BRINGING STUDENTS TO PRACTICE: PERFORMING A REAL-LIFE SIMULATION STUDY IN AN INTRODUCTORY SIMULATION COURSE

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ABSTRACT

Business process simulation can support the analysis and improvement of business processes and, hence, is a valuable technique to teach to students. Consequently, introductory simulation courses are included in a multitude of study programs. Besides providing students with theoretical knowledge and getting them acquainted with simulation software, it is also important to let them experience the complexity involved in conducting a simulation study in practice. In this respect, this paper outlines the inclusion of a real-life simulation study in an introductory simulation course. Besides the content of the simulation study, the instructional design, student feedback, company feedback and challenges perceived by the instructor are outlined. Student feedback shows that, even though the project was perceived as highly challenging, conducting the real-life simulation study provided extensive learning opportunities.

1   INTRODUCTION

Business process simulation (BPS) refers to the imitation of business process behavior through the use of a simulation model. By mimicking the behavior of the real process, simulation can provide insights in the effects of operational changes prior to implementation. In this way, it contributes to the analysis and improvement of business processes (Melão and Pidd 2003). Given its key potential to support decision makers during business process improvement, introductory simulation courses are part of the study programs at several universities and business schools worldwide. Besides disseminating theoretical knowledge on the "mechanics" of developing a simulation model and introducing them to the use of a particular simulation software, it is also important to let students experience the complexity involved in conducting a simulation study in a real-life setting.

   To expand upon this latter observation, a real-life simulation study is integrated in an introductory simulation course offered to students in the Business and Information Systems Engineering master program at Hasselt University. To this end, a collaboration with the logistics service provider H. Essers is established. The simulation study supports one of the running projects of the company's engineering department, i.e. the improvement of the operations at the company's cross-dock. More specifically, the trailer unloading process is considered. From a pedagogical perspective, integrating the real-life simulation study operationalizes recommendations widely supported by educational research such as providing authentic learning contexts and performing learning activities having real-world relevance (Herrington and Oliver 2000).

   This paper outlines how the real-life simulation study is integrated into an introductory simulation course. It pays attention to both the content of the simulation study, i.e. the business process that is considered, and the instructional design which is used. Moreover, student feedback, company feedback and challenges perceived by the instructor are discussed, constituting learning opportunities for instructors considering the integration of a real-life simulation study in their own course. In this way, this paper can

contribute to the improvement of simulation course design by genuinely taking into account the need for authentic learning contexts (Herrington and Oliver 2000).

The remainder of this paper is organized as follows. Section 2 provides some general context about the study program and the course in which the real-life simulation study is situated. Section 3 outlines the content of the simulation study by outlining the current and future unloading process at the cross-dock of H. Essers. In Section 4, the instructional design of the simulation study is outlined. Section 5 discusses the student and company feedback. Section 6 outlines the challenges that the instructor is confronted with and suggests points to further improve the instructional design. The paper ends with a conclusion in Section 7.

2 CONTEXT AND ORGANIZATION OF THE COURSE

The real-life simulation study is positioned within a 6 ECTS introductory simulation course. It is positioned within the master program of Business and Information Systems Engineering at the Faculty of Business Economics. The program focuses on business data science, business process analysis and IT business innovation. The introductory simulation course contributes to the business process analysis focus and aims to teach students basic discrete-event simulation concepts and how a simulation study is conducted. Relevant prior knowledge that the students have includes exploratory data analysis in R (Wickham and Grolemund 2017), general process modelling using BPMN (Chinosi and Trombetta 2012) and the basic principles of queueing theory. The specific end competencies of the introductory simulation course are:

- The student can distinguish, describe and apply the various required steps in a simulation study.
- The student can distinguish and describe the different components of a simulation model and perform related modeling tasks.
- The student can analyze a business problem by means of a simulation analysis and report the results to both technical experts and decision makers.

