TÉCNICO LISBOA

Business Process Engineering and Technology

30th December 2023

Project

Frumherji Ltd. Reykjavik:

Vehicle Inspection - Testing Process

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1. Introduction

This report partially fulfilled the requirements for approval for the Business Process Engineering and Technology 23/24 course.

The goal of this project is to model and analyze the business process model for a vehicle inspection process for Frumherji Ltd., Iceland's leading inspection, testing, and legal metrology company. By implementing BPM (Business Process Management) methods and tools, organizations such as the one in the study can outperform their competitors while meeting the demands of regulatory authorities. Therefore, BPM is a crucial element for achieving operational success. According to a statement made in 2008 by Karl Sigurdsson, senior manager of Frumherji's vehicle department, the company's motivation for undergoing this change was to maintain the market lead and grow profitably. So, for Frumherji Ltd., this study represents an opportunity to understand the company's current processes and uncover ideas for improvement that could be adopted company-wide.

The data used to develop this assignment was collected from the Hesthals station in Reykjavik, which was chosen as a pilot site due to its large volume of business. Some of the company's decision-makers (namely the manager of the vehicle department and the quality and human resources manager) decided to focus the pilot project on the inspection and emission-testing process for private vehicles. The information was gathered by a consultant named Brynja Thorbjornsdotti, who used various process discovery methods, particularly evidence-based (*"gathered process data and made observations about customer service"*) and interview-based methods (*"gathered data through (...) interviews with employees and customers"*).

To develop the current project, the methodology used was divided into three main phases. Firstly, understanding the *as is* process and modeling it through the use of *Camunda*. Then, the second phase was the analysis of the *as is* process model quantitatively and qualitatively leading to the identification of five main issues and the development of the correspondent issue register. In this phase various techniques were used, particularly, process simulation with *Bizagi*. Finally, based on the identified issues, a *to be* process was designed and studied in order to mitigate as much as possible the inefficiencies found and contribute to Frumherji Ltd.'s profitability, quality standards and market-share goals.

2. *As is* process model

To begin with, a study of the current process at the Hestháls station was conducted to understand the *as is* process. The definition of a process architecture proceeds in a top-down fashion, starting by defining the process landscape (level 1) that shows the company's value chains. After, the business process is modeled in BPMN (level 2 and 3), starting from a value chain and decomposing to sub-processes and tasks.

2.1. Process landscape model

To succeed as a process-centered organization, making a meaningful enumeration of the existing processes is vital. There are three main categories of processes: core, support, and management processes. In a process landscape model (depicted in Figure 1), the business processes are grouped into three classes according to their strategic importance.

Core processes, often called primary activities, encompass a business's principal means of creating value: developing goods and services that consumers pay for. Therefore, the vehicle inspection is the critical step in our study example. The execution of core processes is made possible by support processes. This category includes customer service, facilities management, human resource management, IT management, and indirect procurement (for instance, sourcing of hardware, furniture, stationery). Directions, guidelines, and practices for both core and supporting processes are provided by management processes. These include defining the strategy, quality control, financial management, and market research.

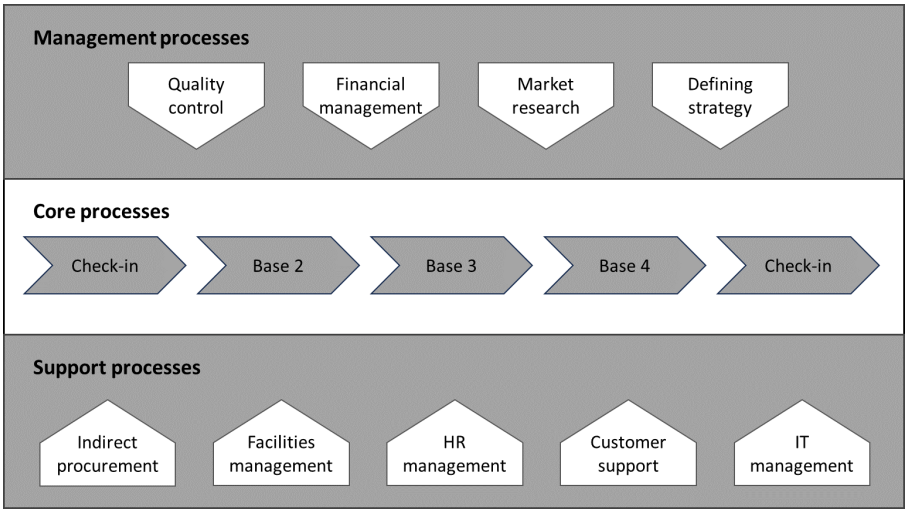

Figure 1 - Process landscape model for the Frumherji Ltd. business.

2.2. BPMN Model

Our BPMN model, crafted using *Camunda*, presents a detailed and structured representation of the Hesthals inspection station's processes. This model not only outlines the normal course of action (happy path) but also addresses how foreseeable errors or exceptions are managed, ensuring a holistic understanding of the workflow. The following sections provide a closer look at the distinct sub-processes within our comprehensive inspection model, illustrating both standard operations and contingency planning for deviations.

2.2.1. Assumptions

In developing the *as is* model for the Hesthals inspection station, we have made several key assumptions to clarify and focus our analysis.

We've chosen to exclude secondary services such as driver testing, issuing license plates, and the sale of drinks and sweets, as these are peripheral to the core inspection process. The staffing at the station is considered to consist of four individuals: one receptionist and three inspectors, each assigned to a specific base, which helps delineate roles and responsibilities within the station.

Another assumption is that the inspection form is updated along the inspection process.

At Base 4, it's assumed that the inspector's main focus is on checking for fluid leaks, worn components, and other similar abnormalities after inspecting the vehicle's underside, which defines a specific scope of inspection for this base. We assume that challenges with large vehicles are prevalent, particularly regarding the limitations of existing hoists, which affects the vehicle placement process and the ability to complete inspections for such vehicles. Furthermore, we assume that any large vehicle unable to complete the inspection at our station is directed to another station better equipped to handle its size.

Regarding the documentation process, we assume that the submission of inspection records into the database is synonymous with sending these records to the regulatory agency. This impacts our understanding of the station's data management and compliance workflow.

2.2.2. High level model

The overall workflow of our general inspection model is detailed as follows (Figure 2). It provides a roadmap of the operational sequence and interactions between different subprocesses, offering an integral perspective for understanding the entire inspection journey from start to end.

