MASTER

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Award date:
2011

Eindhoven, August 2011

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BSc Industrial Engineering — Bilkent University, 2009
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in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

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TUE. School of Industrial Engineering.
Series Master Theses Operations Management and Logistics

Subject headings: human planning processes, behavioral operations management, case (scenario) based analysis, decision-making processes, logistics operations

Quantifying Human Planning Efficiency at Den Hartogh

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Abstract

This paper presents an empirical study of the human planning processes in a Dutch logistics service provider for the (petro)chemical industry, in order to quantify its human planning efficiency and provide insights on its decision-making processes. A simulation model is developed in order to quantify time consequences of repair actions taken by the planners. Results are presented as cases constituted of different combinations of modalities (executions) picked from paths with relatively high order volume. Different options for handling problems are tested to compare their related time consequences. The findings indicate that in case of a problem occurrence, it is better to take a repair action, if the planner anticipated a repair execution delay with a relatively low mean and low standard deviation and it is better not to interfere the problem if the planner expects a relatively high mean and high standard deviation for execution of the repair action.

Key words: human planning processes; behavioral operations management; case (scenario) based analysis: decision-making processes; logistics operations

1. Introduction

Reaching high levels of planning efficiency is what every organization is eager to achieve. Planning efficiency is an important concern particularly for service operators such as freight providers since their operations are heavily reliant on tight schedules and, most of the time, scarce resources. According to de Roo (2003), "planning efficiency is explained by the extent to which the deployment of available resources contribute to achieving the defined goals." In a slightly different manner Basu and Wright (2008) define planning efficiency as a simple measure of whether the plan is being achieved. What these two definitions have in common is worthwhile to notice; both definitions focus on "the achievement" or "the goal". The other element that is crucial to look at is the "available resources." In order to make an assessment of whether the resources on hand are employed wisely to reach the goal of the organization, it is mandatory to come up with a performance measure to quantify planning efficiency.

Planning efficiency concerns are highly relevant to Den Hartogh Logictics, a Ducth based logistics service provider for the chemical industry. One reason stems from the fact that Den Hartogh, currently, is not able to measure the efficiency difference between its initial planning and time consequences of the recourse decisions that are taken when unexpected events are experienced on an order execution. The initial planning is made by the tactical tank planning unit that is responsible for the planning of load-carrying units (tanks) and construction of modalities. These tasks are, mainly, handled by a computerized algorithm that generates the plans. This tactical part of the planning process is out of focus of this paper. On the other hand, operational planning is the second part of the planning process that handles driver allocation and integration of last minute changes into plans. From a behavioral operations management perspective, this is the interesting part of the overall planning process, since it is the unit in which planners manipulate the plans in order to deal with problems occurring due to stochasticity. This paper focuses on analyzing these problems and intends to quantify the time consequences of manipulations/changes on the plans when unexpected events are experienced.

Time is the Key Performance Indicator (KPI) of how well the planning is functioning at Den Hartogh. Since decisions of the planners directly influence time consequences, it is important to notice the significance of the human decision-making process during operational planning. As a matter of fact, behavioral perspective of planning operations needs to be examined in order to understand its added value on the decision-making process. This paper, by incorporating a behavioral perspective into logistics operations, presents findings about the time consequences of the decision-making process of operational planners.

This paper explores the implications of incorporating behavioral factors into human planning processes, specifically in logistics operations. The three main contributions of the paper are as follows: 1) What are the components of human decision-making processes? 2) What are the effects of behavioral factors on decision-making processes? 3)

What is the added value of different behavioral factors on human planning processes?

Section 2 of the paper introduces a literature review, describing issues in the field investigated so far, and highlights the relevance of the behavioral factors in human planning processes. Section 3 describes the research setting and Section 4 follows with the study design and data description. In Section 5, conclusions and inferences are presented in the form of case (scenario) based analysis along with a sensitivity analysis, discussing the implications of this paper and its practical insights. Section 6 discusses notable research limitations and finally, Section 7 introduces possible paths for future research directions in the field.

