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The role of Situation Awareness in Synchromodal Corridor Management: A simulation gaming perspective

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Abstract

Synchromodal transport has the potential to offer flexible, reliable, cost-effective and sustainable freight transportation by enabling real-time switching between transport modes. Given the numerous stakeholders and network interdependencies within freight transport corridors, achieving efficient coordination and management is complex. Multiple stakeholders need to make consistent decisions under dynamic and time-pressed operational situations. Such situations request efficient information sharing, role awareness, optimization of services and assets in freight transport corridors. Situation Awareness (SA) has been proven as essential prerequisite for decision-making under dynamic operational situations. In this research, we aim to explore the decision choices and behavior of stakeholders related to synchromodal corridor management at various levels of SA. For this purpose, we developed a simulation game called ‘Modal Manager’ comprising logistic service providers and infrastructure managers. The participants of the game take over the role of infrastructure managers. They have to cooperate to solve several disruptions and incidents in a flexible way ensuring the time-efficient and reliable transportation of containers while maintaining the optimal utilization of the network. Our research study around the game includes a session consisting of briefing, game play and debriefing with transport professionals in the private and public sector

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in the Netherlands. The game results are expected to shed light on decision-making, information sharing strategies and interventions made by infrastructure managers for efficient synchromodal corridor management.

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1. Introduction

Background

Since the advent of containerization, the quest for efficient freight transportation has led practitioners and researchers in a multitude of directions. Starting from the adoption of multimodal concepts, stakeholders also developed intermodal solutions, nowadays striving for more flexible, reliable, sustainable, cost efficient synchromodal concepts ideas (Muller, 1995). Synchromodality is defined as the “vision of a network of well-organized and interconnected transport modes, which together cater for the aggregate transport demand and can dynamically adapt to the individual and instantaneous need of network users” (Tavasszy et al., 2015, pp 1). This advanced type of freight transportation is regarded by the scientific community as the new stage of freight network development and is expected to deliver considerable advantages in terms of cost and quality of the offered services (Tavasszy et al., 2015). Synchromodality has been proposed as a solution to meet the challenge of Smart, Green and Integrated transport as promoted by the European Union in its Horizon 2020 Strategic Research Agenda. However, when we study the best practices from literature and subject matter experts we observed that these solutions are elegant on paper, but complex to deploy in real life situations.

Synchromodality is still in its initial phase and the expected benefits are not yet quantified and fully understood. The involvement of numerous stakeholders in freight transportation and the complex and subtle relationships formed between them show characteristics of a complex sociotechnical system; systems that involve a large number of physical-technical elements and networks of independent stakeholders (de Bruijn et al., 2009, Carayon, 2006). The stakeholders often have different goals and priorities. However, they have to align their plans, share information to take suitable decisions in this complex and uncertain environment, which impede the adoption of the synchromodal concept. The key prerequisite of synchromodality is information exchange that facilitates the synchronisation of the different modes (Schoenmaker et al., 1999). Synchromodality requires a high level of collaboration between frequently competing stakeholders that puts in place the necessity of making legal changes. Consequently, stakeholders have to take time for critical decisions either with insufficient or excess information in a rapidly changing environment. In such complex situations, a human factors construct known as Situation Awareness (SA) is discussed as an important prerequisite for decision making towards operational efficiency, and performance (Endsley, 1995).

SA in simple terms is the level of awareness of a current situation that an actor has been placed in (Salmon et al., 2008). Furthermore, it is the ability to perceive the current situation, comprehend its meaning and the projecting of the future status based on the perception and comprehension of one actor (Endsley, 1995). For example, in the context of synchromodal transport, an infrastructure manager’s individual SA is related to his/hers ability to perceive a possible disruption in the network, comprehend its level of importance and project the effect it might cause in the network. This ability can support the decision on preventive measures to avoid or mitigate the negative consequences of a disruption.

In our on-going study, we attempt to increase the SA of the key stakeholders within a synchromodal transport network by using simulation gaming.

