Savings Potential Through Autonomous Control in the Distribution of Rental Articles

Florian Harjes and Bernd Scholz-Reiter

Abstract In general, rental articles circulate in closed logistic systems between the lender and one or more dynamically changing customers. The planning processes, related to the allocation of those articles to customer orders, are a challenging task. This is especially the case, if orders have a close temporal distance, as the corresponding order execution takes place between the poles of high customer demands and the lender's economic interests. This paper introduces an autonomously controlled distribution system for rental articles that takes over both the allocation of articles to orders and the related logistic planning. At this, the focus lies on the results of first benchmarks and an estimation of the related potential for savings. A company from the field of event logistics serves as an application example for the distribution approach.

Keywords Autonomous control · Event logistics · Agent-based distribution · Rental articles · Savings potential

Introduction

The allocation of rental articles in event logistics takes place as a sub-process of event management (Harjes and Scholz-Reiter 2012). The latter comprises the complete accomplishment of events, such as concerts, private parties, company anniversaries, etc., including the artistic planning and the logistic services (Harjes and Scholz-Reiter 2013a, b, c, d). Here, the term event logistics defines all logistic

F. Harjes (✉)
BIBA—Bremer InstitutfürProduktion Und Logistik GmbH, University of Bremen, Bremen, Germany
e-mail: haj@biba.uni-bremen.de

B. Scholz-Reiter
University of Bremen, Bremen, Germany
e-mail: rektor@uni-bremen.de

H. Kotzab et al. (eds.), *Dynamics in Logistics*,
Lecture Notes in Logistics, DOI 10.1007/978-3-319-23512-7_12

services and activities related to the letting, transport, construction, and deconstruction of event equipment (Harjes and Scholz-Reiter 2013a, b, c, d; Allen et al. 2010). The corresponding planning processes cover the allocation of resources to customer orders (events), as well as the personnel and route planning for transport to and between different venues (Holzbaur et al. 2005).

Generally, both process planning and execution in event logistics are subject to high customer requirements with regard to due dates and the cost–benefit ratio. Further, dynamic influences, such as rush orders, order changes as well as damaged or stolen equipment lead to complications (Harjes and Scholz-Reiter 2013a, b, c, d). Correspondingly, the planning authority has to find a sensible trade-off between the demands of the customer, the internal process requirements, and the economic interests of the logistics company.

These complex and dynamic parameters often exceed the capacities of central planning and control approaches (Windt and Hülsmann 2007). Therefore, it makes sense to evaluate the applicability of other control methods in the field of event logistics. This paper introduces the first results of a distribution system that follows the principles of autonomous control, a paradigm that aims at robust and flexible processes by shifting decisions from central planning instances to autonomous objects within logistic or production systems (Windt and Hülsmann 2007).

The introduced distribution system applies two autonomous control methods to take over the complete allocation of resources to events, including the tour- and route planning for the transport devices and the corresponding personnel planning (Harjes and Scholz-Reiter 2013a, b, c, d). The presented paper gives a short insight into the concept, implementation, and possible integration by means of an example company. The main focus of the paper lies on the first experimental results and the corresponding potential for savings.

The paper is structured as follows. Section "Example Company" focuses on the example company and section "Autonomously Controlled Distribution" outlines the concept and implementation of the distribution system. Section "Experimental Results" introduces the experimental results that underlie the estimation of the savings potential in section "Savings Potential". Finally, the paper closes with a conclusion and outlook in section "Conclusion".

Example Company

The example company is a full-service agency in the field of event management (Harjes and Scholz-Reiter 2012). Starting from the company headquarters in northern Germany and several branches for marketing and public relations, 60 employees offer a complete set of services for the accomplishment of public or private events.

Its main business segment is the artistic planning, logistic services, and lending of event equipment. The latter comprises equipment reaching from cloak hangers or chairs and tables over catering devices up to stages and related techniques

(Harjes and Scholz-Reiter 2013a, b, c, d). The logistics services mostly deal with the transport of rental articles to and between different venues, including the construction and deconstruction of the equipment at the event. For logistic purposes, the example company runs a central stock directly at the headquarters and owns a car pool consisting of several vans and trucks of varying sizes between 3.5 and 40 t cargo load (Harjes and Scholz-Reiter 2012).

The planning and realization of events decomposes in six phases, starting with the order receipt and ending with post-processing and billing. In between, the customer's wishes first flow into a rough planning according to a local inspection of the venue. Then, the preliminary planning is refined iteratively until the customer is satisfied and the realization can begin (Harjes and Scholz-Reiter 2013a, b, c, d).