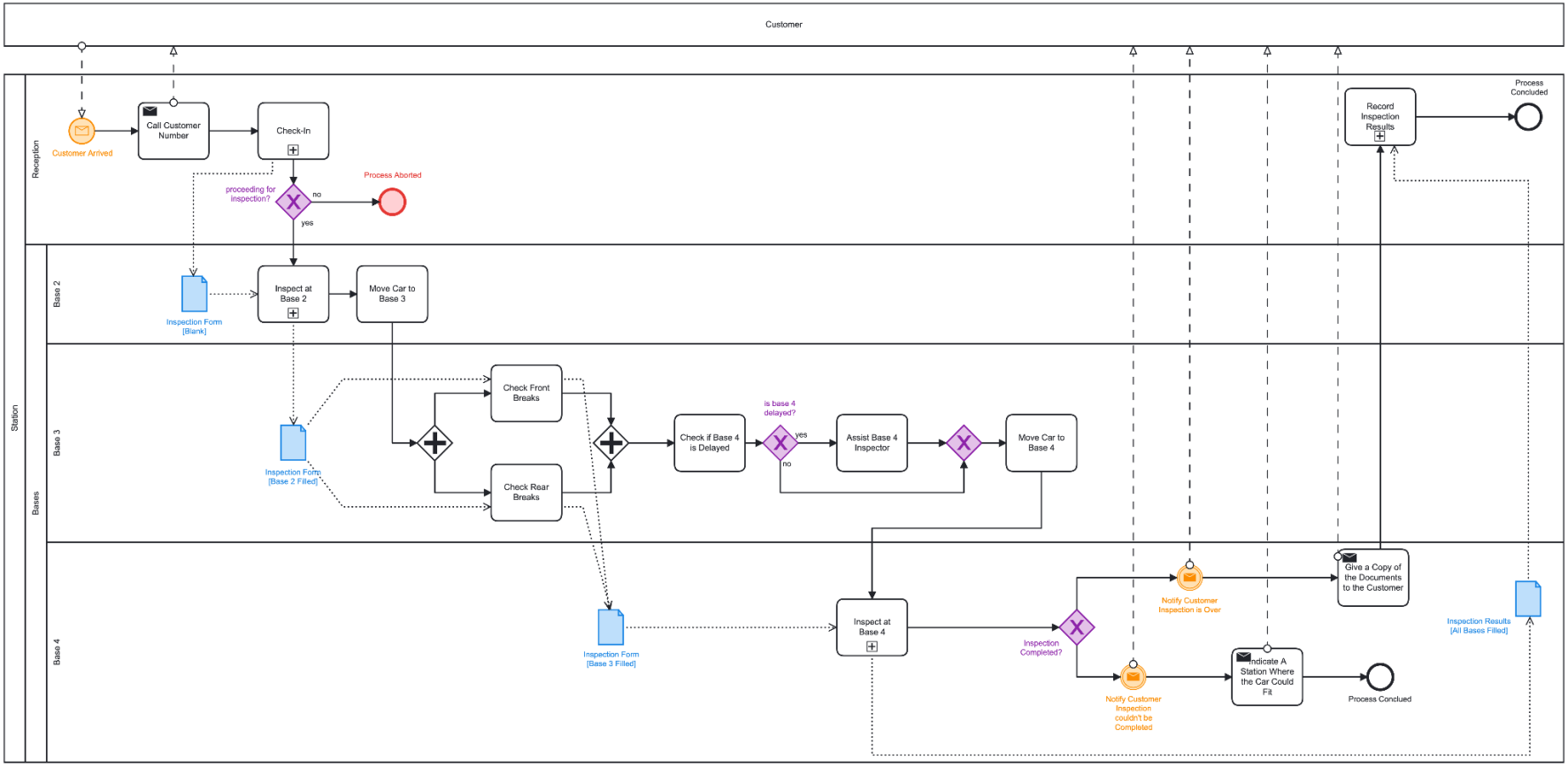

Figure 2 - BPMN diagram of inspection process (*as is* model).

2.2.3. Sub-processes

As the entry point for customers at the inspection station, the check-in subprocess is delineated next (Figure 3).

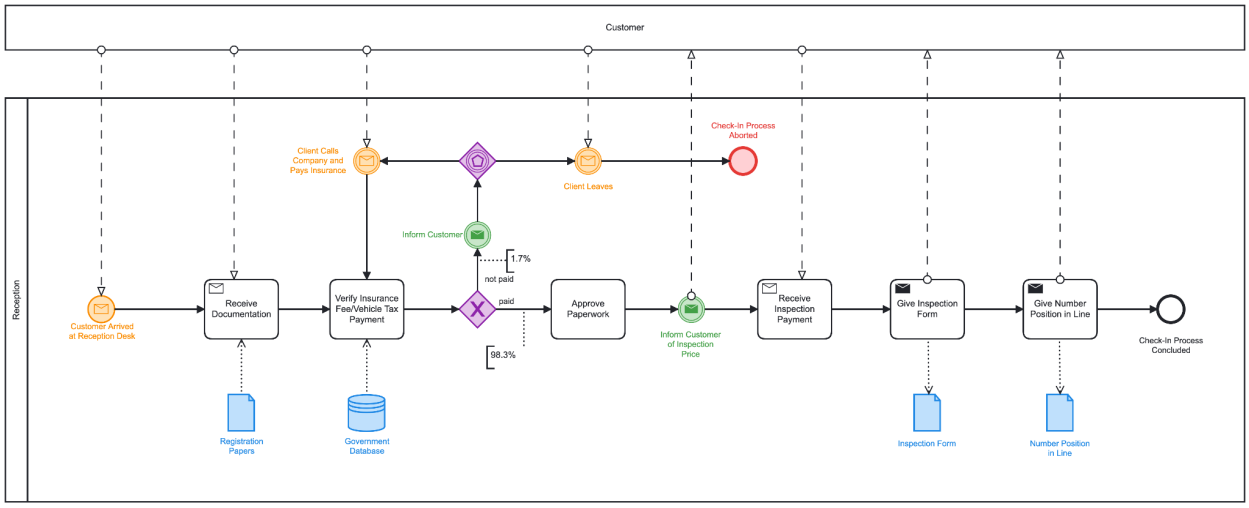

Figure 3 - BPMN diagram of check-in sub-process.

Subsequently, we delve into the specific activities at Base 2 (Figures 4 to 7). This part of the model elucidates the sequence of tasks and highlights the unique operational aspects of Base 2, including the equipment and inspection standards applied.

It's important to mention that the operations at Base 3 are directly mentioned in the overall workflow, as they are relatively minimal compared to other stages.

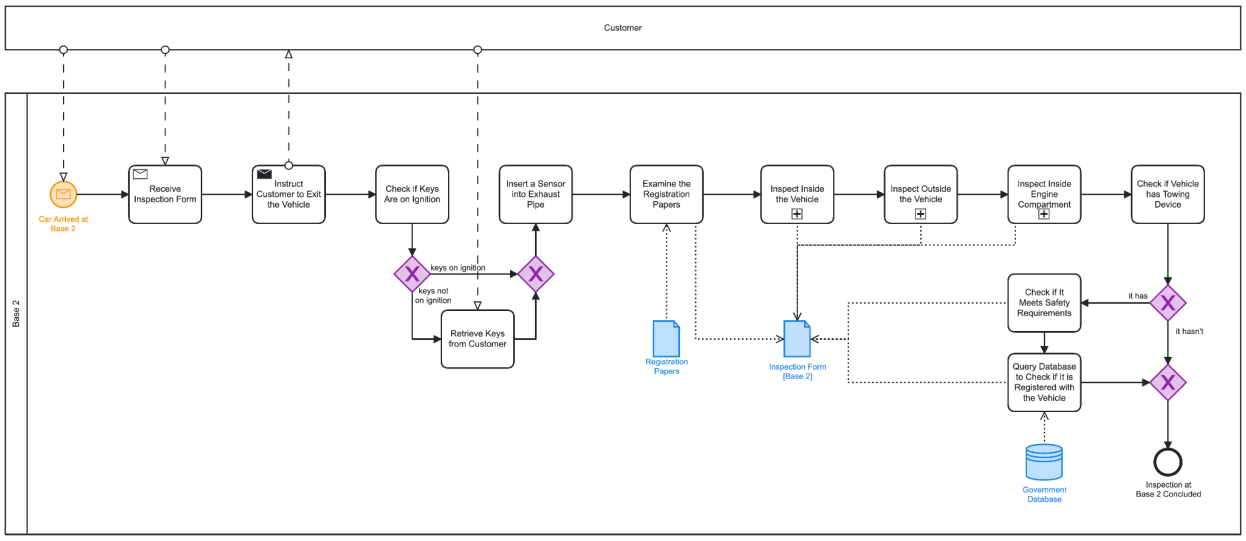

Figure 4 - BPMN diagram of inspection at Base 2 sub-process.

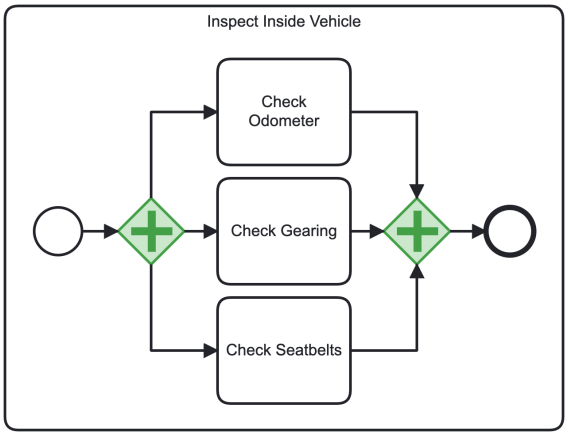

Figure 5 - BPMN diagram of inspection inside vehicle sub-process.