To achieve these end competencies, seven lectures are provided which introduce the basic principles of discrete-event simulation, centered around the key steps that are required to perform a simulation study. Topics include the high-level steps of a simulation study, input data collection and analysis, conceptual modelling, input distribution specification, and verification and validation. Compulsory reading materials includes Martin et al. (2016), Robinson (2008a), Robinson (2008b), Sargent (2013) and White and Ingalls (2005). Besides these lectures, practical sessions are organized which introduce students to a simulation software. Practical sessions focus on self-paced learning of the quintessential modules in the simulation software making use of exercises of increasing degrees of complexity. However, these exercises are not representative for the performance of a simulation study and, hence, are not sufficient to achieve the first and third end competency outlined above. This observation is the rationale for including a real-life case study in the course, accounting for half of the marks of the course. To ensure that students have sufficient time and knowledge to perform the real-life simulation study, lectures and practical sessions are purposefully scheduled in the first part of the 13-weeks semester. A high-level timetable of the course is shown in Figure 1.

Course week	1	2	3	4	5	6	7	8	9	10	11	12	13
Lectures	░	░	░	░	░	░	░						
Practical sessions		░	░	░	░								
Simulation study				░	░	░	░	░	░	░	░	░	░

Figure 1: Overview of timetable of the course. Marked cells indicate the time period over which a particular education activity is spread.

3   OVERVIEW OF THE CONTENT OF THE REAL-LIFE SIMULATION STUDY

The real-life simulation study relates to the unloading process in the cross-dock of H. Essers. In a cross-dock, incoming trailers are unloaded, their content is sorted and reloaded to an outgoing trailer within a very short period of time (Boysen and Fliedner, 2010). The engineering department is conducting a large project aiming at a significant improvement of cross-dock performance. The project is decomposed in several subprojects and one of these involves the reorganization of the process that is followed when trailers are unloaded. The real-life simulation study is situated within this subproject.

In this section, the current unloading process (Section 3.1), the future unloading process (Section 3.2) and the role of the shunter (Section 3.3) are outlined. Moreover, some key policy questions which are put forward to guide the students are included (Section 3.4). Finally, an overview of the data files provided to support simulation model construction is given (Section 3.5).

3.1   Current Unloading Process in the Cross-dock

In the current process configuration, each gate of the cross-dock can be used to load or unload a trailer. A *single warehouse worker* is responsible for completing the entire unloading action.

Several activities can be distinguished in the current unloading process:

- The warehouse worker goes to the central warehouse administration, located in the cross-dock, where the unloading lists are present. These unloading lists were created by the transportation planners and detail which orders need to be unloaded from a trailer.
- The warehouse worker receives an unloading list, containing an indication of the gate at which the trailer is located that should be unloaded. Together with the unloading list, the warehouse worker also receives order labels containing the required order information.
- The warehouse worker moves to the indicated gate.
- Before opening the trailer, the warehouse worker will perform an outdoor safety check.
- After the safety check, the warehouse worker opens the trailer and records the start of actual unloading by performing a scanning action.
- The following procedure is repeated until the trailer is empty:
    - The warehouse worker removes the first parcel from the trailer and temporarily positions them at the gate.
    - At this location, the parcels are processed and registered. The sizes and packaging type (pallet, box,...) are checked as this is important for billing purposes. With respect to labelling, a distinction is made between order labels and parcel labels. Each order on a trailer will receive one order label, containing the required order information. As an order can contain several parcels, each parcel should also be labelled and linked to the unique order label. The best case scenario is that each arriving parcel already contains a barcode which is registered in the transport management system of H.Essers. When a parcel is labelled, but the label is unknown in the company's system, the label is linked to the order label by performing a scanning action. When a parcel is not labelled, the warehouse worker will add a parcel label. This parcel label is linked, whenever possible, to the order label by means of a scanning action. The warehouse worker should determine manually which parcels are linked to which order label.
    - After processing and registration, the parcels are moved to the appropriate loading zone in the cross-dock to await further transportation. The hand scanner of the warehouse worker indicates to which drop-off location a parcel needs to be moved.
    - When the warehouse worker arrives at the appropriate drop-off location, a scanning action is performed at this location in order to register its location in the system.
- The order label is attached to the last parcel of an order.
- When all orders on the unloading list are processed, the unloading list is closed in the system.

- The warehouse worker returns to the central warehouse administration and returns the unloading list, where the latter is processed for administrative purposes.

