract* level, which can be seen as a receipt for collective activity, organizations are described in terms of roles, their dependencies and groups, interactions and global norms and communication requirements. The *concrete* level is a possible instantiation of the abstract organization, by populating it with real agents that play the roles and realize interactions [18], [15]. Organizational design starts from the identification of business strategy, stakeholders, their relationships, goals and requirements and generates a comprehensive (agent) organization model including organization roles, interactions and planning fulfilling the requirements set by the business strategy. Organizational instantiation is the process that accepts an abstract organization model and a set of agents, and resources and generates a concrete organization by assigning responsibilities and organizational goals to each agent. Organizational roles and responsibilities represent general, long-term guidelines while operational control involves specific short-term agreements among agents to perform specific activities for specific time periods [16].

The OperA model for agent organizations enables the specification of organizational requirements and objectives, and at the same time allows participants to have the freedom to act according to their own capabilities and demands. Space limitations do not allow us to discuss here related work on Agent-oriented Software Engineering frameworks, and to describe how OperA compares to other models such as Tropos or Gaia. Such a comparison has been reported in [6]. In short, being a method based on a formal representation, OperA presents an advantage over e.g. Tropos. This formal semantics enable the formal verification of OperA models in terms of completeness (e.g. are the specified roles sufficient to eventually achieve the organizational goals) and liveliness (e.g. successful termination of interaction scenes)[1]. Also the fact that OperA clearly distinguishes between the concept of role and the concept of agent, which enables the abstraction from specific agents in the model, makes it more relevant for the development of scenarios and other organizational models. The OperA framework consists of three interrelated models. The organizational structure of the society, as intended by the organizational stakeholders, is described in the **Organizational Model** (OM). The OM specifies an agent society in terms of four structures: social, interaction, normative and communicative. The social structure specifies objectives of the society, its roles and the model that governs coordination. The interaction structure gives a partial order of the scene scripts that specify the intended interactions between roles. Interaction scene scripts are specified in terms of landmarks, which describe how a

[1]See [7] for details.

result should be achieved, that is, describe the states that must be part of any protocol that implements the interaction scene in the Interaction Model. Society norms and regulations are specified in the normative structure, expressed in terms of role and interaction norms. Finally, the communicative structure specifies the ontologies for description of domain concepts and communication illocutions. The way interaction occurs in a society depends on the aims and characteristics of the application, and determines the way roles are related to each other, and how role goals and norms are 'passed' between related roles. For example, in a hierarchical society, goals of a parent role are shared with its children by delegation, while in a market society, different participants bid to the realization of a goal of another role.

The **Social Model** (SM) specifies the interaction scenes that describe the possibilities for negotiation of role enactment by agents joining the organization. As a result, the agent population of an OM is specified in the (SM) in terms of social contracts that make explicit the commitments regulating the enactment of roles by individual agents. Social contracts describe the capabilities and responsibilities of an agent within the society, that is the desired way that an agent will fulfil its role(s). The use of contracts to describe the activity of the system allows on the one hand for flexibility in the balance between organizational aims and agent desires and on the other hand for verification of the outcome of the system.

Finally, given an agent population for a society, the **Interaction Model** (IM) specifies possible interaction protocols between agents that implement the functionalities described in scene scripts in the OM. After all models have been specified, the characteristics and requirements of the society can be incorporated in the implemented software agents themselves. Agents will thus contain enough information and capabilities to interact with others according to the society specification.

A generic methodology to analyze a given domain and determine the type and structure of the agent society that best models that domain is described in [9]. The methodology provides generic facilitation and interaction frameworks for agent societies that implement the functionality derived from the co-ordination model applicable to the problem domain. Standard society types such as market, hierarchy and network, can be used as starting point for development and can be extended where needed and determine the basic norms and facilitation roles necessary for the society. These coordination models describe the different types of roles that can be identified in the society and issues such as communication forms, desired social order and co-operation possibilities between partners. In the next sections we use OperA to develop a scenario planning model to support strategic decisions at NedTrain.