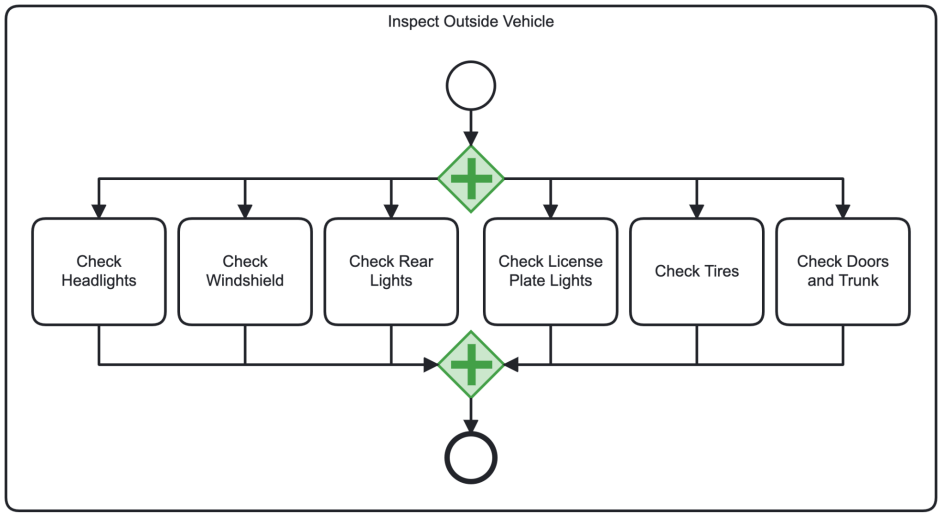

Figure 6 - BPMN diagram of inspection outside vehicle sub-process.

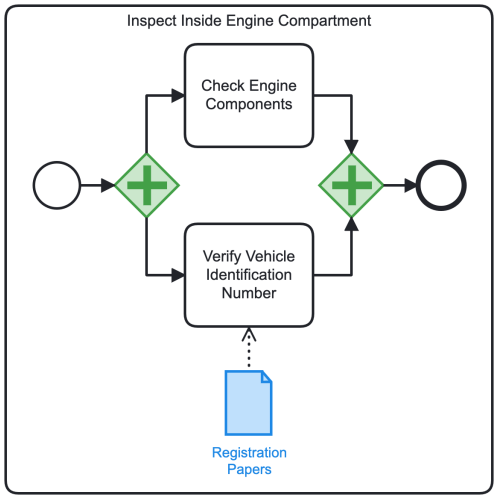

Figure 7 - BPMN diagram of inspection inside engine compartment sub-process.

Following that, the detailed procedure for vehicle inspection at Base 4 is presented (Figure 8). Given the distinct challenges and equipment requirements, especially for larger vehicles, this section is crucial for understanding the tailored steps and resources necessary for this phase.

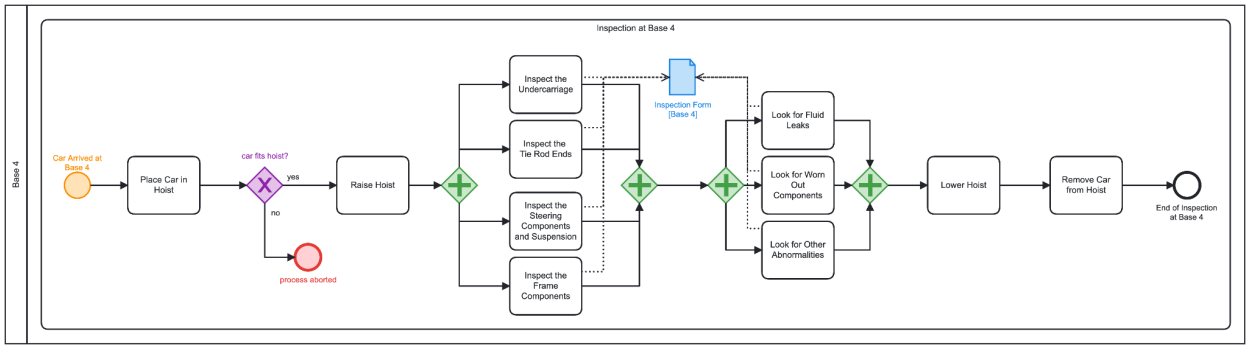

Figure 8 - BPMN diagram of inspection at Base 4 sub-process.

Concluding our process model, the approach for recording inspection results is laid out (Figure 9). This subprocess ensures the meticulous documentation of inspection outcomes, maintaining the accuracy and accountability of the station's operations.

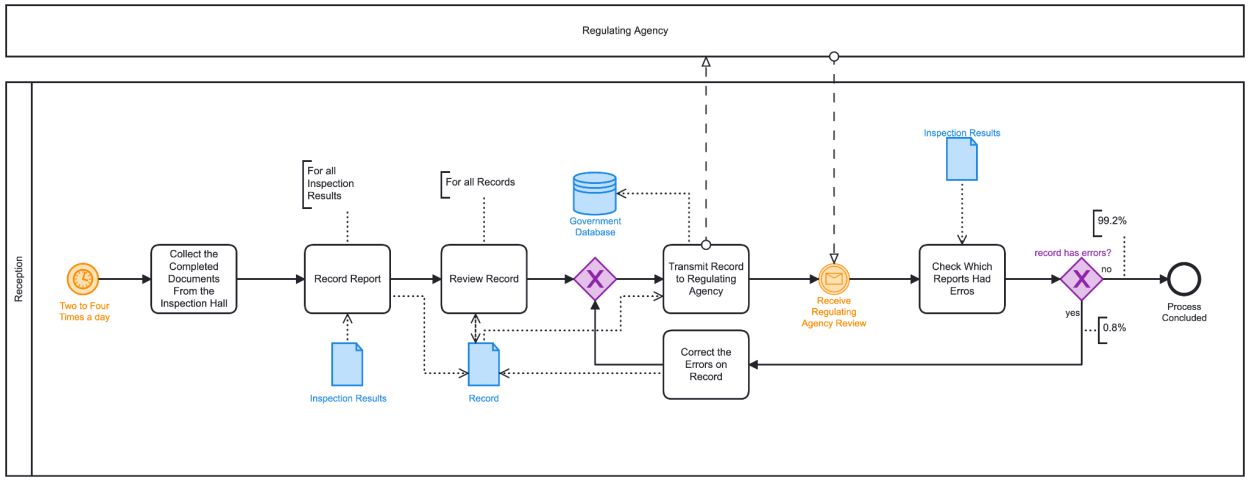

Figure 9 - BPMN diagram of inspection at base 2 sub-process.

3. *As is* process model analysis

3.1. Overview of the process

In this chapter, the goal is to quantitatively and qualitatively analyze the as-is process model defined earlier, leading to an issue register. This analysis seeks to gain insights into the process, pinpointing its weaknesses and possible improvement areas.

Firstly, the process was studied broadly, using various techniques to identify inefficiencies. Namely, value-added and waste analysis were used in this step to qualitatively assess the process while process simulation was used to characterize the *as is* quantitatively. After, the handout was thoroughly inspected in search of issues in the process and then some of these issues were selected to undergo a more detailed analysis.

3.1.1. Qualitative analysis

Two techniques were used for the qualitative analysis of the vehicle inspection process at the Hesthals station. The first, value-added analysis, aims to identify the unnecessary steps of the process while the second, waste analysis, targets the sources of waste. These two techniques allow us to identify potential inefficiencies in the process.

3.1.1.1. Value-added analysis

To conduct a value-added analysis of the study project, it is important to list the various activities (and, if possible, the tasks that compose them) to then classify them as value-adding (VA), business value-adding (BVA), or non-value-adding (NVA). This categorization can only be made after identifying who is the customer of the process and what are the positive outcomes that the customer seeks from the process. In this case, the customers are the vehicle owners who seek to have their car inspected. From their perspective, the positive outcome of the process is that the vehicle passes on the inspection process.

Analyzing each step taking into account the value it adds allows to classify them into the three classes mentioned earlier. VA steps directly contribute to positive outcomes, are the ones the customer is paying for, while BVA steps do not directly add value to the customer but they are necessary for the business. Finally, NVA, are those that do not fall into any of the other two categories.

For the analysis conducted it was decided to focus only on the happy path. The results obtained are in Tables 1 through 5, divided into the major groups of activities identified in the high level of the *as is* model.

As seen in the high level, the process begins at Base 1, with the check-in. The first task is to call the customer's number and this is BVA because it is crucial for operation but does not directly contribute to the service itself. Arguably, the reception of the documentation by the clerk, the verification of the insurance fee and vehicle tax payment and the approval of the paperwork are BVA insofar as they are required due to the regulatory environment of the business. Inspection payment is also clearly BVA, because it represents the revenue collection for the business. More generally, steps associated with handoffs between process participants, such as giving the inspection form and the number position in line are NVA.

Table 1 - Classification of steps in the vehicle inspection process: check-in.