As outlined above, a single warehouse worker is responsible for performing the entire unloading action. As a consequence, it can take up to 1.5 or 2 hours to unload a single trailer. This implies that a gate is occupied for this period of time, which is deemed too long from a management perspective. Consequently, management wants to reorganize cross-dock unloading process such that gates are freed more quickly.

3.2 Future Unloading Process in the Cross-dock

In an effort to reorganize the cross-dock, a *central unloading zone* will be introduced where all goods are unloaded. The central unloading zone will span eight gates. In principle, trailer unloading will only be performed at these eight gates. All other gates can, hence, be used for loading purposes. The central unloading zone will consist of three areas, which are also visualized in Figure 2 which will be used to outline the future unloading process:

- The gate corridor where the gates are situated (upper part of Figure 2, marked in yellow).
- The central unloading zone, which is composed of eight unloading lines and an administration facility (middle part of Figure 2, marked in green).
- A middle corridor which is used to move goods from the unloading zone to the appropriate loading location (lower part of Figure 2, marked in blue).

(a)   (b)   (c)
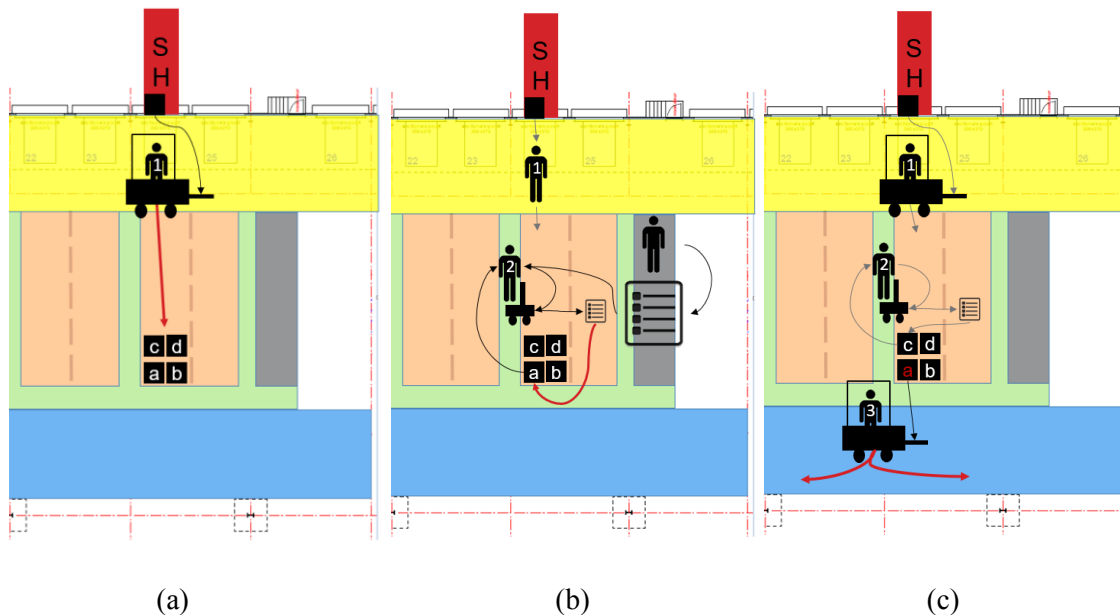
Figure 2: Schematic overview of the future unloading process.

In the future process configuration, *multiple warehouse workers* will be involved in unloading a trailer with the ambition to reduce the unloading time and, hence, the time that a gate is occupied. Three key activities will be distinguished: (i) removing parcels from the trailer, (ii) processing and registration and (iii) moving parcels to the appropriate location. Moreover, an important part of the administrative functions will move to the central unloading zone, which reduces the walking distance for warehouse workers. The latter causes unloading lists to be printed within the central unloading zone instead of at a more remote location. These lists are distributed by the responsible of the central unloading zone, which also takes care of the operational management of the warehouse workers in case work needs to be prioritized.

With regard to labelling, the order label will disappear. Each parcel will be provided with a new and integrated parcel label containing all required information.