2. Literature Review

Humans are critical to the functioning of numerous operating systems, influencing both the way these systems work and how they perform (Gino and Pisano, 2008). Despite the fact that many other disciplines, including economics, finance, and marketing, have successfully incorporated behavioral aspects into a stream of research in their respected fields, the use of human experiments and the integration of behavioral and cognitive factors in operations management is still fairly novel except a small stream of publications going back more than 20 years (Bendoly, 2006). Many techniques and theories ignore important characteristics of real systems and therefore are perceived to be difficult to apply in practice (Loch and Wu, 2005).

Researchers in this relatively new sub-discipline of operations management try to understand and predict interactions between social and psychological variables in order to illuminate decisions-making schemes. The common element is always the same: the human factor. Therefore it can be asserted that the success of operations management tools and techniques heavily rely on understanding of human behavior and human decision-making.

Recently, there has been growing bodies of knowledge in the field. For example, by conducting controlled experiments, Bearden and Rapoport (2005) focus on sequential decision-making problems in Operations Management (OM) and examine how people make these types of decisions compared with normative theory. On the other had, Loch and Wu (2005) provide guidance on how to incorporate more realistic behavioral attributes into analytical models by examining behavioral issues due to individual decision-making, social preferences, and culture.

There are several papers that examined managerial behavior by using real-life data and laboratory experiments. An analogy can be made between the managers examined in these papers and the operational planners that this very paper examines since both samples of decision makers work in highly complex real-life situations. Deshpande et al. (2003) and Keizers et al. (2003) found that due to the complexity of the situation, decisions of managers do not correspond with the expected profit-maximizing decisions, whereas Schweitzer and Cachon (2000) and Croson and Donohue (2006) suggested some form of decision bias.

At the time, Bowman (1963) made a novel contribution to the literature by developing the idea that management's own (past) decisions can be incorporated into a system of improving their present decisions. Within the aggregate production and employment scheduling fields he developed decision rules and the coefficients in the rules were derived from management's past decisions rather than, radically, from a cost or value model. He tested several cases to illustrate and test his theory.

One interesting paper van Donselaar et al. (2010) examines the ordering behavior of retail store managers and investigates their potential drivers. Similar to the setting of this paper, automated order advices (similar to tactical tank planning) are generated before the store manager takes action. The results of the paper suggest that store managers add value to the system by adjusting the automated order advices.

3. Research Setting

Den Hartogh is a Netherlands based logistics provider for the chemical industry, offering intermodal and road solutions. It receives thousands of orders every month and serves in a region covering West, Central and Eastern Europe. The company has storage facilities for liquids, access to marine terminals and rail connections, a transport fleet for road and intermodal traffic and cleaning facilities at various locations. Its activities aim to deliver creative solutions and high level of service to its customers. Den Hartogh Logistics work closely with its clients in order to deliver significant value to the entire logistics process.