Steps	**Performer**	**Classification**
Call Customer Number	Receptionist	BVA
Receive Documentation		BVA
Verify Insurance Fee/Vehicle Tax Payment		BVA
Approve Paperwork		BVA
Receive Inspection Payment		BVA
Give Inspection Form		NVA
Give Number Position in Line		NVA

Moving on to the beginning of the inspection at Base 2, the inspector receives the inspection form which will follow the vehicle through the bases, as an identifier and a way to record the results from the various tests. Therefore, this step can be classified as BVA since it ensures that the inspection process carries out smoothly. After that, instructing the customer to exit the vehicle is also BVA because it helps ensure not only the safety of the process, but also its efficiency since inspectors will be conducting the process from that point onwards. Checking if the keys are on the ignition is BVA since it is a necessary step in order to proceed with the emissions testing. Then, testing the emissions is a VA step as it is a part of the process the customer is paying for: if we removed this task from the list, the inspection would be incomplete and therefore the customer would not get the whole service he or she paid for. Subsequently,

the inspector examines the registration papers, which is considered a NVA step because it consists only of reading the documents. Then, comparing the vehicle identification number with the one on the paperwork is BVA. Afterwards, for the same reasons stated before for the emissions' testing, inspecting the inside and outside the vehicle and the engine compartment are all VA. Finally, checking if the car has a towing device and querying the database to see if it is registered is a BVA step as it is related to legal requirements of the inspection process. On the other hand, checking if the said towing device meets safety requirements was classified as VA since it is most likely something the customer is willing to pay for.

Table 2 - Classification of steps in the vehicle inspection process: Base 2.

Steps	**Performer**	**Classification**
Receive Inspection Form	Inspector (Base 2)	BVA
Instruct Customer to Exit the Vehicle		BVA
Check if Keys Are on Ignition		BVA
Insert a Sensor into Exhaust Pipe		VA
Examine the Registration Papers		NVA
Compare the Vehicle Identification Number With the Paperwork		BVA
Inspect Inside the Vehicle		VA
Inspect Outside the Vehicle		VA
Inspect Inside Engine Compartment		VA
Check if Vehicle has Towing Device		BVA
Check if It Meets Safety Requirements		VA
Query Database to Check if It is Registered with the Vehicle		BVA

Then, the inspector from Base 2 moves the vehicle to Base 3. This step is BVA since it contributes to the seamless flow of the process. After that, checking the front and rear brakes is a VA step insofar as it is a key component in the process that defines if the vehicle will ultimately pass the inspection or not. Following that, as can be seen in the case study, if there were delays at Base 4, the inspector from Base 3 would assist the inspector from the next base. This step is useful for the business to run smoothly as it helps optimize the flow of vehicles, reducing waiting times. Therefore, the final step also falls into the BVA category.

Table 3 - Classification of steps in the vehicle inspection process: Base 3.

Steps	Performer	Classification
Move Car to Base 3	Inspector (Base 2)	BVA
Check Front Brakes	Inspector (Base 3)	VA
Check Rear Brakes		VA
Check if Base 4 is Delayed		BVA
Assist the Base 4 inspector		BVA

At last, the car is moved to Base 4 (BVA step). There, the car is raised using a hoist, in order to allow the Base 4 inspector to look underneath the vehicle. The two steps that compose this task (driving the car to the hoist and raising it) are BVA since they enable the worker to proceed with the inspection process. All the other steps included in this subprocess, which are listed in Table 4, are VA since they directly contribute to positive outcomes (this is, in order for the vehicle to pass inspection it is mandatory that all these tests are done).

Table 4 - Classification of steps in the vehicle inspection process: Base 4.

Steps	Performer	Classification
Move Car to Base 4	Inspector (Base 3)	BVA
Drive Car to Hoist		BVA
Raise Hoist's Heigth	Inspector (Base 4)	BVA
Inspect the Undercarriage		VA
Inspect the Tie Rod Ends		VA
Inspect the Steering Components and Suspension		VA
Inspect the Frame Components		VA
Look for Fluid Leaks		VA
Look for Worn Out Components		VA
Look for Other Abnormalities		VA

The final part of this process is the check-out, back in Base 1. To begin, the receptionist collects the reports from the desk at the exit of the inspection hall. This step is a handoff and

therefore is classified as NVA. Then, recording and reviewing (which can be seen as a control step) the data from those reports is BVA because it is important for the next mandatory step, which is to transmit the records to Umferðarstofa (the regulating agency). The latter step is VA since it is the officialization of the inspection process' results and consequently, assumes major importance for the customer who seeks to obey the law. Assuming there are no errors in the report transmitted to the agency, the process ends here.

Table 5 - Classification of steps in the vehicle inspection process: check-out.

Steps	**Performer**	**Classification**
Collect Report	Receptionist	NVA
Record Report		BVA
Review Record	Manager of the vehicle department	BVA
Transmit Record to Regulating Agency		VA

The goal of this analysis is to minimize or eliminate NVA steps. The few NVA steps identified for this process are mainly related to handoffs. These could probably be eliminated by means of automation, by putting in place an information system to allow employees from all bases to access information and update customers on the process.

3.1.1.2. Waste analysis

Contrary to the value-added analysis, waste analysis looks at the process from a negative angle, trying to find waste everywhere in the process. There are three main categories of waste: move, hold, and overdo. The results obtained from this analysis are presented in Table 6.

Table 6 - Identification of wastes in the vehicle inspection process.

Waste		**Step**
Move	Transportation	● A process worker moves with the inspection forms from one inspection base to another; ● The workers from Base 3 sometimes move to Base 4.
	Motion	● Vehicles have to go through different inspection bases to undergo different tests, the inspection equipment, that is located on a movable trolley, needs to be shifted around; ● Keys need to be retrieved from customers, occasionally; ● The cars must be raised using a lift to be inspected; ● The receptionist's task of scheduling a vehicle inspection for a new customer involves switching between applications, creating motion waste and slowing down the workflow.
Hold	Work-in-process	● When a vehicle does not pass the first inspection, it is returned for adjustments and left in a pending status.
	Waiting	● A technician at the base of the inspection station waiting for the next vehicle.
Overdo	Over-processing	● A vehicle needs to come back to a station due to an omission; ● Technicians take time to measure vehicle emissions with higher accuracy than required, only to find that the vehicle clearly does not fulfill the required emission levels.

3.1.2. Quantitative analysis

Regarding the quantitative analysis of the process at study, the *Bizagi* simulation tool was used to determine some performance measures related to the time and cost dimensions. The data and assumptions used are as follows:

1. Mean time for:
    a. Check-in: 1 minute (wait time is 8 minutes);
    b. Base 2: 7 minutes;
    c. Base 3: 2 minutes (7 minutes if helping Base 4 was needed);
    d. Base 4: 8 minutes;
2. Moving between bases takes 1 minute;
3. Assuming 15$ an hour for each of the 4 employees;
4. 75 vehicles inspected per day;

3.1.2.1. Process simulation

Using *Bizagi*, we simulated the high level process. Here we present the results, one table with the wages for each worker (Table 7) and the other with the times for each task (Table 8). Below we present two tables, one relating to the wages of each worker and the other relating to the time of each task, presenting only the relevant tasks. For the full results, refer to Annex A.

***Bizagi* simulation results:**

Wages:

Table 7 - Bizagi simulation results showing the wage of each worker.

Resource	Utilization (%)	Total fixed cost ($)	Total unit cost ($)	Total cost ($)
Inspector Base 2	12.17	0	150	150
Inspector Base 3	7.00	0	86.25	86.25
Inspector Base 4	12.17	0	150	150
Receptionist	12.30	0	151.5	151.5
	Total:	0	537.75	537.75

Activities:

Table 8 - Bizagi simulation results showing the time of each task.

Task Name	Instances Completed	Total Time Waiting Resource	Min. Time	Max. Time	Avg. Time	Total Time
Station	75	2h 34m 43s	27m	39m 2s	29m 44s	1d 14h 25m 43s
Check-in	75	44m 43s	8m	15m 2s	8m 35s	10h 44m 43s
Base 2 Inspection	75	0m	7m	7m	7m	8h 45m
Move Car to Base 3	75	0m	1m	1m	1m	1h 15m
Check Front Brakes	75	0m	1m	1m	1m	1h 15m
Check Rear Brakes	75	0m	1m	1m	1m	1h 15m
Assist Base 4 Inspector	24	0m	5m	5m	5m	2h
Move Car to Base 4	75	0m	2m	2m	2m	2h 30m
Base 4 Inspection	75	35m	8m	13m	8m28	10h 35m
Record Inspection Results	3	0m	2m	2m	2m	6m

3.2. Issue register

From the thorough reading of the document describing the case study, an extensive number of issues were listed. Those results can be found in Annex B. Then, out of all these fault points identified, five were selected to undergo a deeper analysis, leading to an issue register.