3. METHODOLOGY FOR SCENARIO MODELLING

Multi-agent models have been only sparsely used for decision support and policy-making. However, the ability of agent models to connect heterogeneous individual behaviour to different patterns of collective behaviour, makes agent organizations particularly useful to model uncertain situations, such as scenarios, involving different parties with different expectations and needs [12]. Traditional policy analysis aims at efficiency or optimality of strategy given environment conditions.

Scenarios represent interaction among stakeholders and incorporate their different perceptions and requirements. Furthermore, in order to be legitimized in their eyes, the development method must ensure the participation of all stakeholders such that the resulting model integrates their particular perceptions, capabilities and requirements. The very nature of scenario planning, suggests that agent organizations incorporating intelligent adaptive agents that model the different stakeholders, are valuable to predict, understand and interpret on the one hand the collective behaviour of the organization as described by the scenario, and on the other hand the consequences of the change to the different component system and entities that form the organization [3].

Work on agent-based models of organization scenarios is very much in the exploratory phase and there has been so far hardly any methodological or tool support. Methodologies to support the structured development of scenarios are needed, that (1) enable the systematic analysis and incorporation of different perspectives, (2) assess the robustness of insight to the particular way agents and interactions are represented, and (3) guides and interprets results achieved [4]. Due to its strong foundation on organizational perspective, that exactly enables this incorporation of different perspectives, the OperA model is appropriate for the development of organizational models [9]. Therefore, the OperA methodology and framework was chosen for the construction of Organizational Model for NedTrain. In this project, we use a methodology derived from the environmental simulation field [2] and adapted to the OperA framework, consisting of three phases:

1. **Model construction**: during this phase analysis of the environment, stakeholders, perceptions and business strategies takes place, resulting in an OperA Organizational Model (OM).

2. **Model validation**: involves a thorough evaluation of the OM by the stakeholders, e.g. by enabling each stakeholder to 'enact' its role in the system and discussing the representation of roles objectives, plans and interactions. That is, agents representing different stakeholder positions are specified that enact the roles specified in the OM, resulting in different possible Social Models (SM).

3. **Scenario animation**: using the model to simulate scenarios shows the dynamics that arise from the interactions using different priorities, weights and negotiation strategies. This corresponds to the implementation of an Interaction Model corresponding to each of the different possible SMs.

The challenge of the first phase is to identify stakeholders and interactions and describe their different perceptions. The resulting OM model for NedTrain is described in section 5. Besides its objectives of evaluation and refinement of the model, the second phase also aims at generating consensus among the stakeholders and ensuring their understanding and acceptance of the strategic changes. Finally, during the third phase, the effects of different ways of realizing strategy are generated and analyzed. In section 6, we look at how phases 2 and 3 are currently taking place at NedTrain.

4. THE NEDTRAIN SITUATION

NedTrain is a rolling stock Maintenance Provider, owned by Dutch Rail (NS). It runs 2 workshops, 5 depots and 25 service locations around the Netherlands, employing approximately 4000 people. Clients include national, local and international Train Operators. Originating from a state owned monopolist, NedTrain now faces strong competition and has to adapt itself to the requirements of the European market. Changes in political and business environment made clear that the current organizational model must be reconsidered. Moving from state owned monopolists, railway companies are increasingly becoming competitors over a shared infrastructure and maintenance services.

At the same time the technology used for railway transportation is changing rapidly. Modern trains are composed of subsystems requiring various maintenance strategies. Some components are maintained at regular intervals based upon distance or time. Other components are only inspected at regular intervals, while repair or replacement depends on the individual technical condition. The second group asks for continuous automated monitoring and dynamic job scheduling to prevent in-service failures (failure during operations) and to minimize means of production. Since traditional railways are optimized for the first group of subsystems, the existence of the second disturbs smooth logistics fundamentally. Especially in the Netherlands it puts high pressure on rolling stock availability and costs, due to the geographic structure of the network and the locations of maintenance facilities.