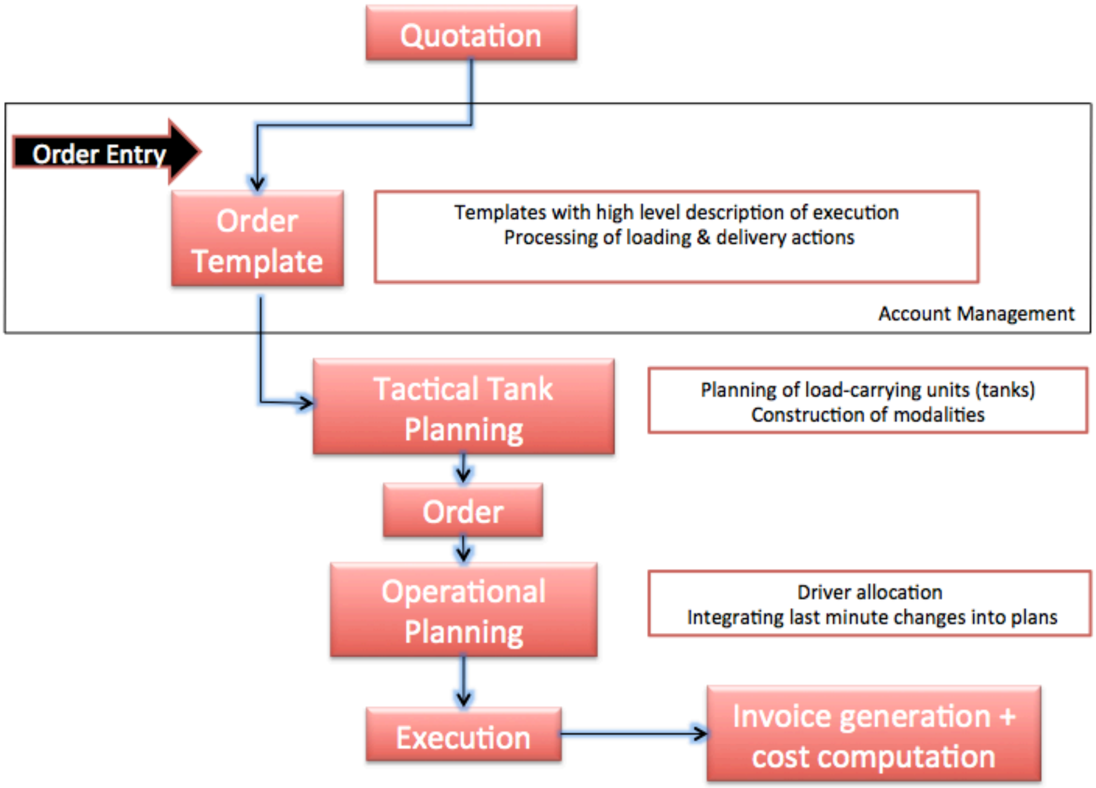

Figure 1: Divisions and their interactions at Den Hartogh.

When Den Hartogh receives an order, the processing of loading and delivery actions on the pre-order are started to be handled by the account manager by using its standard pre-order, which is a template with high level description of execution. After the pre-order is processed, tactical tank planning process starts. Tactical tank planning unit is responsible for the planning of load-carrying units (tanks) and construction of modalities. After this stage, the execution of the order starts to be processed by the operational planning. Operational planning is the second part of the planning process that handles driver and truck allocation and integration of last minute changes into plans. During operational planning, planners may interfere the plans if unexpected events are experienced and the consequences of such stochastic events need to be manipulated. When the execution of the order is finalized, an invoice is generated and the cost of the execution is calculated.

Prior to introducing the reader to problems that may occur and different ways of handling them, it is essential to present the basic operational principles that hold for orders of Den Hartogh.

An order is either road (only by truck) or intermodal (a combination of at least two of the following modes of transportation: truck, ferry and rail) and the term “route” refers to either a ferry or rail transport. All individual steps of actions are called ”modalities”.

Execution of an order refers to all the actions between loading and delivery. A set of modalities describes the execution of an order, where a modality can either be of “trucking” or “route (ferry or rail)” type. Each modality has a start and an end action (load, unload, pick-up, drop, depot, clean and a few less relevant others). In general each order has a load and an unload action, but there are customers which Den Hartogh performs a drop action for a load or an unload action. In such a case the load or the unload action is replaced, where in terms of modalities it results in a drop or pick-up modality. Road orders are transported by a truck with a tank (road barrel or tankcontainer on a chassis) and seldom have “route (ferry or rail)” type of modalities. In terms of modalities this results in a load to deliver modality. Intermodal orders are transported with a tankcontainer and have in general the following execution: trucking from loading to the begin terminal of the route (ferry or rail), ferry or rail modality, trucking from the end terminal of the route to the delivery address. In terms of modalities this results in load to drop, pick-up to drop (ferry or rail), and pick-up to deliver modalities. For a significant percentage of the orders two route modalities are planned (e.g. rail from ES to NL and then a ferry from NL to GB). Den Hartogh does not operate based on distribution. Operations are based on full truckloads with a single loading and a single delivery address (only a very small percentage has either multiple loading or multiple delivery addresses). There are full modalities (road barrel or tankcontainer on a chassis contains product) and empty modalities. Modalities between loading and delivery are known as soon as the order is in the system. Yet, the actual modalities are determined by the tactical tank plan. For some orders tactical tank plan has the freedom to perform the cheapest execution., while for some other orders there are requirements (constraints) on the route (e.g., ferry route has to be taken for a particular order). The latter orders have a predefined route before it is fed to the tactical tank planning algorithm.