This paper addresses the detailed planning of the event execution; the artistic aspects are not of interest. Within the example company, a project manager is responsible for the allocation of specific equipment and personnel to events and the corresponding creation of pick lists and cargo lists. The project manager falls back to his expert knowledge, an automated planning or scheduling does not take place (Harjes and Scholz-Reiter 2012). The only exception is a rudimentary function of the enterprise resource planning software that provides a temporal availability overview for the equipment, comparable to a Gantt chart. The corresponding route planning resides with the transport personnel and often bases on tools such as Google maps or customary navigation systems.

This centralized, knowledge-based proceeding generally results in a high planning effort and is not very flexible. The latter often requires a complete replanning, if the above-mentioned dynamic aspects influence the availability of already disposed equipment, personnel, or transport devices. Further, the handling of order peaks often leads to the leasing of foreign equipment and/or transport devices with additional costs. Overall, the efficiency and robustness of the logistic services shows the potential for greater improvements (Harjes and Scholz-Reiter 2013a, b, c, d).

Autonomously Controlled Distribution

The considered distribution system combines two autonomous control methods to solve the subproblems related to resource allocation in event logistics (Harjes and Scholz-Reiter 2012). The central point of the system is the Platform for Simulations with Multiple Agents (PlaSMA), a multi-agent-based simulation software (MAS) with special features for the consideration of logistic and production systems (Gehrke et al. 2010). PlaSMA was originally developed for the comparative, scenario-based evaluation of autonomous control methods and strategies (Warden et al. 2010). Within the autonomously controlled distribution system, PlaSMA serves as a platform for the agent-based generation of planning decisions (Harjes and Scholz-Reiter 2013a, b, c, d).

All existing resources have a representing agent within the PlaSMA simulation. The agent representation follows the ontologies for goods, transport, and communication given in PlaSMA (Warden et al. 2010; Harjes and Scholz-Reiter 2013a, b, c, d). During a simulation run, all agents try to fulfill their personal objective function, which depends on the kind of individual agent. A transport agent, for example, tries to maximize its load factor and minimize the distance travelled, while an agent who represents a piece of equipment focuses on the punctual arrival at the event (Harjes and Scholz-Reiter 2012).

The final planning decisions are the result of mutual negotiations between the agents within the simulation. The idea behind this proceeding is that the fulfillment of the individual agent's objectives leads in total to a fulfillment of the global planning objectives (Harjes and Scholz-Reiter 2013a, b, c, d). The corresponding order situation and the related parameters, such as the event dates and places or the requested article types, come from the ERP-system and form the scenario that underlies the simulation. The occurrence of dynamic effects leads to a corresponding change of the scenario and requires an additional simulation run with adapted parameters (Harjes and Scholz-Reiter 2013a, b, c, d).

The outcome of a simulation run corresponds to the results of the manual planning process, meaning one pick and cargo list per event and the related personnel planning. Further, the autonomously controlled distribution takes over the route planning (Harjes and Scholz-Reiter 2013a, b, c, d). At this, the Distributed Logistics Routing Protocol (DLRP) comes into operation. It is derived from the routing protocols of data packages in large communication networks, such as the Internet (Rekersbrink et al. 2008; Rekersbrink 2009). Within the distribution system, the transport agents use route planning functions of the DLRP as behavior. The required world model in form of a graph that represents the street network is part of the simulation scenario. The world model consists of the venues and the central stock as nodes, while the available streets between them form the edges of the transport graph (Harjes and Scholz-Reiter 2013a, b, c, d).

The general robustness of the process and the reasonability of the planning results have been proven in first experiments (Harjes and Scholz-Reiter 2013a, b, c, d). The range of the test scenarios took place around five events in four cities. The length of the events was up to 3 days and the amount of requested articles fluctuated between 35 and 100 pieces of equipment. The autonomous distribution system was able to generate reasonable planning results, including transport routes for all scenarios (Harjes and Scholz-Reiter 2013a, b, c, d).

Experimental Results

In contrast to the validation mentioned above, the following experiments aim at the evaluation of the overall performance of the distribution system. The achieved reduction in the travelled distance is of central interest, as this constitutes the main starting point for savings. The capacity utilization is also important, but due to the heterogeneity of the event equipment, it is more difficult to improve and therefore not as meaningful.

Table 1 Results for 20 smaller events in 5 days

Parameter	Days	Events	Articles	Available vehicles	Leasing vehicles	Distance travelled (km)
Actual state	5	20	36/38/42	6	0	730/1504/1359
Autonomous Distribution	5	20	36/38/42	6	0	498/972/709

The foundation of the experiments is a set of scenarios basing on the average workload of the company in the example. The scenarios comprise up to 20 events distributed over a period of 5 days. The size of the events lies between 36 and 175 articles of different volume and weight, reaching from single tables up to heavy stage parts and technical equipment. The venues are located within a radius of 111 × 67 km, the available car pool comprises two vans/small trucks (2 × 3.5 t), three medium trucks (3 × 7.5 t), and one lorry with 40 t. The four cars of the example company only serve for the transport of small devices and personnel, therefore they are not considered in the simulations.