The aim of this paper is to present the idea and the design of a game developed to increase the SA of transport infrastructure managers to make suitable decisions towards improved performance within a synchromodal transport network. In Section 2, we describe the key decision makers and their decisions related to synchromodal transportation. We will also highlight the role of Situation Awareness in decision-making. Section 3 presents the

game description and final section concludes the paper with a discussion on the value of the game and expected results linking to future work.

2. The Synchromodal transportation concept and Situation Awareness

Synchromodality as defined above takes advantage of the complementarity of the different transportation modes to deliver cost effective, flexible, reliable and sustainable services to the clients (Bedhani et al., 2016). The key stakeholders operate on four different levels. Figure 1 consists of a layered hierarchical representation of the key stakeholders that are involved in multimodal/synchromodal transportation. This model is adjusted from the TRAIL layered model developed by Schoemaker et al. (1999).

The stakeholders engaged in the first level provide the necessary infrastructure for the modes to operate. This can include stakeholders such as road, rail and waterways infrastructure providers and port authorities. The next level includes the provision and the management of assets and services to offer the necessary transportation by single modes of transport. The stakeholders that combine the services of the level 2 stakeholders to offer door-to-door delivery of shipments from an origin to a destination are on level 3. Note that in the case of unimodal and multimodal transport (parallel modes) levels 2 and 3 may overlap. The last layer, level 4, consists of shippers and receivers that are the freight owners and demand a certain level of offered services. The decision makers in this fourth level set the destination, cost, and quality constraints of the services. The stakeholders of each level set the demand that should be supplied by the stakeholders of the level below.

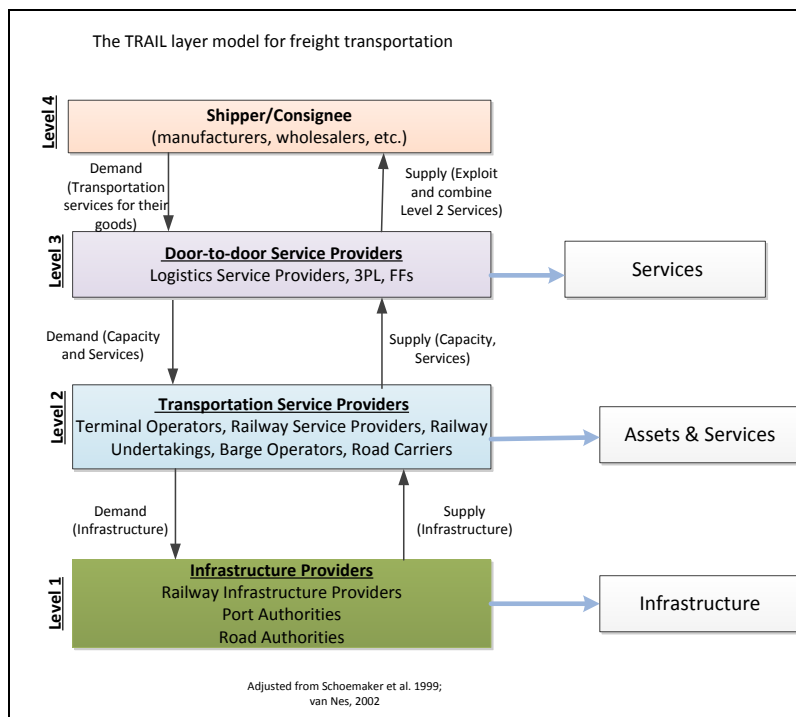


Figure 1. Four level decision making, adjusted from Schoenmaker et al., 1999

While multimodal transportation requires vertical collaboration between the different layers, efficient synchromodal services go one level further and demand horizontal integration amongst the stakeholders of one layer. The provision of this new service therefore requires the alignment of resources in a way that guarantees maximum utilisation and high customer satisfaction levels. Taking under consideration shippers and consignees needs, synchromodal service packages can be designed by defining routes, synchronising timetables and optimising