In the remainder of this subsection, the future process configuration is outlined in more detail. As indicated above, the unloading list is printed at the administration facility located in the central unloading zone in the future process configuration. Moreover, it is linked to a particular gate. The head of the central unloading zone assigns warehouse worker 1 to a particular unloading action, without the unloading list.

Warehouse worker 1 performs the following tasks:

- Warehouse worker 1 moves to the indicated gate.
- Before opening the trailer, warehouse worker 1 will perform the outdoor safety check.
- After the safety check, warehouse worker 1 opens the trailer and records the start of actual unloading by performing a scanning action.
- Warehouse worker 1 starts unloading the trailer and positions the parcels at the indicated unloading line (Figure 2a). This warehouse worker is only responsible for unloading the trailer and conducts no further scanning or labelling activities.

While warehouse worker 1 is unloading the trailer, *warehouse worker 2* is also assigned to the unloading process:

- Warehouse worker 2 receives the unloading list at the administration facility located in the central unloading zone (Figure 2b). The warehouse worker links the unloading list to a mobile label printer by means of a hand scanner.
- Warehouse worker 2 registers and processes each parcel, including its dimensions, packaging types and (when applicable) damages. Afterwards, a parcel label is printed using the mobile label printer and is attached to the parcel (Figure 2b).
- When warehouse worker 2 is working on a particular unloading list, it is technically possible to pause this list in order to start processing another unloading list. However, this is not the intended behavior in the future process configuration.

While warehouse worker 1 is unloading the trailer and warehouse worker 2 is processing the parcels, *warehouse worker 3* is responsible for moving the parcels from the central unloading zone to the appropriate loading location to await transportation (Figure 2c). As each parcel receives a unique parcel label, it is clear for warehouse worker 3 which parcels can already be moved to a location. It is important to note that warehouse worker 3 will typically not be assigned to a particular unloading line. The warehouse worker will switch between unloading lines depending on whether parcels are available that are registered and labeled and, hence, can be moved to a location.

Warehouse workers will be trained such that each of them can perform each of the key activities in the future process configuration, i.e. (i) removing parcels from the trailer, (ii) processing and registration and (iii) moving parcels to the appropriate location.

The project management team of H. Essers expects that the future process configuration will have the following key benefits for the company:

- The time that a gate is occupied to unload a trailer will be reduced. A trailer can be removed from the gate when all parcels are removed from the trailer. In the current process configuration, this is only the case when all parcels are unloaded, processed and moved to its appropriate location in the cross-dock.
- Process flexibility will increase as it is also possible to assign multiple warehouse workers to each of the key activities in the new unloading process. When particular parcels have an urgent connection on an outgoing truck, multiple warehouse workers can be assigned to each of these activities.

3.3   Role of the Shunter

A shunter or terminal tractor is a tractor which is used to move trailers between locations on the H. Essers site, for instance from the parking to a warehouse or between warehouses. Related to the cross-dock, shunter operations involve (i) moving a full trailer from one of the parking lots to a gate and (ii) moving empty trailers to the parking lot to free the gate. Full trailers will be parked at the parking lot when either (i) no gates are available when the truck arrives or (ii) when the goods on the trailer are not immediately needed.

The shunter, which has to service the entire site at which the cross-dock is located, influences the unloading process. In busy times, important waiting times need to be taken into account when a shunter task is submitted in the system. Consequently, gates can remain occupied (when an empty trailer has to be removed) or can be idle (when a full trailer needs to be pushed against the gate) longer than necessary for unloading purposes.

3.4   Key Policy Questions

Students are assigned the task to conduct a simulation study related to the reorganization of the cross-dock unloading process. To provide some guidance, it is indicated that, with regards to the reorganization of the cross-dock unloading process, H. Essers is especially interested in gathering insights in:

- The effect of this reorganization compared to the current process layout in terms of output measures such as the unloading time.
- An appropriate distribution of warehouse workers over each of the three key activities in the reorganized cross-dock unloading process, i.e. (i) removing parcels from the truck, (ii) processing and registration and (iii) moving parcels to the appropriate location.
- The shunter capacity that is required from the perspective of the unloading process at the cross-dock.