The challenges faced by NedTrain can be summarized as follows:

- From rigid operations driven by timetables to dynamic scheduling of operational services and maintenance jobs triggered by events.
- From homogeneous processes for a single client to heterogeneous processes to comply with a number of different contracts.
- From top down planning and scheduling to dynamic negotiation between companies with conflicting interests.
- From rigid maintenance allocations based on depot planning to dynamic negotiation based on train-centered automatic evaluation of technical condition

Operators uses different trains for their services. Trains and other rolling stock has been delivered by various manufacturers over time and represents different generations of technology. So Fleet management has to deal with subfleets. For older sub-fleets Operators bear full responsibility and can decide upon use and maintenance independently. In contrast, manufacturers guarantee reliability, availability and costs in more recent contracts. In return operators are obliged to comply with the maintenance plans which are supplied by manufacturers. Since sub-fleets may be contracted in different ways, Fleet management and maintenance providers have to deal with rather heterogeneous maintenance processes. This introduces an extra level of required coordination, in order to manage the various subfleets according their contracts within the overall interest of the operator. Furthermore, operators must respect the agreements made (usually) with their country's government about the transportation, fixed in a Service Level Agreement (SLA), which includes agreements about travelling frequencies, rolling stock types, number of seats that should be available, etc.

Facing the complexity of managing dynamically (sub)fleets of individual trains according to condition based maintenance, different contracts and conflicting interests between Operators, NedTrain initiated a study to analyze future scenario's and to support strategic decision making using the concept of agent organizations. In particular, the project aims at supporting fleet management solving the question of how to allocate individual trains to operational services and to maintenance. The project reported in this paper is part of this plan, and was meant to evaluated the possibilities of MAS technology to solve these challenges.

NedTrain operates as a Maintenance Provider, receiving orders from Fleet Managers serving different Operators. In some cases NedTrain provides all maintenance for an Operator. In other cases NedTrain is one of the Maintenance Providers that is contracted by an Operator. Individual Train Units aim for an optimal mixture of reliability, availability and costs. Information from different sources as inspection staff, train borne control systems and track-side sensors, enables a Train Unit to determine its technical condition. However, extra coordination is necessary in order to assure the interests of the Fleet Manager. Usually the Fleet Manager has some kind of SLA with the Operator to deliver a daily set of trains and so is usually called Daily Seat Provider. That is, the behaviour of the group of intelligent agents representing trains, besides determining the best solution for each individual train, must also comply with the SLA of the Fleet Manager. Proposals for maintenance plans are then determined by the Train Unit through intelligent reasoning aiming at in-service failures prevention. Given these plans of proposed maintenance tasks assigned to individual trains, the availability of means of production at the Maintenance Provider and the expected flow of the transportation process, optimal depot assignment and job scheduling will be calculated. Due to the nature of operations and the characteristics of rolling stock, scheduling becomes fairly dynamic.

The envisioned model of operation is not deterministic as its results are dependent on independent discrete decisions (by Fleet Management and Maintenance Provider) with a stochastic system (the set of Train Units). In this situation, statistic decision support is not usable. A simulation model is however a good analysis tool as it enables to represent operational management decisions. Moreover, an agent-based simulation model was chosen due to its possibilities to represent and relate heterogeneous, autonomous entities with different information and decision rules, to the global behaviour of the overall system [12]. In addition, agent models are able to represent the capabilities, requirements and objectives of different stakeholders, and provide as such a means for discussion and validation. In the following, we describe the (simplified) agent-based simulation model developed at NedTrain.

5. ORGANIZATIONAL MODEL

To facilitate the study, a simplified operation model of the company was used. In this model, the rail network consists of two main national lines with their own depot each, a local line and an international line. Both national lines are serviced by commuter and intercity trains, operated by the same Fleet Manager of a single Operator (Operator1). Both depots belong to NedTrain. One of the depots has also contracted all maintenance of a second, local Operator (Operator2). The other depot may be called by a third, international Operator (Operator3) who also has the opportunity to use another, competing Maintenance Provider (MP2). This geographically simplified model of operation is depicted in figure 1 where Train types A, B, C or D are different train types served by the Depots.

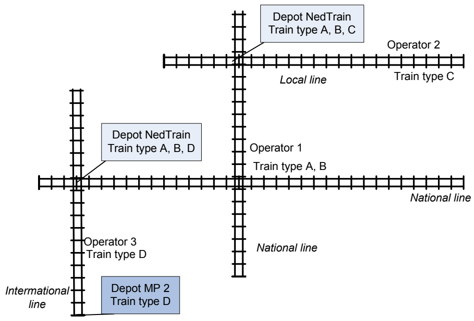

Figure 1: ***Simplified model of operation.***

We have used the OperA methodology [9] to analyze the NedTrain situation and design the organization model, OM. A brief summary of the methodology is given in table 1.