capacity utilisation. A prerequisite is information exchange between and within the four levels. Therefore, one of the biggest challenges towards the synchronisation of modalities is the real-time sharing of the details of transport orders (for example size, origin, destination, etc.), location, services, capacity and disruptions in the network (Tavasszy et al., 2015). Various stakeholders in the supply chain control the data. Their provision should be orchestrated in a way that all parties involved have the information they need. Effective ways of information exchange contribute to the SA of stakeholders involved in the synchromodal transportation network. We focus on the stakeholders in the first level of the model shown in Figure 1. Based on our conversations with infrastructure managers from the Dutch rail and road networks we understood that, currently, infrastructure managers don't communicate with individual stakeholders and don't consider their preferences and attitudes while managing their network. Given that the different infrastructure managers have divergent interests it is hard to predict or assess the behaviour when such advanced transport solutions are introduced in the market. Despite the advantages in synchromodal transportation, infrastructure managers still do not have a holistic management approach for the network and its alternate routes. They mostly focus on resolving incidents, while the communication of information on the available capacity and possible incidents to the users of the infrastructure-in our case mostly Logistic Service Providers (LSPs) - remains limited. The lack of collaboration between the infrastructure managers of different modes, results in absence of awareness on the opportunities and difficulties in the design and execution of synchromodal services.

Situation Awareness (SA) is a driver of performance by enabling stakeholders to make decisions in a complex environment (also illustrated in Figure 2). SA has been largely studied from an individualistic perspective, and in recent years research focus has been shifted to collaborative SA that involves teams, groups and networks. Two prominent schools of thought in collaborative SA exist. The first is shared SA (SSA) of Bolstad and Endsley (1999), where stakeholders form a common operational picture of the situation through information sharing, shared displays and processes. The second is the distributed SA (DSA) (Salmon, 2008), where Salmon proposes that stakeholders can develop and maintain SA by sharing the right information to the right person at the right time, and not all stakeholders need to have access to an overall knowledge. In our research, we would like to understand the impact of different SA configurations (individual, shared and distributed) on decision-making and performance of stakeholders in synchromodal corridor management.

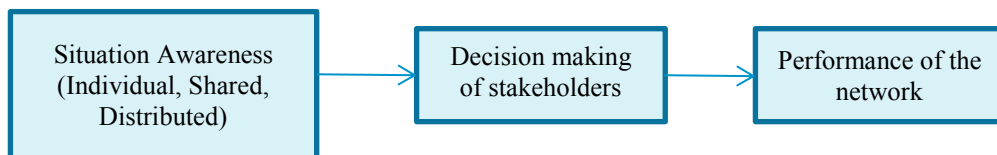


Figure 2 Situation Awareness: A important pre-requisite to decision making in complex systems (adjusted from Endsley (1995))

Within the context of the above challenges we designed a game concept to facilitate Situation Awareness to empower infrastructure managers to orchestrate an efficient synchromodal transport network. We use simulation games as our key research method due to three main reasons. Firstly, simulation games can represent and demonstrate the challenges in complex sociotechnical systems in a realistic yet interactive way (Duke and Geurts, 2004; Bekebrede, 2010). Secondly, they are able to engage human participants in a safe and controlled setting to make decisions related to complex problems (Klabbers, 2006). Finally, simulation games offer rich data on the behaviour of stakeholders. Even though it is in a quasi-realistic setting, it is a cost-effective and efficient method compared to action research, surveys or simulation when human decision making is involved (Kurapati et al., 2015).

We will describe the game known as the 'modal manger game' in the following section.

3. The modal manager game

The modal manager game is a so-called “Microgame”, short simulations games that support situated learning for a specific problem statement (Kurapati et al., 2014; Lukosch et al., 2016). The game consists of different missions, representing a network of road, rail and barge transport routes together with the various intermodal terminals in a hypothetical transport corridor in the Netherlands shown in Figure 3. The player assumes the role of an infrastructure manager, and has to deal with four Logistic Service Providers (LSPs), A, B, C and D, who are automated players within the game. Each of the LSPs is modelled such that they make route choices based on their respective priorities: A is known for reliability, B for sustainability and C for being cost effective. D introduces an element of randomness without a clear priority. Their preferred route choices are colour coded for the player’s reference.

The game can be configured to accommodate several points of origin and destinations for the containers. In the example of Figure 3, containers originate from one terminal and have three destinations.