Table 1 shows a first excerpt of the results for 20 smaller events with a varying amount of articles and an event duration of 3 h on average (min 1, max 5 h), plus the time slots for delivery and removal as well as construction and deconstruction of equipment. The first line of the table shows the results of the actual state, the second line contains the results of the autonomously controlled distribution system. The actual state represents the manual centralized planning of the project manager, which has been implemented in the form of a software tool as a reference for experimental purposes. The validation of the tool's propriety took place by means of several reference scenarios.

The results show that both approaches are able to execute all orders using the given car pool. A leasing of vehicles is not necessary. The advantage of the autonomous distribution system is the efficient summary of several orders to one route. The actual centralized planning mostly executes fewer or even single orders per trip for complexity reasons. Further, the central planning only considers event equipment that is currently available at the stock. The autonomous distribution system additionally allocates available equipment at already running events. This decentralized distribution leads to differences regarding the travelled distance between 232 and 650 km for a period of 5 days.

The differences regarding the efficiency of the route planning increase depending on the amount of articles required. Table 2 shows the results of three scenarios with larger events. The average distance to the central stock, as well as the considered time period, correspond to the settings of the first experiments, whereas the available car pool is reduced to one van/small truck of 3.5 t, two medium trucks with 7.5 t, and one lorry with 40 t. The amount of requested pieces of equipment lies between 86 and 175.

The results for the larger scenarios confirm the previous observations. Both approaches are able to handle the orders with the given car pool, but the

Table 2 Results for larger events

Parameter	Days	Events	Articles required	Available vehicles	Leasing vehicles	Distance travelled (km)
Actual state	5	20	86/125/175	4	0	2414/2114/2264
Autonomous distribution	5	20	86/125/175	4	0	1218/1178/1774

autonomous distribution system shows even larger differences regarding the travelled distance of the transport vehicles. Due to the higher article numbers, efficient compilation of transports becomes more important. This results in savings between 490 and 1196 km for autonomous distribution during the considered period.

Savings Potential

The savings potential of the outlined approach for an autonomous distribution system in the field of event logistics mostly centers on the reduction of the distance travelled during the order execution. The efficient compilation of both routes and transports leads to a decent potential for savings. With regard to the example company, a medium enterprise with an annual turnover of around nine million euros, the introduction of the distribution system is worth considering.

Currently, the example company accomplishes around 130 events per year using their own resources. This number contains only the "medium" and "large" events, meaning orders that need more articles than a single van can contain. The number of smaller orders constitutes an additional amount of approximately 130–150 events. Altogether, the number of trips per order is around three.

Starting from these assumptions, the following efficiency analysis considers two scenarios for the introduction of the autonomous distribution system. The first bases on an in-house development carried out by the IT—and the transport department of the company in the example. The second one assumes the issuance of an industrial project, carried out by a specialized external company.

In-House Development

In the first case, the adaption of PlaSMA and the DLRP as well as the implementation of the overall system would cost around 64.000 €. This calculation also includes the integration of the system into the existing software architecture of the company in the example. The individual steps of the development and integration process and the corresponding costs and duration are as follows:

- Software Development, including the documentation (9 months): 44,540 €
- Software Integration, including tests and trainings (1.5 months): 12.271 €
  Hardware Development/integration, including purchase and tests of components (1.5 months): 7093 €.

The calculation above bases on the deployment of an engineer for project management purposes with ca. 3824 € gross salary per month and an IT-specialist for programming with a gross salary of 2612 € (Hans-Böckler-Stiftung 2013; VDI 2012). The hardware development concerns the development and integration of identification and communication devices for an automated recording of material flows directly at the venue. The hardware is attached to the transport vehicles and ensures information transparency which is indispensable for the application of autonomous control (Harjes and Scholz-Reiter 2013a, b, c, d).

With regard to the experimental results in the previous section, the savings due to the shorter distances travelled would be around 28.300 € per year, depending, among other things, on the fuel prices. The assumed savings consider the operational costs of the existing car pool which is, for example, around 82 Cent per km for a van (Mercedes-Benz Sprinter 213 CDI, 3.6 t cargo load) (ADAC 2013). Under these circumstances, an amortization of the investment (64.000 €) is possible after approximately 3 years. Including the development and integration phase, the autonomous distribution could be profitable after 4 years.