Next to this, student creativity is stimulated by indicating that H. Essers is open to creative simulation-based recommendations to operationalize the reorganization of the process.

3.5   Data Files Provided to the Students

To support the construction of the simulation model, students are provided with several (anonymized) data files. The most of them contain raw data dumps from the company's information system. Moreover, they purposefully contain a significant amount of information which is not relevant for the purpose of the simulation study at hand. In this way, students need to critically assess all available data to determine which pieces of information could be helpful to support particular modelling tasks. Moreover, the appropriate filtering operations need to be conducted. Information about the reliability of some of the columns in the dataset is provided in the project assignment as this requires domain knowledge.

More specifically, the following data files are provided to the students:

- *Overview of the conducted time study*. As the future unloading process is not yet implemented, duration estimates for the three key activities cannot be based on, e.g., historical data. Consequently, H. Essers conducted a time study measuring the duration of each step in the process for a limited number of trailers. Students are provided with the raw measurement data, which needs to be aggregated to obtain estimates for activity durations.
- *Dataset related to processed trailers*. A dataset consisting of 1898 rows and 52 columns containing (anonymized) information on the trailers which are unloaded or loaded at the cross-dock in a particular time frame. This file contains the identification information for the trailer and the total unloading time. The total unloading time could, for instance, be used as a benchmark to compare the process performance of the future unloading process against.

- *Dataset related to processed shipments.* A dataset consisting of 25897 rows and 55 columns containing (anonymized) information at the shipment level. It outlines the trailer to which the shipment is related, the number of parcels it contained, its weight, several timestamps related to its unloading/loading, etc. This dataset contained a valuable proxy for the arrival time of a trailer, which is essential information to gain insight in the arrival pattern .
- *Parcel scanning dataset.* A dataset consisting of 57249 rows and 22 columns containing a record for each parcel scanning action performed during a particular period. It contains, for instance, information on whether a particular parcel is damaged, the location at which the parcel needs to be deposited, etc.
- *Stock scan dataset.* Conducting a stock scan implies that all shipments that are present in the cross-dock at a particular point in time are scanned. The stock scan from the day before the starting point of the other datasets is provided consisting of 679 rows and 44 columns. Using this file, students could derive the starting conditions for the simulation in terms of the number of parcels still present at a particular location in the cross-dock.
- *Shunter task dataset.* A dataset containing 1980 rows and 19 columns describing all shunter tasks performed on the entire site (of which the cross-dock is only one facility) during a particular period of time. Detailed information is provided for each shunter task such as the destination and origin of the trailer movement, the time at which the shunter task was entered in the system, the time at which the task has started and the time at which it ended. From this dataset, insights in the typical waiting times related to a shunter request and its actual duration could be retrieved.
- *Cross-dock staffing overview.* A data file (anonymously) describing cross-dock staffing is also provided. It conveys information on the available warehouse workers for each hour of day during each day of the working week. Students needed summarize this information to turn it into an implementable resource schedule.
- *Unloading slots for partners.* H. Essers is part of a European network of logistics service providers. This implies that trailers from partner organizations also need to be unloaded at the cross-dock of H. Essers. Due to contractual agreements, it is crucial that these trailers are unloaded in time. To this end, unloading slots are defined which need to be respected. This data file provides an overview of these unloading slots such that students could take them into account.
- *Overview of distribution trucks*. Domain experts stated that the number of unloading lines required to unload a trailer largely depends on the type of truck. To identify a particular type of trucks, i.e. distribution trucks, in the other datasets, an overview of the identifiers for distribution trucks is provided. Students need to use this information to execute appropriate filtering operations in the other datasets.
- *Gate plan of the cross-dock.* A gate plan for the cross-dock enables students to have a spatial overview of the cross-dock.

4   INSTRUCTIONAL DESIGN OF THE REAL-LIFE SIMULATION STUDY

While the previous section focused on the topic of the real-life simulation study, this section centers around its instructional design. An overview is given of the goals of the real-life simulation study (Section 4.1), the deliverables and evaluation criteria (Section 4.2), and the timetable (Section 4.3).