	Step	Description	Result
OM	Coordination Level	Identifies organization's main characteristics: purpose, relation forms	Stakeholders, facilitation roles, coordination requirements
	Environment Level	Analysis of expected external behavior of system	operational roles, use cases, normative requirements
	Behavior Level	Design of internal behavior of system	Role structure, interaction structure, norms, roles, scripts
SM	Population Level	Design of enactment negotiation protocols	Agent entrance scripts, Role enactment contracts
IM	Interaction Level	Design of interaction negotiation protocols	Scene script protocols, Interaction contracts

Table 1: ***Overview of OperA methodology.***

Facilitation aspects of the case are analyzed at Coordination Level by considering the nature of the main activities within the domain. The objectives of the participants in the NedTrain agent organization reflect the interests of the stakeholders in the real world, which leads to complex decision making for maintenance and operational services scheduling because of two facts: (1) differences between interests of stakeholders, and (2) stakeholders that are not willing to share private information. Another reason for complex decision making results from the increasing need of dynamically anticipating to the environment. The NedTrain case is characterized by two main goals: (1) scheduling maintenance, and (2) allocating trains to operational services. Scheduling of maintenance is defined by two different types of contracts:

- Fixed Maintenance Volume: Defines in advance the daily volume of maintenance an Operator can make use of.
- Maintenance On Demand: Defines the way parties can negotiate about the volume of maintenance on a daily basis.

Wrt relation forms, activities related to scheduling fixed maintenance volume and allocating the trains to operational services are organized in a hierarchy reflecting the traditional paradigm of railway organizations, that enable a global view on fleet level on the risk for in-service failures. However, negotiation about maintenance on demand follows a network structure reflecting the collaboration aspect between equal partners. Facilitation requirements resulting from these relation forms are the need for negotiation features together with a global control on fleet reliability. This is necessary to be able to allocate the most reliable trains to operational services and to determine the required maintenance on fleet level. The negotiation feature is needed to let parties negotiate about maintenance jobs. The following facilitation roles result from the Coordination Level analysis:

- **Notary:** It keeps track of a collaboration contract between agents.
- **Monitor:** It is responsible for controlling and supporting the contract.
- **Fleet Management:** responsible for a global view on allocation and fleet risk.

At Environment Level, the analysis of stakeholders and their requirements leads to the identification of roles describing the expected functionality of the society. The social structure results from those roles and their dependencies. For this case, stakeholders and their corresponding roles are as follows. The social structure describing roles and their dependencies is depicted in figure 2

- **Train Unit (TU):** Its objective is to maximize reliability against minimal costs.
- **Daily Seat Management (DSM):** Its objective is to allocate Train Units to operational services according to the contracted requirements and to minimize the overall risk for in-service failures.
- **Maintenance Management:** Its objective is to maximize fleet reliability within the limits of the contracted availability by assigning maintenance jobs to Train Units. It is represented by two roles:
  - **Fixed Maintenance Volume Management (FMVM):** uses the Fixed Maintenance Volume contract.
  - **Maintenance On Demand Management (MODM):** negotiates with the Planning Unit to contract vacant maintenance capacity.
- **Fleet Management** (which encloses Daily Seat Management and Maintenance Management): Its objective is to supply Train Units to operational services according to the contracted requirements and against minimal costs.
- **Operator:** Its objective is to maximize profitability by providing operational services with respect to the SLA with the Government.

- **Maintenance Provider:** Its objective is to maximize profitability by maintaining Train Units and to maximize Fleet Management satisfaction by offering high quality, cost effectiveness and reliability.
- **Planning Unit (PU)** (which is part of a Maintenance Provider): Its objective is to maximize Maintenance Provider earnings by assigning vacant maintenance capacity to requests by Maintenance On Demand Management, taking into account the scheduled use of the contracted Fixed Maintenance Volume.
- **Government** (not included in this model): Its objective is to offer sufficient public transportation against minimal costs.