Industrial Project

The second case, an industrial project, would cause much higher costs, as the hourly rates of the involved engineers and specialists would increase. The following calculations trace back to the hourly rates for industrial orders of the BIBA—Bremer Institut für Produktion und Logistik at the University of Bremen GmbH. These would amount to 5258 € per month for an engineer and 3950 € per month for an IT-specialist. The points already mentioned for the first case would then be as follows:

- Software Development, including the documentation (9 months): 64.496 €
- Software Integration, including tests and training (1.5 months): 17.095 €
- Hardware Development/integration, including purchase and tests of components (1.5 months): 14.534 €.

The total costs for this case would rise to 96.000 €, which is a third more than the in-house development. The reductions regarding the mileage of the transport does not change, therefore, the amortization per year is again 23.800 €. This results in an amortization period of 5 years, while the system would work profitably after 5 years.

Conclusion

This paper presents a first estimation of the savings potential of an autonomously controlled distribution system in the field of event logistics. The system takes over the allocation of rental articles (event equipment), transport devices, and personnel to orders as well as the corresponding route planning.

A special focus lies on the reduction of the distance travelled during the event accomplishment. Simulations of several periods of 5 days, with 20 events each, show savings between 232 and 1196 km. Extrapolated to 1 year and with regard to an example company from the considered business area, annual savings of about 23.800 € seem to be possible. For the company in the example, an amortization period between 4 and 5 years is feasible. The dimension of the required investment depends on the decision, if the implementation and integration of the system take place in-house or as an industrial project.

Further research will focus on the optimization of the system, especially regarding the target- and cost functions of the agents within the PlaSMA-Simulation. From the economic perspective, the effects of the autonomously controlled distribution on the manpower requirements and possible savings regarding the size and utilization of the car pool will be from major interest.

Acknowledgments This research is supported by the German Research Foundation (DFG) as part of the Collaborative Research Centre 637 "Autonomous Cooperating Logistic Processes—A Paradigm Shift and its Limitations" at the University of Bremen.

References

ADAC (2013) www.adac.de, http://www.adac.de/_mmm/pdf/autokostenuebersicht_mr_47088.pdf. Accessed 21 Nov 2013

Warden T et al (2010) Towards ontology-based multiagent simulations: the plasma approach. Kuala Lumpur, pp 50–56

Allen J, O'Toole W, Harris R, McDonnel I (2010) Festival and special event management. 5. Hrsg. Wiley, Hoboken

Gehrke J et al (2010) An agent-based approach to autonomous logistic processes—colloborative research centre 637: autonomous cooperating logistic processes. KI-Künstliche Intelligenz 24 (2):137–141

Hans-Böckler-Stiftung (2013) Lohnspiegel.de, http://www.lohnspiegel.de/main/zusatzinformationen/fachinformatiker-innen. Accessed 21 Nov 2013

Harjes F, Scholz-Reiter B (2012) Autonomous control in event logistics. Rende (CS), Italy, DIME, University of Genua, pp 302–308

Harjes F, Scholz-Reiter B (2013a) Agent-based disposition in event logistics. Res Logistics Prod 3:137–150

Harjes F, Scholz-Reiter B (2013b) Informationstransparenz in der Veranstaltungslogistik. Ind Manage 29(5):39–42

Harjes F, Scholz-Reiter B (2013c) Selbststeuernde Logistik im Umlaufmanagement von Verleihartikeln. HNI Verlagsschriftenreihe, Paderborn, pp 217–227

Harjes F, Scholz-Reiter B (2013d) Selbststeuerndes Routing für Verleihartikel. Ind Manage 29 (6):1–6

Holzbaur U et al (2005) Logistik. Eventmanagement—Veranstaltungen professionell zum Erfolg führen. Springer, Heidelberg, pp 105–142

Rekersbrink H (2009) Methoden zum selbststeuernden Routing autonomer logistischer Objekte—Entwicklung und Evaluierung des Distributed Logistics Routing Protocol (DLRP), Bremen

Rekersbrink H, Makuschewitz T, Scholz-Reiter B (2008) A distributed routing concept for vehicle routing problems. Logistics Res 1:45–52

VDI (2012) www.ingenieurkarriere.de, http://www.ingenieurkarriere.de/bewerberservice/beratung/gehaltscheck/gehaltscheck.asp. Accessed 21 Nov 2013

Windt K, Hülsmann M (2007) Changing paradigms in logistics—understanding the shift from conventional control to autonomous cooperation and control. In: Hülsmann M, Windt K (eds) Understanding autonomous cooperation and Control—the impact of autonomy on management, information, communication and material flow. Springer, Berlin, pp 4–16