4.1   Goals

The two primary goals of the real-life simulation study are to enable students to (i) perform a simulation study within a realistic business context and (ii) work with raw data files from the information systems of the company. In this way, the project in the course should resemble an actual simulation project they might need to conduct during their professional careers as close as possible.

Besides these primary goals, two other goals should be mentioned. Firstly, the project also aims to strengthen the students' skills of making appropriate simplifying assumptions and to argue why they are

made. This ability to decompose a problem and identify the most prominent subproblems will also help them in their professional careers.

Secondly, the simulation study also builds on the competencies of students to adjust the content of their communication to a target audience. In the project, a distinction is made between to target audiences: the technical experts of the company and company management. While the latter group is mainly interested in the results and conclusions of the analysis, the former also wants to gain insight in the way in which the results are obtained. Consequently, different ways of reporting and communication are required, which is explicitly incorporated in the deliverables and evaluation criteria of the project, as will be outlined in Section 4.2.

4.2   Deliverables and Evaluation Criteria

The required deliverables for the simulation study are communicated explicitly to the students at the start of the project, providing them with a clear goal. The *deliverables* for the project are:

- The simulation model that is used to generate the analysis results.
- A written report which describes and discusses the conducted simulation study, the developed simulation model, the analysis results, and their conclusions. It is explicitly mentioned to students that the report is targeted at the technical experts within the organization. However, the report should also contain an executive summary of at most 4 pages, which is directed at management and decision makers.
- An oral presentation outlining the key analysis results and conclusions of the simulation study. This presentation has company management and decision makers as a target audience. The presentation time is limited to 10 minutes.

With respect to the *evaluation criteria*, a distinction is made between the criteria used for the simulation model and the written report on the one hand and the oral presentation on the other hand. Regarding the simulation model and the written report, the following evaluation criteria are put forward:

- Construction of the simulation model: structure of the model, level of detail, degree of realism, clarity,…
- Input analysis: the quality of the data analysis using the provided data files as an input.
- Justification of the choices made: the degree to which the modelling choices and assumptions are justified.
- Conducted experiments, output analysis and discussion of the obtained results.
- Formulated recommendations: profoundness of the recommendations, degree to which these recommendations are actionable for the company,…
- General quality of reporting: clarity, style, language, adequacy of the executive summary,…

The evaluation criteria for the oral presentation are:

- General presentation style: clarity and fluency of the oral presentation, adequacy of the responses to questions posed by domain experts,…
- Focus on results: focus of the presentation on key results/conclusions of the study given management as the target audience.
- Clarity and professionalism of the slides: clarity and appropriateness of the slides given management as the target audience.
- Timing: degree to which the time limitation of 10 minutes is respected.

4.3 Simulation Study Timetable

An overview of the case study timetable during the 13-week semester is provided in Table 1. Groups of three students were formed in week 2. Two weeks later, in week 4, a company visit was organized. The program of the company visit consisted of a general overview of the relevant business process by domain experts, a guided tour through the cross-dock, and a Q&A session. The guided tour enabled students to observe the process that they will need to model at a later stage. This is considered highly important in order to make the abstract concepts in the presentations and the project assignment tangible for students.

After the company visit, the project assignment and data files are made available to the students. The project assignment contained all required information with respect to the project such as deliverables, deadlines, an overview of the process, the key policy questions, and a description of the data files. As a consequence, the company visit constituted the kick-off of the simulation study.

To provide feedback to students during the simulation study, two feedback sessions were organized. In week 7, a Q&A session with domain experts was organized for each group of students separately. During this session, questions related to the process could be asked. It was clearly communicated in advance that only a limited time slot was available for each group, requiring students to assign priority to the most pressing questions. The Q&A session with domain experts also constituted an opportunity to check assumptions that the students were planning to make. In week 8, a progress discussion with an instructor was scheduled for each group. This discussion focused on the constructed simulation model and aimed to provide students with feedback on the current version of the model and feedforward on important elements that still needed to be included.

The deliverables were submitted in the last two weeks of the semester, i.e. weeks 12 and 13. In week 12, the deadline for the submission of the simulation model and written report was planned. One week later, the presentations took place with the attendance of the domain experts and the other students.