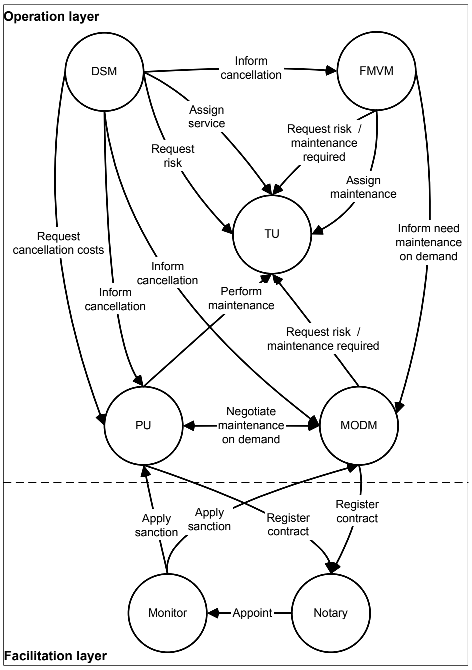

Figure 2: ***Social structure.***

Finally, at Behavior Level the internal behavior of the organization is designed. For each role, a role description is specified that identifies the activities and services necessary to achieve its (social) objectives. In general, a role is described in terms of its objectives, sub-objectives, norms and rights. As an example, in table 2, we show the description of the role Maintenance On Demand Management to clarify the dynamic characteristic of maintenance. MODM serves the Operator in managing a variable demand for maintenance volume that is not captured within a fixed maintenance volume contract or managing different offers when more Maintenance Providers are contracted.

The social structure relates the role definitions to their dependencies. The dependencies between roles reflect the interactions of roles to realize their objectives. The dependencies are specified by interaction scenes, which capture a certain multi-agent dialogic activity [11]. The interaction structure describes the partial order of interaction scene scripts. The interaction structure is depicted in figure 3.

The schedules for maintenance and allocation to operational services are based on the technical condition of a Train

Role: Maintenance On Demand Management	
Objectives	Maximize fleet reliability by assigning maintenance jobs to TU by negotiating with PU to contract vacant maintenance capacity
Sub-objectives	Determine available Train Units for maintenance Request maintenance required Request fixed maintenance volume availability Determine need for variable maintenance volume Determine maintenance volume Request operational risk Determine profitable tasks Determine logistics Determine bidding possibilities Negotiate volume Schedule maintenance Register contract
Rights	Decide need for variable maintenance volume Decide negotiable maintenance tasks
Norms	**If** parties have made agreements about maintenance volume **then** MODM **is** obliged **to do** register agreements with notary **If** offer is profitable **then** MODM **is** permitted **to do** accept offer **If** DSM cancels maintenance **then** MODM **is** obliged **to do** comply with cancellation **and** determine new need variable volume

Table 2: Example of a role: MODM

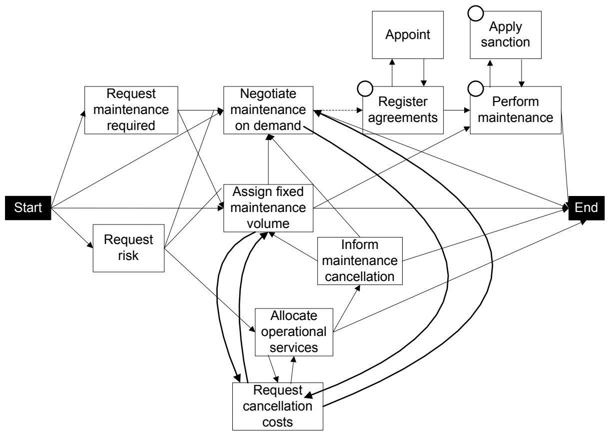

Figure 3: ***Interaction structure.***

Unit. The Train Unit is able to express its condition in terms of a risk value for in-service failure (operational risk) and to determine the required maintenance, both deduced from the technical condition. Based on this information schedules are created. DSM allocates the operational services to the Train Units in a hierarchical fashion (where DSM has control over the assignments) on the basis of the lowest operational risks and with respect to the operational time table (scene *Allocate Services*). FMVM determines which maintenance tasks are scheduled for the entire fleet also on the basis of a hierarchical relation (scene *Assign Fixed Maintenance Volume*). Scheduling maintenance on demand requires negotiating between the PU and MODM, by which the PU represents the interests of the Maintenance Provider (increase turnover by extending profitable maintenance volume) and the MODM represents the interests of the Operator (increase reliability with minimum costs). This is handled in the network-related interaction scene *Negotiate Maintenance On Demand*. The interaction scenes that follow take care of the compliance