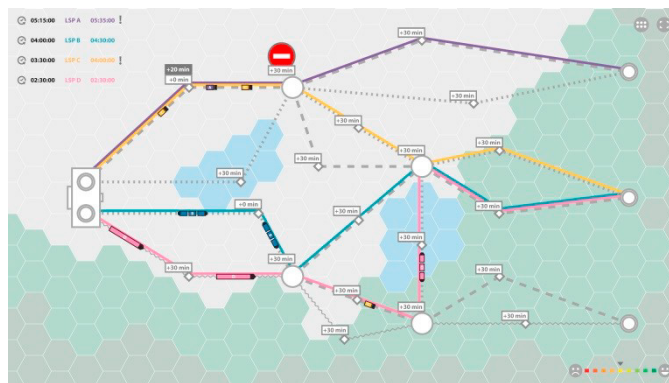


Figure 3: Screenshot of the modal manager game

During the game play, the participants should make sure all the containers arrive to/at their destinations within the specified time limit of the game. They should pay attention to the happiness levels of the LSPs, which is based on the change in their profit due to route change and the average delays of their containers. This introduces a dilemma to the player to balance network efficiency and happiness levels. The various measures that a player can take during the game are:

- **Inform:** Provide generic information about disruptions (the LSPs can decide on the alternative route)
- **Advice:** Give the LSPs advice to take a certain route with an explanation of the reason and related consequences
- **Direct:** Redirect the LSPs to another route without providing additional information.

The overall goal of the game is to explore which measures are taken (decision-making of the players), and what effects the measures have on the behaviour of the LSPs and the network performance. The performance of the players is measured by the average delays in the network, the number of containers that arrive their destination on time, and the happiness levels of the LSPs. The game has several complexity levels. In the first level of the game, the player controls only one modality within the synchromodal network and operates in a situation, which reflects the current situation of modal management. In the second level, the player is still in charge of one mode but has to consider the preferences of LSPs while choosing the different measures. In the final game play level, the player is a ‘super modal manager’ who can manage all the three modalities, and has to balance between the network performance and the happiness levels of the various LSPs. In the final level, several disruptions occur in the

network that create congestion. The player has to respond to such unexpected situations with the three measures (inform, advise, control) to ensure network performance.

The participants of the model manager game will be infrastructure providers of different modalities in the Netherlands. The game will be part of a workshop, which start with a briefing lecture about corridor management by the facilitator. The participants fill out a pre-game questionnaire that collects their demographic information, their expectations from the workshop and their current attitudes towards synchromodal corridor management. Then they will play the different levels of the modal manager game. After each level, the facilitator will invite the participants to reflect on the game play and relate it to real world applications. After the first level of game play the facilitator will start the discussion on current practices in synchromodal corridor management, and the advantages and challenges of the three different measures available in the game. After the second level of game play, the discussion will include the benefits of keeping LSPs happy, ways to build trust with LSPs, and challenges and opportunities in balancing network performance and LSP happiness levels. After the final game play level, participants will discuss on ways to collaborate with infrastructure managers of other modalities together with challenges and benefits of doing so. The session will conclude with an elaborate de-briefing session where the facilitator collects the experiences of the participants through an interactive discussion and a post-game survey. This phase will include a brief lecture on the theoretical concepts and current findings on synchromodal corridor management. Additionally, possible solutions towards synchromodal corridor management will be discussed. The game session will yield quantitative results from the in-game data relating to the player decisions and survey data on attitudes and preferences. Qualitative results include observations of the game play and recording of the debriefing sessions. We will discuss the expected results of such a game session together with the implications to Situation Awareness in the following section.