Table 1: Overview of the real-life case study timetable.

Course week	Activity
2	Group formation
4	Company visit and provision of the project assignment
7	Q&A session with domain experts (for each group separately)
8	Intermediate progress discussion (for each group separately)
12	Submission deadline of simulation model and written report
13	Presentation to domain experts and other students

5 STUDENT AND COMPANY FEEDBACK

This section discusses the feedback provided by students after the course ended (Section 5.1) and outlines the feedback received from H. Essers (Section 5.2).

5.1 Student Feedback

After the introductory simulation course has ended, student feedback with respect to the real-life simulation study was gathered. In general, students experienced the project as challenging, but highly relevant. It enabled them to gain insight in the complexity of performing a simulation study in a realistic setting using raw data files. Moreover, the close interaction with domain experts was judged very positive compared to the artificial (introductory) exercises performed during the practical sessions. Not only the analysis of real-life data and the construction of the simulation model were deemed useful. Students also highlighted the skills they acquired with respect to reporting and presenting with a particular target audience in mind.

Despite the generally positive attitude towards the project, some points of critique were also formulated. Some students deemed the project too challenging as they had to make simplifying assumptions with respect to some characteristics of the process. However, this was envisioned by design as strengthening this skill

was one of the goals of integrating the real-life simulation study. Nevertheless, it is important to inform the students in advance that assumptions can be made as long as they are justifiable and clearly stated in the report. Another remark that was formulated related to the match between the content of the practical sessions and the real-life case. However, this was not a widespread remark among students and it did not relate to the core idea of the integration of the real-life simulation study.

5.2   Company Feedback

In general, H. Essers representatives experienced the simulation study as very positive, which relates to both the way it was organized and the obtained results. Without entering into details, the outcomes reported by students were largely consistent with their expectations. The most challenging part is establishing a reasonable project scope for an introductory simulation course. A related challenge involves determining the datasets and data fields which are required to support the students without providing them with large amounts of irrelevant data. These challenges were alleviated to a large extent by entering into profound discussions with the instructor during the early stages of the project's design.

6   CHALLENGES FOR THE INSTRUCTOR AND POINTS FOR IMPROVEMENT

This section outlines the challenges experienced by the instructor during the integration of a real-life simulation study in an introductory simulation course (Section 6.1) and retrospective reflections marking points to improve the instructional design (Section 6.2).

6.1   Challenges from the Perspective of the Instructor

From the perspective of the instructor, a key challenge involves striking a balance between (i) ensuring that the project is representative for a real-life simulation study and (ii) taking into account the limited simulation experience of students and the limited time available. Within the introductory simulation course under consideration, both elements are balanced by providing a detailed project assignment. This project assignment clearly defined and delineated the process that needed to be studied and contained a description of the meaning of each column in the data files. Furthermore, explicit attention is attributed to the steps of which a simulation study consists in the first lecture. In this way, students gather a high-level insight in what it involves to conduct a simulation study.

Another major challenge for the instructor is finding a company which is fully committed to the project. A non-negligible time investment is asked from the company. At the minimum, they are required to gather the required data files and assist while writing the project assignment, e.g. by providing feedback on intermediate versions. In the project described in this paper, company involvement went significantly further as they also organized a company visit, came over to the university campus for a Q&A session and attended the final presentations.

Regardless of the level of involvement of the company, integrating a real-life simulation study in a simulation course still requires an important time investment on the part of the instructor, which is also a challenge. The ideas conveyed in this paper might be an inspiration as to how the integration of such a real-life case can be operationalized. Moreover, efficiency gains are possible as the key principles of the project for a particular year can serve as a template for subsequent academic years. I also experienced these efficiency gains when organizing the second edition of the real-life simulation study.

6.2   Points to Improve the Instructional Design

Even though all involved parties were satisfied with the results of the simulation study, three points to further improve the instructional design are identified in retrospect. Firstly, students could learn even more from the simulation study when their progress is followed up more closely. From Table 1, it follows that there is a single progress discussion in week 8. Students might benefit from presenting their progress every two to three weeks such that the instructor can ask questions or raise points of concern (for instance with

respect to timing). Besides the opportunity to receive feedback more frequently, students are also stimulated to start working on the project earlier in the semester. For the instructor, a closer involvement during the teaching period also facilitates the evaluation of the projects at the end of the course as he/she is more up to date with e.g. the modelling choices that a group made.