4. Research Design

One of the early stages of the research process was to analyze the planning processes of Den Hartogh and specifically to examine the reasons of interruptions on planned logistics processes. Several interviews were conducted with operational planners and the planners were also surveyed with forms in order to understand the nature of operations and to list problems that were encountered commonly on planned logistics processes. Some of these problems were found as loading/unloading delays, cleaning problems with tanks, delays of ferry/train transportation, documentation problems, technical problems and etc. A list of problems on the forms can be found in the Appendix. Similarly, the interviews with the operational planners revealed several repair actions taken to handle the stochasticity experienced. Some of these recourse actions were listed as changing loading/unloading time/date, assigning alternative tankcontainer, assigning alternative driver, changing the delivery time/date and etc. A list of recourse actions that were listed on the forms can also be found in the Appendix.

To provide additional insights, orders of Den Hartogh were simulated using AnyLogic University 6.6.1, a multi-method simulation modeling tool. Yet, since Den Hartogh serves a giant network of customers, two representative paths were chosen to analyze upon. Those two representative paths were picked as the ones with relatively high order volume (from customers with high order frequency).

As for the data, two main file groups were provided by Den Hartogh: tactical tank planning and operational planning data files for the months from September 2010 until March 2011. These data files included an array of information such as order ID, order start date/time, order end date time, address information and etc. In particular, tactical tank planning data file includes information on orders when they are first issued; it can be said that the tactical tank planning information represents what is planned to happen (how the order should proceed) on an order. On the other hand, operational planning data file includes information on an order after the order is completed (when the delivery of the products is made). Operation times of individual modalities on a path were collected from the operational planning data and the discrepancies between the tactical tank planning and the operational planning data for the same order were used to gather statistics on modalities with problem occurrences (e.g. loading/unloading delays).

It was noted previously in Section 3 (first entry of the basic operational principles that hold for orders of Den Hartogh) that a path can be served by either road (only by truck) or intermodal (a combination of at least two of the following modes of transportation: truck, ferry and rail) transportation. Therefore, a path consists of the following combination of modalities:

1. Truck only
2. Truck and Rail
3. Truck and Ferry
4. Truck, Rail and Ferry

4.1 Research Scoping

Interviews with the planners and examination of the historical data showed that the first two combinations of modalities are the most common ones for Den Hartogh's orders. Therefore we chose them as the two representative paths for the quantitative analyses in this paper.

The first path represents an order planned with truck transport only. Initially it is essential to list all individual modalities of a path in order to determine the smallest units that can be quantified within an order. Since the operational planning data file provides information on the realized (completed) modalities for each order, no general path can be drawn from the operational planning file. This is for the reason that the operational planning data changes continuously during the execution of an order (can be for different reasons but mainly due to problems occurring during the execution of an order) and the operational planning data for every single order is unique. Contrarily for the tactical tank planning data, orders belonging to the same path have the same modalities and modality sequences (obviously with different modality start and end dates/times). Therefore the actions for the simulation tool are generated from the tactical tank planning file, in order to have a template backbone for the path to be simulated.