Scene Script: Negotiate variable volume	
Roles	Planning Unit, Train Unit, Maintenance On Demand Management
Results	Obtain list of maintenance tasks scheduled by MODM, which a PU executes for a TU
Patterns	MODM obtains minimum reliability / availability **and** MODM obtains realisation fixed volume **and** MODM requests TU for operational risks **and** MODM determines need variable volume **and** MODM requests available TU for required maintenance tasks and decrease failure costs **and** MODM obtains track hours and maintenance volume for the maintenance tasks **and** MODM obtains logistic costs **and** MODM creates list of the most valuable tasks arranged on ratio **and** MODM determines first offer and maximum price for product **and** PU determines minimum price and counteroffer **and** PU and MODM negotiate until reached consensus or could not agree **and** MODM negotiates the valuable tasks **until** fleetRisk = minimumReliability **or** fleetAvailability = minimumAvailability **and** MODM is informed about rescheduling **and** MODM and PU register maintenance
Norms	**If** fleetRisk > minimumReliability **or** fleetAvailability < minimumAvailability **then** MODM **is** obliged **to do** start negotiation **If** fleetRisk ≤ minimumReliability or fleetAvailability ≥ minimumAvailability **then** MODM **is** obliged **to do** stop negotiation **If** offer is acceptable **then** obliged **to do** accept offer **If** PU and MODM agreed **then** PU and MODM **is** obliged **to do** register maintenance

Table 3: Example of a scene script: *Negotiate maintenance on demand*

with the agreements for the negotiators.

The schedules are created some time in advance. The technical condition of the Train Units frequently changes. Therefore, schedules are subject to change and require a dynamic approach. This model includes a rescheduling mechanism. A new schedule is accepted if the associated costs for cancellation are compensated by overall better results.

In OperA interaction scenes are specified as scene script descriptions. To study the example of the MODM in more depth, the interaction scene *Negotiate Maintenance On Demand* is given in table 3. This scene describes the creation of extra production capacity. It is initiated when the fixed maintenance volume is not sufficient to guarantee a reliable fleet. Alternatively, for the operators that have not signed contracts in which the maintenance volume is contracted in advance, such as the international Operator in the example, the scene is initiated to schedule all maintenance tasks. The negotiation requires a common base to compare the bids of the different parties (MODM and PU). For this purpose, we introduced a cost factor. The negotiation mechanism that was chosen for this scene prescribes the buyer (i.e. the MODM) as the initiator of the negotiation.

Behavior Level design results in the complete Organization Model for the domain. Due to space limitations, we are not able to present the complete model, but present examples of relevant role and scene script descriptions. The design of the Social and Interaction Models are the next steps in the OperA methodology, corresponding to phases 2 and 3 in the scenario development framework proposed in section 3. In the following section, we will describe the second and third phases of the methodology for scenario modelling for the NetTrain case.

6. MODEL VALIDATION AND ANIMATION

According to the scenario development model presented in section 3, the model construction phase (1) is followed by the phases model validation (2) and scenario animation (3). The **validation phase** involves a thorough analysis of the model and its components. This verification is supported by the formal semantics of OperA models, which is based on the LCR logic [10]. At the present, we are working on tools that support the (semi) automatic verification of OperA models, but for the project reported in this paper, verification is done by hand.

Furthermore, it is necessary to provide a means to analyze the perceptions and interactions of the different stakeholders and to convert the envisioned future into common knowledge and shared goals. The model described in section 5, was used to promote the awareness of stakeholders for the situation forthcoming from the strategic changes. Even though, after strategic changes take place, all stakeholders will profit from the optimal value chain, the outcomes of change were not clear to them. The model made possible to understand the complexity of the different roles and of the interactions between them, and the highly dynamic processes derived from the environment changes. The results of the different scenarios make possible to inform and discuss with the different stakeholders of the issues that divided them and of the dependencies between their different requirements and plans. From the perspective of the Maintenance Providers, one also wants to analyze scenarios that consider maximal fixed volume maintenance, or maximal on demand maintenance, or in which they are free to buy and sell each others' maintenance quotes. These different scenarios can be implemented using the maintenance model by varying the objectives and plans of the agents that enact the different roles and by negotiating different ways to realize the interaction scenes.