4. Expected results and discussion

Synchromodal corridor management knows quite some challenges, based on its nature as complex sociotechnical system, comprising out of a large number of interrelated, often competing stakeholders. We identified this complexity of the network is one of the main reasons why the promising theoretical concept did not make it into practice so far. A first step towards this transition is to make the stakeholders involved aware of the advantages and possible solutions towards challenges related to synchromodal corridor management. SA has shown to be a prerequisite of performance in such complex, dynamic situations. Therefore, we developed a game session that addresses the development of SA of vital stakeholders in a transportation network, the infrastructure managers. Simulation games are powerful means to represent complex situations (Bekebrede, 2010), and allow stakeholders to take over certain roles (Duke and Geurts, 2004). Games can represent changing scenarios, helping stakeholders to develop individual and team awareness, understood as a prerequisite to successful decision making (Faria et al., 2009; Mayer, 2009; Egenfeldt-Nielsen, 2007). In our game design, we allow stakeholders to experience the consequences of certain measures to handle the complexity of synchromodal corridor management. We defined those measures as the ability of inframanagers to inform, advice, and direct other stakeholders in the network, namely the logistical service providers. The aim of the inframanagers is to keep the capacity of the network high and its use up. The satisfaction of the LSPs with as well as their trust in the information provided by the inframanagers are intermediary aspects influencing the decisions of the stakeholders. The extent of the right amount of information is given at the right time and in the right way (informing, advising, directing), influences the likelihood that the LSPs will follow the information, and the ability of the inframanager is able to maintain the capacity of the network without congestion.

A simulation game always represents a simplified version of reality yet safe environment to experiment with (Peters et al., 2010). This is also true for our game. Still, the game shows a high level of complexity. To avoid ending up with players being frustrated about the high level of complexity of the problem to solve, the game is embedded in a session with break-in briefings and an informed debriefing in the end. In this way, players are

enabled to reflect on what they experienced in the game, and to translate this back to alternative solutions towards synchromodal corridor management in the real world.

The different levels of situational awareness the players develop during the game are related to the distinct levels of play options in the game.

Inform option of the inframanagers relates to the Shared SA (SSA) between the stakeholders, where the inframanager shares the same information to all the LSPs. This could correspond to a network information system where the information is displayed and accessible to all LSPs. The interpretation of the information is subjective, and its consequences are unknown to LSPs. This mode of information sharing corresponds to developing a common operational picture among stakeholders related to a given situation using shared displays (Endsley, 1995; Nofi, 2000).

Advise: This option relates to the Distributed SA (DSA) level where the inframanager shares only relevant information to relevant LSPs by explaining the consequences of the information. Salmon (2008) asserts that in time pressed situations DSA is effective since it doesn't create information overload among stakeholders. Additionally inframanagers can make a trade-off (suggested by Boy (2013)) between LSP satisfaction and performance of the network by providing information strategically to a certain LSP.

Direct option of an inframanager relates to his or her Individual SA (ISA). He/she needs to perceive a certain situation in a network, comprehend its meaning and project the future state of affairs (Endsley, 1995). Based on this projection, the inframanager enforces a certain route to the LSP. This can be viewed as a 'command and control' option from an individualistic perspective of the inframanager.

From the game play results, we can compare the effect of the different measures in terms of SA on the performance of the network and happiness of LSPs. Future work will include additional instruments (surveys, MATB, TIPI) to understand the factors influencing SA, decision making and performance at individual, group and network levels. For the adoption of synchromodal transportation concepts, it is crucial to modify the decision-making processes of inframanagers towards information sharing with vital infrastructure users. Simulation gaming is a suitable method to influence decision making by fostering SA of stakeholders. While informing (SSA) is an easy mode of communication, it leaves a huge amount of freedom to the LSPs, and might result in low levels of trust and satisfaction, as no alternative actions or decisions are connected with this measure. Selective advise (DSA) might turn into a valuable tool applied to control synchromodal transportation while at the same time increasing customer satisfaction, as alternative solutions are illustrated. Directing (ISA) might also lead to desired outcomes, when further developed towards an incentive structure. In the current transportation network, infrastructure managers are quite restricted in the options of directing stakeholders towards certain routes, modalities, or times of transportation. The most common action is to simply close down a certain route. In future, and with help of our game, other measures could be developed together with the stakeholders, such as priority use of certain lanes on highways, subsidy of vital hubs in the network, or increase of rail capacity on certain routes. Our overall objective for the future is that, we would like to using the modal manager game within gaming sessions and workshops with stakeholders from the Dutch freight transport network to accomplish three objectives. Firstly, to increase the Situation Awareness of infrastructure managers to achieve the efficient transport of freight using synchromodal solutions; secondly to provide an insight into the benefits of collaboration with other stakeholders within the synchromodal transport network, and finally to steer their mind-set towards the adoption of synchromodal solutions.