Table 1 lists the modalities of the first path. The first column represents the action performed and the second column represents the location of where the action is performed. The flow of the operations can be described in detail as follows: An empty tankcontainer is picked-up from A and transported (via trucking) to G. After the cleaning of the tankcontainer is done in G, the tank is transported (via trucking) to T for loading. When the loading operation is completed, the tankcontainer (full tankcontainer) is picked-up from T to be transported (via trucking) to A for drop (delivery).

Action Type	Location
Trucking	A - G
Cleaning	G
Trucking	G - T
Loading	T
Trucking	T - A
Drop (Delivery)	A

Table 1: Modalities of Path 1

One important point to note when listing the modalities of a path is what happens to the modalities between two orders of the same path. As it was noted previously in Section 3, full modalities are the modalities between loading and delivery and empty modalities the modalities after the delivery until the next loading. By simulating only one order of a path, the empty modalities would be missed since they are always booked on the previous order. In order to be able to incorporate the empty modalities into the simulation (since it is important not to miss the modalities on between Order 1 (O1) and Order 2 (O2) of the same path for completeness), the connected combination of two orders were set as the basis modality listing of the simulation. In order to achieve this, combination of two orders (same type of orders on the same path) was traced with the truck that served both of the orders consecutively. Table 2 shows the modalities of two consecutive orders for Path 1. Location names are presented with their initials for confidentiality reasons. On the table, the empty modality (pick-up at A) can be seen in between the two orders.

Order #	**Action Type**	**Location**
O1	Trucking	A- G
O1	Cleaning	G
O1	Trucking	G - T
O1	Loading	T
O1	Trucking	T - A
O1	Drop (Delivery)	A
Empty Modality	Pickup	A
O2	Trucking	A - G
O2	Cleaning	G
O2	Trucking	G - T
O2	Loading	T
O2	Trucking	T - A
O2	Drop (Delivery)	A

Table 2: Modalities of two consecutive orders for Path 1

The second path represents an order planned with a combination of both truck and rail transport. Table 3 lists the modalities of the second path chosen. The first column represents the action performed and the second column represents the location where the action is performed. The flow of the operations can be described in detail as follows: An empty tankcontainer is drop at V for loading. After loading is completed, the tankcontainer (full tankcontainer) is picked-up from this location to be transported (via trucking) to BR. The tankcontainer is dropped at the rail terminal and transported (via rail transport) to B.

The tankcontainer is picked-up at B to be transported (via trucking) to T. The drop (delivery) happens at T.

Action Type	Location
Drop	V
Loading	V
Pickup	V
Trucking	V– BR
Drop	BR
Route (Rail)	BR - B
Pickup	B
Trucking	B- T
Drop (Delivery)	T

Table 3: Modalities of Path 2

Similarly, in order to be able to account for the empty modalities for completeness, combination of two orders (same type of orders on the same path) was traced with the truck that served both of the orders consecutively. Table 4 shows the modalities of two consecutive orders for Path 2. In the table, the empty modalities (trucking between T – M, drop at M, route (rail) between M – R, pick-up at R and trucking between R – V) can be seen in between the two orders.

Order #	Action Type	Location
O1	Drop	V
O1	Loading	V
O1	Pickup	V
O1	Trucking	V - BR
O1	Drop	BR
O1	Route (Rail)	BR - B
O1	Pickup	B
O1	Trucking	B – T
O1	Drop (Delivery)	T
Empty Modality	Trucking	T - M
Empty Modality	Drop	M
Empty Modality	Route (Rail)	M - R
Empty Modality	Pickup	R
Empty Modality	Trucking	R - V
O2	Drop	V
O2	Loading	V
O2	Pickup	V

O2	Trucking	V - BR
O2	Drop	BR
O2	Route (Rail)	BR - B
O2	Pickup	B
O2	Trucking	B – T
O2	Drop (Delivery)	T

Table 4: Modalities of two consecutive orders for Path 2

4.2 Data Analysis and Simulation Experiment

Once the individual modalities of the two paths selected were settled, a statistical analysis was conducted to determine the operation times of individual modalities. The operational planning data file for the months from September 2010 until March 2011 is used to determine the means and standard deviations of the listed modalities. The sample size of the data was adequate (>30 samples) to make reliable conclusions on the operation times of individual modalities. Since the normal distribution is the most commonly used approximation for random variables that tend to cluster around a single mean value, the operations times of the modalities were described as bounded normal distributions (in order not to allow minus values).