The five main issues, which are explained in the next subchapters, are: long waiting times, employees overwork, customer's mistakes, receptionists working multiple jobs, and hoists' size and speed limitations.

3.2.1. Issue 1 - Long waiting times

Priority: 2

Description: During Thorbjornsdottir's observations, the wait for service, once the paperwork was complete, was from five to 78 minutes, but she learned from personnel at Frumherji that it could be as long as 90 minutes.

Data and assumptions:

1. Average of 75 vehicles inspected per day so 75 customers go through the reception
2. Operating hours are 8 hours per day.
3. Consider the average waiting time (AWT) of 42 min.

   AWT= 5+782 min
4. 30% of customers experience above average wait times (more than 48 min)
5. An inspection of the vehicle after the wait takes an average of 20 min.
6. Considering only the 3 lines for smaller cars in the calculations.
7. An abandonment rate of 10% is assumed for our analysis, implying that, should the wait exceed the average waiting time, 10% of customers will abandon the service.
8. All rounding has been performed upwards.

Qualitative impact:

1. Decreased customer satisfaction due to extended wait times.
2. Negative impact on the overall perception of service efficiency.

Quantitative impact:

Number of customers that in a day have a above average waiting time (NCAWT):

NCAWT=0.3 x 75 ≈ 23 clients/day

Average daily service abandonment rate (DAR) by customers:

DAR= 0.10 x 75 ≈ 8 clients/day

Daily Service Capacity:

Now, we will assess the impact on the daily service capacity, considering the waiting time after paperwork submission. In analyzing service capacity (SC) across three lines presented in Figure 10, the formula assumes a direct processing rate, accommodating variable service times spanning from 5 to 90 minutes without conforming to a specific distribution.

$$SC=\frac{(8\,h * 60\,min)}{Inspection\,Time + Waiting\,Time} * 3\,lines = \frac{480}{20+x} * 3$$

5 min waiting time: SC ≈ 58

42 min waiting time: SC ≈ 23

78 min waiting time: SC ≈ 15

90 min waiting time: SC ≈ 13

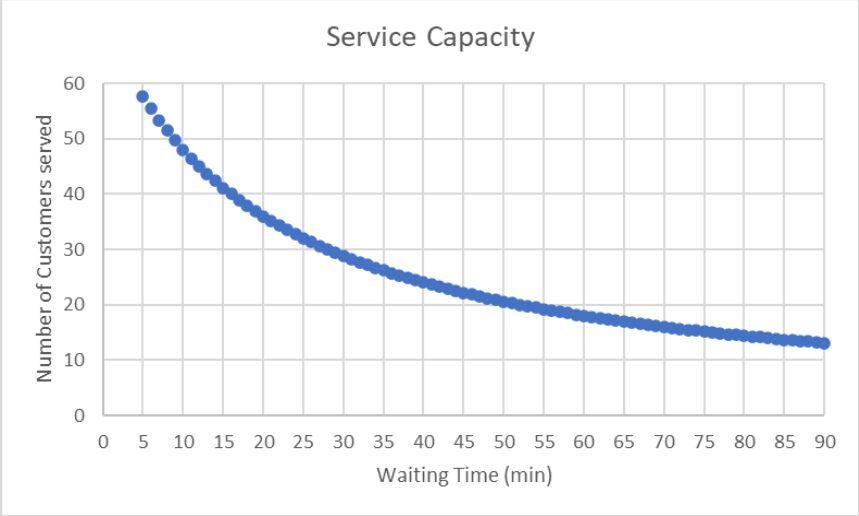

Figure 10 - Service capacity at the Hesthals station.

3.2.1.1. Why-why diagram

Examining the prolonged wait times in vehicle inspection and emissions testing, a why-why diagram serves as an effective tool for in-depth analysis (as seen in Figure 11). This method allows us to systematically unravel the root causes contributing to extended wait times. By employing this structured approach, we aim to pinpoint key factors and devise practical solutions to enhance operational efficiency and address the substantial challenge at hand.

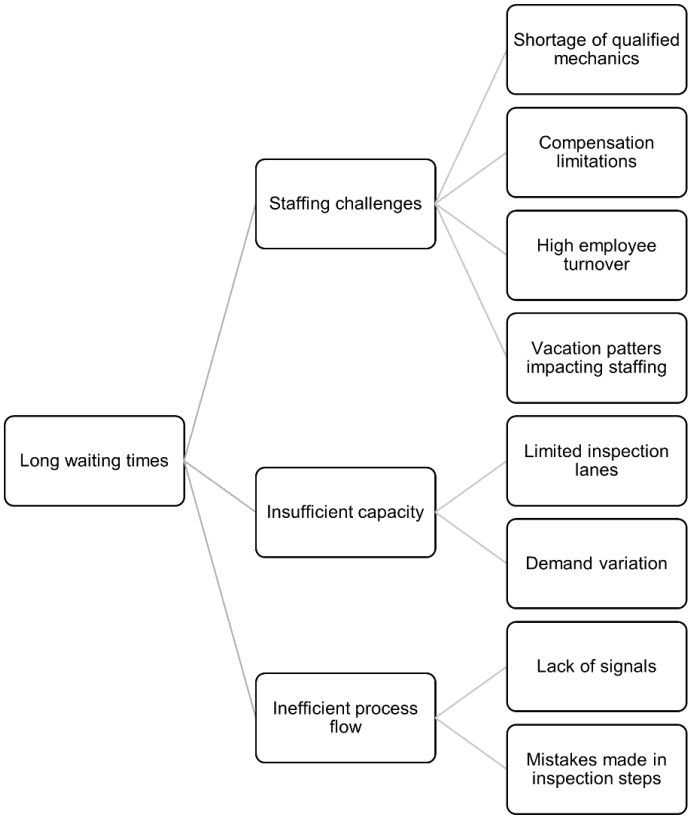

Figure 11 - Why-why diagram of the issue of long waiting times.

3.2.2. Issue 2 - Employees overwork

Priority: 1

Description: The inspectors work overtime, due to the amount of cars that come and due to delays. That forces the clerk to work overtime as well.

Data and assumptions:

5. Mean time for:
    a. Check-in: 1 minute (wait time is 8 minutes);
    b. Base 2: 7 minutes;
    c. Base 3: 2 minutes (7 minutes if helping Base 4 was needed);
    d. Base 4: 8 minutes;
6. Moving between bases takes 1 minute;
7. Assuming 15$ an hour for each of the 4 employees;
8. 75 vehicles inspected per day;
9. An employee has a schedule of 8 hours, more than that is considered overtime.

Qualitative impact:

1. Necessity to pay overtime to workers;
2. Can lead to workers feeling tired and discontent, increasing the risk of burnout;
3. Forces customers to stay later than they expected.

Quantitative impact:

Analyzing the Bizagi results above, we can see that, on average, the Check-in takes 10h44m in total, which is 2 hours and 44 minutes more than the employees are supposed to work. Base 2 Inspection plus the Moving the Car to Base 3 takes 8h45 + 1h15 = 10 hours (2 hours longer), Base 3 inspection (seen by the Check Front Brakes, Check Rear Brakes, Assist Base 4 Inspector, Move Car to Base 4 activities) was the only base that didn't have overwork,

having a total time just under 7 hours, and Base 4 Inspection takes 10h35 hours (1 hour and 35 minutes more).

Price per day if all 4 employees worked 8 hours = 4 * 8 * 15 = 480$

Price per day taking into account overworking = 574,75$

Almost 100$ spent per day paying overwork to the employees.