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References

- Bedhani, B, Fan, Y., Wiegman, B. and Zuidwijk, R., 2016. Multimodal Schedule Design for Synchromodal Freight Transport Systems. *European Journal of Transport and Infrastructure Research* 16, 424-444.
- Bekebrede, G. (2010). Experiencing complexity: a gaming approach for understanding infrastructure systems (Doctoral dissertation, TU Delft, Delft University of Technology).
- Bolstad, C. A., & Endsley, M. R., 1999. Shared mental models and shared displays: An empirical evaluation of team performance. In proceedings of the human factors and ergonomics society annual meeting (Vol. 43, No. 3, pp. 213-217). Sage CA: Los Angeles, CA: SAGE Publications.
- Boy, G.A, 2013. Orchestrating situation awareness and authority in complex socio-technical systems. In M. Aiguier, Y. Caseau, D. Krob, and A. Rauzy, editors, *Proceedings of the Third International Conference on Complex Systems Design & Management CSD&M 2012*, 285–296. Springer, Berlin, Heidelberg, Germany.
- Carayon, P., 2006. Human factors of complex sociotechnical systems. *Applied ergonomics*, 37(4), 525-535.
- De Bruijn, H., & Herder, P. M., 2009. System and actor perspectives on sociotechnical systems. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, 39(5), 981-992.
- Duke, R. D., & Geurts, J., 2004. Policy games for strategic management. Rozenberg Publishers, Amsterdam.
- Egenfeldt-Nielsen, S., 2007. Third generation educational use of computer games. *Journal of Educational Multimedia and Hypermedia*, 16(3), 263.
- Faria, A. J., Hutchinson, D., Wellington, W. J., & Gold, S., 2009. Developments in business gaming: A review of the past 40 years. *Simulation & gaming*, 40(4), 464-487.
- Klabbers, J. (2006). *The magic circle*. Sense Publishers, Amsterdam.
- Kurapati, S., Groen, D., Lukosch, H., & Verbraeck, A., 2014. Microgames in practice: a case study in container terminal operations. In *ISAGA 2014: 45th Conference of the International Simulation and Gaming Association*, pages 1–14. SAGSAGA, Dornbirn, Austria.
- Kurapati, S., Lukosch, H., Verbraeck, A., & Brazier, F. M., 2015. Improving resilience in intermodal transport operations in seaports: a gaming approach. *EURO Journal on Decision Processes*, 3(3-4), 375-396.
- Lukosch, H., Kurapati, S., Groen, D., & Verbraeck, A., 2016. Microgames for situated learning: A case study in interdependent planning. *Simulation & Gaming*, 47(3), 346-367.
- Mayer I., 2009. The gaming of policy and the politics of gaming: a review. *Simulation & Gaming* 40(6), 825–862.
- Muller, G., 1995. *Intermodal freight transportation*, 3rd edn. Eno Foundation for Transportation, Westport, CN.
- Nofi, A. A., 2000. Defining and measuring shared situational awareness (No. CRM-D0002895. A1). Center for Naval Analyses Alexandria VA.
- Peters, V., Van de Westelaken, M., & Bruining, J. (2012). Simulation games as a safe environment. *Simulation and Games studies*, 22, 59-64.
- Salmon, P. M., 2008. Distributed situation awareness: Advances in theory, measurement and application to team work. (Doctoral Dissertation. Brunel University School of Engineering and Design).
- Salmon, P. M., Stanton, N. A., Walker, G. H., Baber, C., Jenkins, D. P., McMaster, R., & Young, M. S., 2008. What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science*, 9(4), 297-323.
- Schoemaker, Th.J.H., Koolstra, K. and Bovy, P.H.L., 1999. Traffic in the 21st Century - A Scenario Analysis for the Traffic Market in 2030. In: Weijnen M.P.C., E.F. ten Heuvelhof, *The infrastructure playing field in 2030*, pp. 175-194, Delft University Press, Delft.
- Tavasszy, L.A., Bedhani, B., Konings, R., 2015. Intermodality and Synchromodality. Available at SSRN: <https://ssrn.com/abstract=2592888> or <http://dx.doi.org/10.2139/ssrn.2592888>