First, it is necessary to understand the type of problems that occur often and the time consequences of these problems. The forms (as in the Appendix) that were distributed to the operational planners in order for them to note down the problems they faced and the repair actions they took to solve these problems show that the most commonly encountered problems (68.75% of the problems encountered) at Den Hartogh are as follows:

1. Wrong information in job (includes mistakes occur due to account manager)
2. Loading delay
3. Unloading delay
4. Vehicle shortage (no road-barrel available due to previous products)

After sorting the common type of problems, the time consequences of these problems were recorded. Yet, this was only possible for the loading and unloading problems since the time consequence of these problems can be quantified by comparing the tactical tank planning and operational planning data of a specific modality on the path. The discrepancy between the tactical tank planning and the operational planning data for that specific modality on the path indicates the amount of the delay. However for "wrong information in job" and "vehicle shortage" problems, it is not possible to conclude such quantification from either the tactical tank planning or the operational planning data. Therefore, in this research, the simulation tool will quantify the time consequences of repair actions for loading and unloading problem occurrences.

The start times of route (rail) modalities depend on train schedules; therefore a delay that happens on a preceding modality (even a small delay) can cause the scheduled train to be missed. In order to incorporate such situations, on Path 2, just before the route (rail) modalities, a modality to check whether the scheduled train can be taken is added to on the simulation. If the total processing time until that point (rail modality) is more than the sum of all preceding modalities, than a delay is added. This delay represents the case when the tankcontainer takes the second available train due to the miss of the first one.

Another assumption for the simulation setup is that only one problem occurs (either loading or unloading) at a time. This assumption is made in order to be able to see the individual effect of a single problem on a path.

The simulation tool is constructed with a serial structure and for Path 1 and Path 2, time consequences of both loading and unloading problems are generated. In the case of both loading and unloading problems, the first modality is always either of these modalities. (e.g. for a loading delay, the simulation starts with a loading delay modality on the first order, followed by empty modalities and the modalities of the second order until the next loading).

As just noted, the first modality of the simulation tool is always the modality with the problem occurrence. In this module of the simulation, there are two different distributions (whereas a single normal distribution exists for the regular modalities). One is the regular (non-problematic) normal distribution and the second one is a table function (with discrete distributions) with probabilities of delays with different values.

In the problem occurrence module, there are three different branches that an order can follow. The first one is the case with no problem occurrence, the second one is the case when a problems happens but not interfered by the planner (in some cases planners do not intervene if a problem happens because they assume the problem will be solved by itself, causing only an extra delay) and the third one is the case when a problem happens and a repair action is taken by the planner. According to the branch an order follows, a delay associated to that specific branch is added.

Among these branches, repair action branch does not have a fixed delay time. The reason is due to the vague nature of the repair action delay times. The forms that were distributed to the operational planners in the first stages of this project to understand the common problems they face also revealed the common repair actions they take to correct those specific problems. For the loading and unloading delays, the common repair actions and their related usage probabilities are as follows:

- Loading delay
  No change 50%
  Alternative Truck 50%
- Unloading delay
  No change 20%
  Alternative tank 60%
  Change of loading time/date 20%

Even though the usage probabilities are available, the repair time delays of these repair actions truly depend on the specific order that is under investigation. Therefore, a different approach was taken. Instead of assigning a fix amount of delay time on a specific repair action branch, the branch is named as "repair action" and different mean, standard deviation values fitted on a normal distribution are tested.