Secondly, a peer grading mechanism can be introduced to let students evaluate the contribution of each team member to the final model and report. As with any type of group work, free riding can also be an issue during a real-life simulation study. While such behavior might be detected by asking questions to all group members during the final presentation, peer grading also provides students with a tool to express their opinion on the fairness of work division. The peer grading results can be used when determining the individual student scores.

Finally, it is key that sufficient metadata is available on the data files provided to students. As indicated in Section 3.5, this relates to the meaning of columns in the data files and the reliability of their content. Moreover, students also need to be informed about e.g. preliminary filtering operations that are required, but for which it is not reasonable to assume that they possess the necessary domain knowledge. The degree to which metadata should be provided will depend upon the process under consideration and the background of the students following the course.

7   CONCLUSION

This paper discussed the integration of a real-life simulation study within an introductory simulation course. It lets students experience the complexity of conducting a simulation study in a real-life setting, which is complementary to the theoretical knowledge on simulation and the skills to work with simulation software acquired during the course. Moreover, it operationalizes the recommendations in educational research to provide authentic learning contexts and to perform learning activities having real-world relevance.

The real-life simulation study presented in this paper relates to a process of H. Essers, a logistics service provider. To improve the operations at their cross-dock facility, the company was considering to reorganize the trailer unloading process. While a trailer is currently unloaded by a single warehouse worker, the future configuration distinguishes three key activities: (i) removing parcels from the trailer, (ii) processing and registration and (iii) moving parcels to the appropriate location. These three key activities will be performed by different warehouse workers in an effort to reduce the unloading time. Students were asked to perform a simulation study related to the reorganization of the unloading process and were provided with several data files from the company's information systems to support model construction.

Integrating a real-life simulation study in a simulation course is challenging for the instructor as the degree of realism of the project needs to be balanced against constraints in terms of time and limited simulation experience of students. Moreover, finding a fully committed company can be difficult. Despite such challenges, the positive feedback from students makes it worth the efforts. In general, students experienced the project as challenging, but highly relevant. Consequently, the integration of a real-life simulation study contributes to the improvement of simulation course design as it genuinely provides authentic learning contexts.

ACKNOWLEDGMENTS

REFERENCES

Boysen, N. and M. Fliedner. 2010. "Cross Dock Scheduling: Classification, Literature Review and Research Agenda." *Omega* 38(6):413-422.

Chinosi, M. and A. Trombetta. 2012. "BPMN: An Introduction to the Standard." *Computer Standards & Interfaces* 34(1):124-134.

Herrington, J. and R. Oliver. 2000. "An Instructional Design Framework for Authentic Learning Environments." *Educational Technology Research and Development* 48(3):23-48.

Martin, N., B. Depaire, and A. Caris. 2016. "The Use of Process Mining in Business Process Simulation Model Construction." *Business & Information Systems Engineering* 58(1):73-87.

Melão, N. and M. Pidd. 2003. "Use of Business Process Simulation: A Survey of Practitioners." *Journal of the Operational Research Society* 54(1):2–10.

Robinson, S. 2008a. "Conceptual Modelling for Simulation Part I: Definition and Requirements". *Journal of the Operational Research Society* 59(3):279-290.

Robinson, S. 2008b. "Conceptual Modelling for Simulation Part II: A Framework for Conceptual Modelling". *Journal of the Operational Research Society* 59(3):291-304.

Sargent, R. G. 2013. "Verification and Validation of Simulation Models". *Journal of Simulation* 7(1):12-24.

White, K. P. and R. G. Ingalls. 2015. "Introduction to Simulation". In *Proceedings of the 2015 Winter Simulation Conference*, edited by L. Yilmaz et al., 1741-1755. Huntington Beach, California: IEEE.

Wickham, G. and G. Grolemund. 2017. *R for data science*. Sebastopol, Canada: O'Reilly.

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