3.2.2.1. Pareto chart

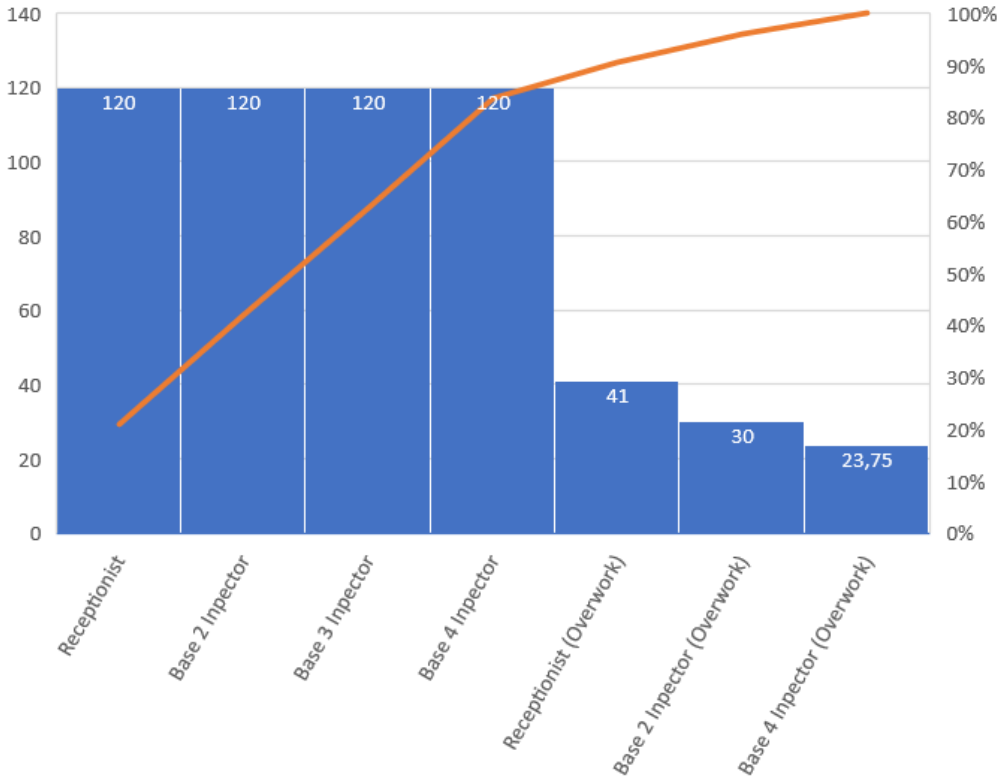

Figure 12 - Pareto chart of the issue of employees overwork.

A Pareto chart is a good way to visualize the information. In the graph (Figure 12), it is presented the daily wage for each worker and the amount of money it costs to pay for the overworking. We can see that most of the money spent comes from the normal daily salary of the employees. However, a significant part of the costs, close to 10%, is spent on paying overtime labor, 41 + 30 + 23,75 = 94,75$. That is a huge amount of money that could be saved.

3.2.2.2. Why-why diagram

Why-why diagrams help to get to the root causes of problems (Figure 13). Since the overworking of employees is one of the most important issues we found, because of its long-term and short-term effects, it's important to know what causes it. In reality, the overwork of employees is a complex issue, because a lot of parts in the process have some kind of impact on it.

The main causes are the base inspectors and the receptionist.

In the case of the base inspectors, it is due to the Base 2 and Base 4 delays. Base 2 delays are related to the customers' behaviors, them not stopping in the right place or them taking the car keys back to the reception when they shouldn't, so we need to implement measures that clear those problems. Base 4 delays are caused by the instruments. The hoist, although it works fine some of the time, is a device that has its flaws. Sometimes it may take way too long, sometimes cars might not even fit and are unable to conclude the inspection.

In the case of the receptionist, overwork happens because of the long queues in the reception, because of an overflow of clients, or when the inspectors work overtime, the receptionist has to also work additional overtime to finish data entry after the inspectors left the worksite.

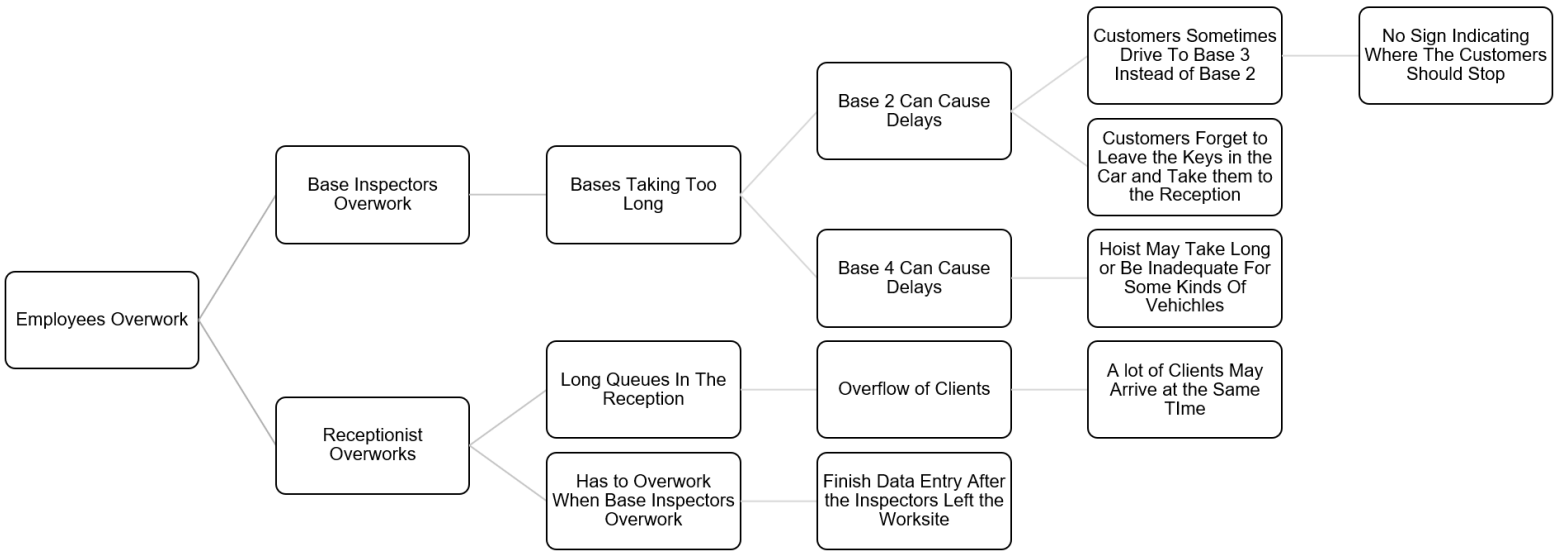

Figure 13 - Why-why diagram of the issue of employees overwork.

3.2.3. Issue 3 - Customer's mistakes

Priority: 4

Description: Customers can make mistakes that hinder the initial steps of the inspection process, particularly at Base 2. For instance, mistakenly driving past Base 2 and directly into Base 3 because there was no sign indicating where to stop or not leaving the keys in the ignition at Base 2.

Data and assumptions:

1. Knowing the average is 75 vehicles inspected per day and there are 3 lanes, the decision was made to model for 25 instances, mimicking the behavior of only one lane;
2. To model the Base 2 subprocess using Bizagi, was considered a negative exponential distribution with a mean arrival time of 20 minutes. Furthermore, the processing times considered for each task in this subprocess are detailed in Table 9;
3. 20% of customers drive past Base 2 and directly into Base 3;
4. 30% of customers forget to leave the keys on the ignition;
5. 50% of customers have a towing device.

Table 9 - Processing times for the Base 2 subprocess.

Task	Processing time (min)
Receive Inspection Form	0,17
Instruct the Customer to Exit the Vehicle	0,5
Check if Keys are on Ignition	0,5
Retrieve Keys from Customer	3
Insert a Sensor into Exhaust Pipe	0,5
Examine Registration Papers	1
Inspect Inside the Vehicle	1
Inspect Outside the Vehicle	2,5
Inspect Inside Engine Compartment	1,5
Check if Vehicle has Towing Device	0,5
Check if it Meets Safety Requirements	1,5
Query Database to Check if it is Registered with the Vehicle	0,5

Bizagi simulation results: Performing a *what-if* analysis (Figure 14), it's clear that the higher the percentage of clients forgetting to leave the car keys on the ignition, the higher is the average time spent at Base 2 since inspectors waste time retrieving the keys from the lounge. In this analysis, 11 scenarios were analyzed and average times ranged from approximately 9 to 12 min.

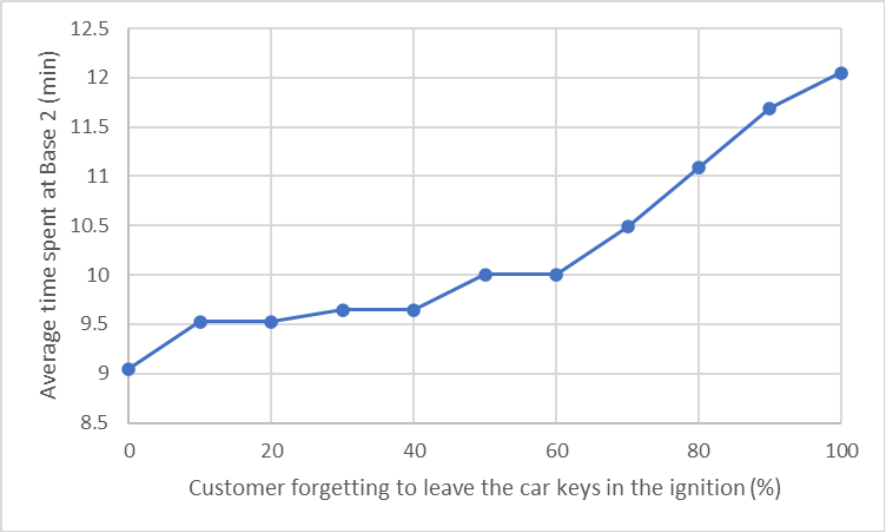

Figure 14 - Bizagi simulation results for the issue customer's mistakes (namely, forgetting to leave the car keys in the ignition).