Once the simulation tool is executed on AnyLogic, three results are generated, namely, the total processing times when no problem occurs, when a problem occurs but not interfered by the planner and lastly when a problem occurs and a repair action is taken by the planner.

5. Conclusions and Inferences

Average processing time of the complete order is what should be paid attention to when analyzing the results, since time is the KPI of how well the planning is functioning at Den Hartogh. Since the objective of this project is to quantify planning efficiency, the lowest value for the average processing time should be chosen.

Of the results generated for the three different cases (no problem (case 1), problem occurs but not interfered by the planner (case 2) and problem occurs and a repair action is taken by the planner (case 3)) specified, the **no problem** case for both paths (for every standard deviation/mean combination) has the lowest average processing time of the complete order. This was an expected result since both in case 1 and case 2 the average processing time is lengthened either because a waiting time is added for the problem to resolve itself (in case of case 2) or for the execution of the repair action (in case of case 3).

In order to interpret the results generated for case 2 and case 3, the differences of values generated for every standard deviation/mean combination are standardized. The following tables indicate the standardized values of the differences for the actions (loading/unloading) of both paths.

STD/MEAN	20	30	50	70	90	110	200
10	1.08	1.10	0.62	0.39	-0.29	-0.33	-2.15
13	1.29	0.89	0.47	0.51	0.30	-0.75	-2.17
16	1.19	1.25	0.55	0.26	-0.16	-0.33	-2.28
19	1.00	0.83	0.58	0.37	-0.02	-0.25	-1.85
30	0.70	0.89	0.74	0.62	0.11	-0.59	-2.04
80	0.30	0.32	-0.31	-0.10	-0.31	-0.65	-1.77

Table 5: Results for unloading of Path 1

STD/MEAN	160	260	360	460	560	660	760	1000
40	1.42	1.16	0.73	0.27	-0.13	-0.46	-0.91	-1.88
50	1.39	1.13	0.74	0.37	-0.11	-0.52	-0.90	-1.85
60	1.30	1.07	0.69	0.32	-0.08	-0.55	-0.87	-1.81
70	1.31	1.11	0.68	0.33	-0.10	-0.47	-0.92	-1.83
80	1.26	1.07	0.70	0.30	-0.06	-0.48	-0.94	-1.86
90	1.24	1.02	0.68	0.30	-0.06	-0.49	-0.89	-1.88
150	0.99	0.84	0.68	0.27	-0.10	-0.48	-0.90	-1.85

Table 6: Results for loading of Path 1

STD/MEAN	40	60	80	100	120	140	200
10	1.88	1.35	-0.94	0.34	-0.69	-0.57	-0.32
13	2.09	1.48	-0.49	-0.25	-0.13	-0.74	-1.53
16	2.20	0.95	0.37	-0.85	-0.53	-0.95	-0.31
19	1.20	0.53	0.21	-0.07	-1.10	-1.22	-1.92
30	0.87	0.90	0.31	-0.21	0.21	-1.95	-0.34
80	1.12	0.51	-0.70	-0.23	-0.06	0.07	-0.50

Table 7: Results for unloading of Path 2

STD/MEAN	30	60	90	120	150	250
10	1.94	0.57	-0.13	0.54	-0.12	-1.31
13	1.51	0.76	-0.22	-0.29	-0.99	-1.98
16	0.97	0.54	0.10	-0.47	-0.24	-2.04
19	1.79	-0.27	1.24	0.84	-0.71	-1.58
30	0.86	0.31	0.65	-0.32	-0.67	-1.64
80	0.44	0.70	-0.06	0.60	-0.21	-1.09

Table 8: Results for loading of Path 2

From the tables above, the following can be interpreted: when the value differences between case 2 and case 3 executed for a particular standard deviation/mean combination, a value above +1 indicate that case 3 is always favorable over case 2. On the other hand, when this value is below -1, then case 2 is always favorable over case 3. For values between -1 and +1, since the values generated for both cases are close to each other, there is no obvious execution dominance of either of the cases and the for values in this interval and the average processing time for the two cases are very close to each other.