During the third phase of the scenario development method, **scenario animation**, the agent-based model will be instantiated to represent different possible futures. The strategic decisions described in section 4 can lead to different possible scenarios, which can be 'visualized' by populating the organizational model with agents behaving according to different aims and constraints. Role enactment negotiation is specified in OperA as a special interaction scene script that describes the possible negotiable aspects (such as deadlines, results, capabilities) and generates a social contract describing the activities of a role enacting agent. As any other scene script, a role enactment negotiation script can provide more or less interpretation freedom to the agents through the level of specification described by its landmarks. For example, the script for the role enactment negotiation for the Train Unit role enables agents, representing specific trains, to specify contract clauses fixing issues such as maximum waiting time, preference for depot, and possibility for phased maintenance (different parts at different moments). Another example, the role enactment negotiation script for the MODM role (cf. table 2) enables different agents to use different values for operational risk, profitable tasks, volume, etc.

By allowing populations of agents to negotiate different parameters, different scenarios are achieved. For instance, a possible scenario aims at minimizing cost and optimizing maintenance planning, while giving a lower priority to reliability. That is, what happens if we try to plan maintenance to optimize the use of depots, if this means that trains will in some cases have to operate at higher risk levels? Another scenario considers the case in which risk must be minimized even if this means higher operation costs due to non-optimal use of depots, or recurse to competitor maintenance providers.

Unpredictability of maintenance jobs to be executed will become manifest as technical advances enable trains to sense more aspects of their state, and economical pressures demand longer operation of rolling stock or better allocation of depots. By analyzing the results of the different scenarios, decision makers at NedTrain will be able to discuss and measure the effects of different strategic choices derived from these changes. For instance, if the volume of the Maintenance Provider's means of production equals the average demand by the Fleet Managers, variations in the volume of maintenance jobs over time result in waiting queues of rolling stock in front of the depots. Therefore the fleet availability decreases. The Fleet Management has to choose between two unwanted effects: To accept lower operational capacity or higher investments in rolling stock. On the other hand, asking for high fleet availability by Fleet Management can only be answered by introducing peak capacity of production means at the Maintenance Provider. This effect is amplified by the growing length of expensive train sets. Capital costs of the operator and the costs of maintenance are communicating vessels. These are issues represented in the scenario described in section 5. However, the consequences of this strategic move are difficult to understand and even more to adapt to, which results in reluctance by different parties to adjust.

7. CONCLUSIONS

The use of an agent-based model makes possible to represent multiple and contrasting viewpoints. This provides for rich scenarios, which can furthermore be animated to study instantiations based on different priorities and capabilities of the stakeholders. For example, the needs and goals of the Operators (optimal planning of train units) are often in conflict with those of the Maintenance Provider (constant, well balanced workload at the depots). Furthermore, agent models have proved to be useful tools to involve stakeholders in a collective design on management plans [12, 2].

At the present, we have fully specified the organizational model of the agent-based scenario at NedTrain. This model has already served to increase the awareness of the different stakeholders to the consequences of the strategic changes taking place, and to lead the decision-making process, as described in section 6. A follow up to this project will result in an implemented agent-based scenario simulation system for the model described in this paper. In this system, the different visions of the future, can be visualized and analyzed by weighting differently the priorities of each stakeholder.

The results of application of the agent-based scenario planning methodology at NedTrain demonstrate the validity of the use of agent models as specification tool for organization systems, as well as a basis for discussion, validation and acceptation of strategic changes. Of course, in the future, the method must be further applied to other domains, tested and refined in order to be able to draw wider conclusions. This project also served as an evaluation of the possibilities of agent modelling and agent technology for the system needs at NedTrain. From the experience so far, agent technology will be a likely option for the support of the implementation of real life maintenance planning systems.

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