Qualitative impact:

1. Can make clients feel frustrated and less satisfied with the service;
2. Can lead to stress in the inspection lane;
3. Longer waiting times;
4. Workers need to do extra work to compensate for these mistakes (for instance, going to the lounge to retrieve the car keys).

Quantitative impact:

$$time\ wasted\ redirecting\ the\ cars\ to\ Base\ 2\ =\ 25\ cars/day/lane\ *\ 20\%\ *\ 2\ min\ =\ 10\ min\ day/lane$$

$$time\ wasted\ redirecting\ the\ cars\ to\ Base\ 2\ =\ 10\ min\ /\ 25\ cars\ =\ 24\ s\ car/day/lane$$

To include the effect of mistakenly driving into the wrong base in the values obtained in the *what-if* analysis, the time lost per day was estimated and divided by the number of daily instances in a lane. Then, this extra time was added into the average time obtained using Bizagi (considering 30% of customers forget to leave the keys on the ignition) leading to a value of 10min3s spent by each vehicle in Base 2.

3.2.3.1. Why-why diagram

To fully analyze issue 3, the decision was made to build a why-why diagram. As this issue is simple and pretty straightforward to understand, the why-why technique was considered enough to justify it. The diagram in Figure 15, allows us to perceive some of the causes of the issue of customer's mistakes, continuing with the trend followed in this subchapter of analyzing only customer's mistakes in Base 2, particularly, driving past Base 2 and forgetting to leave the car keys in the ignition.

As can be seen, the causes identified for mistakenly driving into Base 3 were separated into two major groups: lack of communication and oversight. Lack of communication refers to the absence of signals indicating where to stop and also to the fact that the only sign in the inspection hall is in Icelandic, which can pose a language barrier for non-Icelandic speakers. On the other hand, we can have inaccurate directions given by the staff, mainly the inspectors, which can inadvertently lead clients to the wrong location or give confusing guidance. Regarding the error of forgetting the keys, it can be due to lack of communication (again, lack of signals and/or guidance) or oversight. In this case, oversight can be the result of the customers being rushed, unaware or distracted.

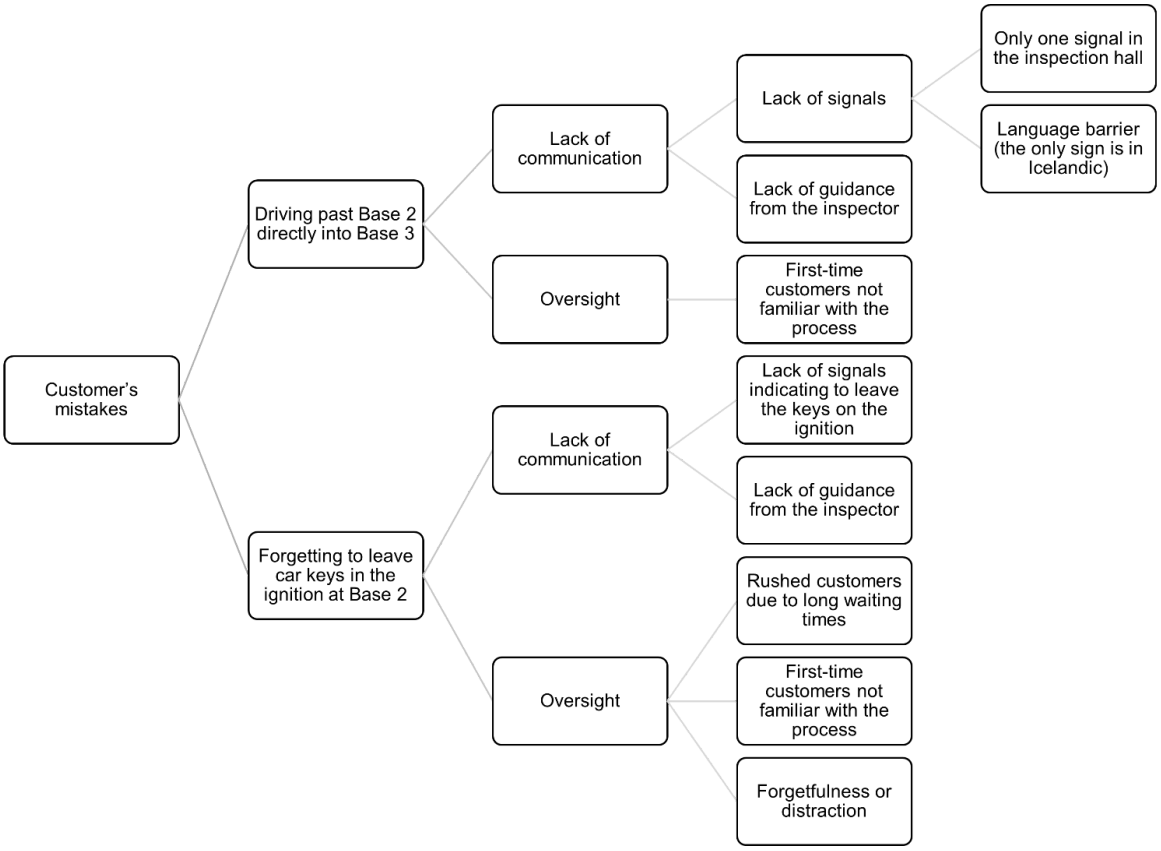

Figure 15 - Why-why diagram of the issue of customer's mistakes.

3.2.4. Issue 4 - Receptionists working multiple jobs

Priority: 1

Description: Receptionist has the job of selling drinks and sweets, attending customers who were there for other services such as driver testing, giving clients their license plates, collecting the completed documents from the inspection hall two to four times each day and recorded them, all in addition to attending the customers that were there for inspections.

Data and assumptions:

1. Half of the total time of the delays is caused due to the multiple jobs, the other half is due to the huge amount of customers that come with no reservation (it works on a first-come/first-served for the most part).
2. 110 daily customers, 70% (around 75 customers) of which come for the inspection, 30% (around 75 customers) come for the other services.
3. Other services take, on average, 4 minutes.
4. The receptionist goes to collect the completed Documents from the Inspection Hall three times a day and takes 1 minute, plus one minute to put them into the database.

Qualitative impact:

1. Receptionist spends a lot of time on the secondary services of the Hestháls station, in detriment to the primary service (the vehicle inspections).
2. Contributes to the employees having to work overtime.
3. Contributes to the long queue in the reception.
4. Delays in the reception area, even when there were no cars in the inspection hall.
5. Leads to a worse service overall, because the receptionist is focused on too many things, having to switch between responsibilities several times a day.

Quantitative impact:

35 customer * 4 minutes + 3 times * 2 to collect and input the documents = 146 minutes =

= 2h 26min spent in other services.

3.2.4.1. Why-why diagram

In the Why-Why diagram below, we see clearly the causes of the Receptionist having to work multiple jobs. That is because there are a lot of services being attended only in the reception area and none are automated, and the Receptionist also has to deal with picking up and recording the finished documents.