These results boil down to the following conclusion: if the planner, in case of a problem occurrence, expects a relatively **low mean and low standard deviation** value for execution in case of a repair actions is taken, it is better to take a repair action. Since every repair action is unique to the problem on hand, it is the experience and anticipation ability of the planner that matters in making such a judgment in case of a problem occurrence. On the other hand, if the planner expects a relatively **high mean and high standard deviation** value for execution in case of a repair action is taken, it is better not to interfere the problem.

6. Research Limitations and Future Research Directions

This paper presents key insights on the decision-making processes and planning efficiency of Den Hartogh, however facing several limitations in the scope and depth of the study.

On a certain modality combination, it is assumed that only one type of problem occurs at a time. However the interviews conducted with the planners indicate that several problems may be encountered on a single order. Furthermore, in some cases problems occur due to consequences of repair action taken to correct a previous problem occurring on the order. In that respect such cases with multiple problems are not investigated within this paper, leaving out many cases commonly encountered by Den Hartogh. This limitation can be addressed by simulating cases with multiple problem occurrence allowed for a single order.

110 forms were collected from the planners during the data collection stage, in order to understand the problems occurrence reasons and their related repair actions. Considering the vast order volume and problems encountered, it is not certain how adequate information these forms provide in terms of the frequencies of problems faced and handled. Even though the number is statistically significant number (>30), the number of forms collected can be increased in an extended study.

This paper provides indications of time consequences only for loading and unloading problems experienced. Yet, these two problems represent only 30% of the problems that occur on the orders at Den Hartogh. Research scoping was done in this respect due to quantitative limitations of the data. The data files allowed precise statistical analysis to be conducted only for the two problems included in this research. The analysis presented in this paper can be extended if approximations are done in order to quantify other problem occurrence reasons.

Acknowledgements

This research project is the joint work of researchers from Eindhoven University of Technology, Tsinghua University and employees of Den Hartogh Logistics. It is the result of approximately one and a half years of work with the following milestones: data collection, data analysis and development of the simulation tool. Different stages of the project have been conducted in different locations; if to summarize, the data collection and process analysis stages were mainly conducted in Den Hartogh Logistics and the development of the simulation tool was primarily carried on in Eindhoven University of Technology, Tsinghua University.

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Appendix

FORM FOR OPERATIONAL PLANNERS

Planner (initials) :_____________
Job #:_______________________

Date:__________________________
Tank/container #:_______________

Problem Observed

- ☐ **Mistaken tactical tank plan**
- ☐ **Delay of ferry/rail**
- ☐ **Wrong information in job (includes mistakes occur due to account manager)**
- ☐ **Loading delay**
- ☐ **Unloading delay**
- ☐ **Tank is not properly cleaned/restcargo**
- ☐ **Overbooked ferry/rail**
- ☐ **Technical problems**
- ☐ **Vehicle shortage** (if so please specify):
  ………………………………………………………………………
- ☐ **Mistakes/Problems occur due to the <u>customer</u>** (if so please specify):
  ………………………………………………………………………
- ☐ **Mistakes/Problems occur due to the <u>driver</u>** (if so please specify):
  ………………………………………………………………………
- ☐ **Documentation problems** (if so please specify):
  ………………………………………………………………………
- ☐ **Other** (if so please specify):
  ………………………………………………………………………….

Repair Actions

- ☐ **No change**
- ☐ **Change the delivery time/date**
- ☐ **Change of loading time/date**
- ☐ **Change of unloading time/date**
- ☐ **Alternative tankcontainer**
- ☐ **Alternative truck**
- ☐ **Alternative driver**
- ☐ **Alternative route**
- ☐ **Alternative cleaning**
- ☐ **Change modality** (if so please specify):
  ………………………………………………………………………
- ☐ **Other** (if so please specify):
  ………………………………………………………………………