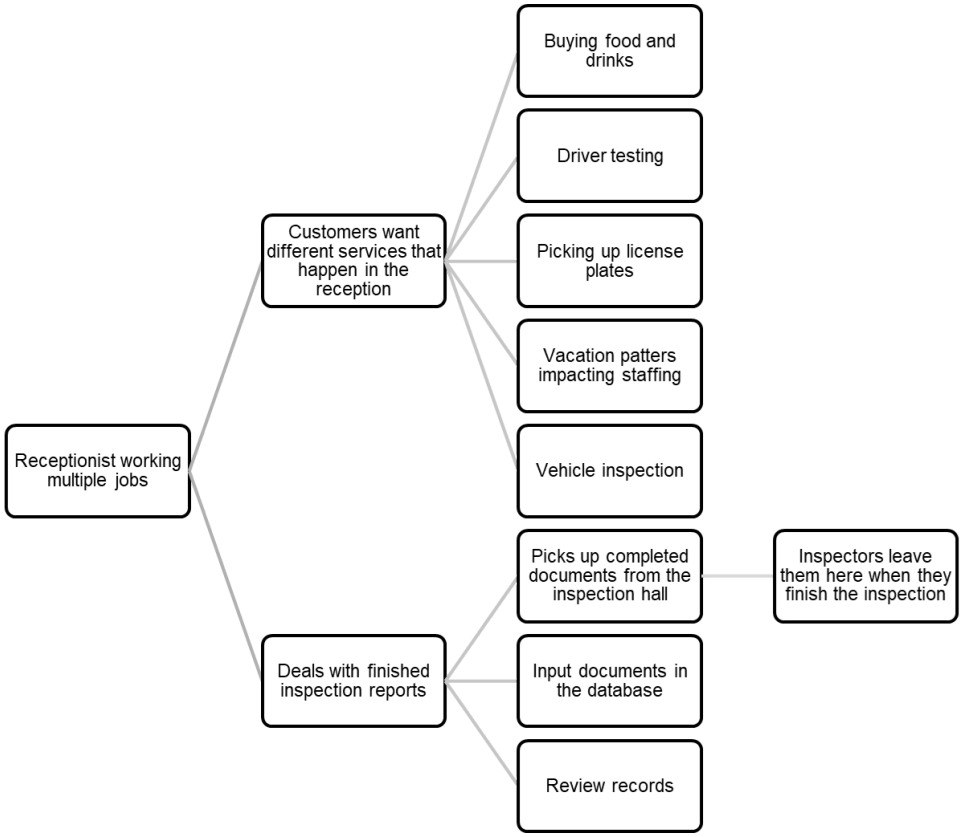

Figure 16 - Why-why diagram of the issue of receptionists working multiple jobs.

3.2.5. Issue 5 - Hoists' size and speed limitations

Priority: 5

Description: The increasing number of large imported vehicles poses significant challenges due to inadequate infrastructure. Over at Base 4, the small hoists struggle to accommodate these bigger vehicles. Additionally, the slow operation of these hoists leads to delays, compelling the inspector from Base 3 to assist at Base 4, which, in turn, further slows down the overall process.

Data and assumptions:

1. We assume that some delays at Base 4 are caused by the slow and inadequate hoists, although this is not directly mentioned.
2. Average of 75 vehicles inspected per day (25 per lane)
3. Aligning the vehicle and setting the lift points takes seconds.
4. Lifting/lowering a vehicle takes 30 seconds.
5. Releasing the vehicle takes 15 seconds.
6. 10% of vehicles are too large for the hoist (50% of icelanders have SUVs as of now).
7. Trying to place large vehicles in the hoist takes 2 additional minutes.
8. 20% of those vehicles are unable to proceed.

Qualitative impact:

1. Lifting and lowering vehicles is slow.
2. Accommodating larger vehicles is harder and produces delays.
3. Inspector at Base 3 needs to assist Base 4.
4. Routine safety checks needed.

Quantitative impact:

$$time\ used\ hoisting\ regular\ vehicles\ =\ 30s\ +\ 30s\ +\ 30s\ +\ 30s\ =\ 2min$$

$$time\ used\ hoisting\ larger\ vehicles\ =\ 2min\ +\ 2min\ =\ 4min$$

$$time\ used\ on\ hoist\ daily\ =\ (25\ vehicles\ *\ 0,9\ regular\ *\ 2min)\ +$$
$$(25\ *\ 0,1\ large\ *\ 0,8\ able\ *\ 4min)\ +$$
$$(25\ *\ 0,1\ large\ *\ 0,2\ unable\ *\ 2min)\ =\ 54min$$

$$unable\ to\ proceed\ vehicles\ daily\ =\ 75\ vehicles\ *\ 10\%\ large\ *\ 20\%\ unable\ =\ 1,5\ vehicles$$

3.2.5.1. Why-why diagram

To provide a deeper understanding of the challenges faced by our inspection center, particularly the delays caused by the inadequate hoists, we've developed a why-why diagram (Figure 17).

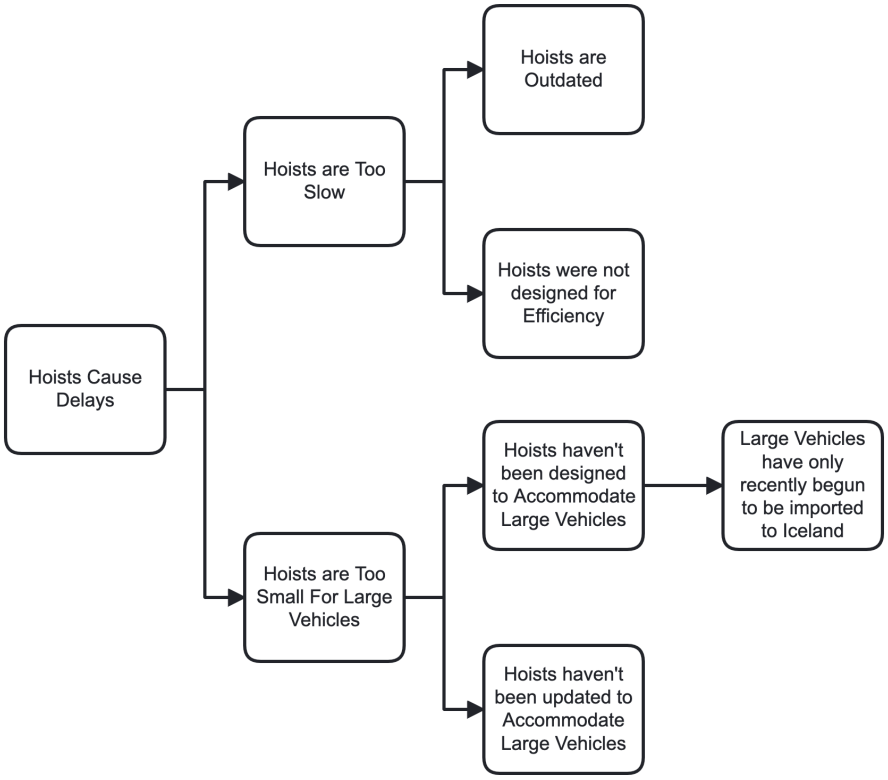

Figure 17 - Why-why diagram of the issue of hoists causing delays.

4. *To be* process model

4.1. Assumptions

In the development of the *to be* model for the Hesthals inspection station, we maintain the core assumptions established in the *as is* model. This continuity ensures that our analysis and proposed changes are grounded in the same operational context and challenges identified previously.

It's important to note that while the fundamental assumptions remain unchanged, the impact of these assumptions may shift in light of the proposed changes detailed in the respective section. This includes the integration of new technologies, process optimizations, and infrastructure modifications, all aimed at enhancing the efficiency and capacity of the inspection station. The detailed descriptions of these proposed changes provide insight into how they interact with and influence the existing assumptions, offering a comprehensive understanding of the envisioned future state of the inspection station.

4.2. Proposed changes and expected benefits

In response to the identified issues at the Hesthals station, some strategic changes were proposed to enhance the efficiency of the process. The goal is to address customer dissatisfaction, improve overall service delivery, and maintain the company's reputation for stringent inspections. The proposed changes and expected benefits are outlined below.

Issue 1: Long waiting times

We advocate for the reintroduction of an appointment system for mandatory vehicle inspections, featuring intervals of 15 minutes for appointment slots. This initiative is designed to efficiently manage and optimize customer flow, significantly reducing waiting times and enhancing overall operational efficiency. By making appointment scheduling mandatory for service, we anticipate improved planning capabilities and a notable reduction in the likelihood of no-shows. The 15-minute intervals have been strategically chosen to ensure a seamless process - while one customer initiates the inspection, the next is already positioned at Base 3, eliminating any potential overlaps in service.

To further reinforce the commitment to appointment punctuality, we recommend the implementation of a nominal fee for booking appointments. This strategic measure seeks to incentivize customers to honor their scheduled appointments, discouraging no-shows and fostering a more predictable workflow. As part of this proposal, customers would be required to pay a modest fee of 10 $ when booking appointments online.

In alignment with our commitment to customer convenience and operational streamlining, we suggest the establishment of a user-friendly online appointment booking system. This platform is designed to facilitate the scheduling of inspection appointments, providing customers with a seamless experience while concurrently reducing the administrative workload associated with appointment management. To complete this booking, it is necessary to submit all required documents online. Through this digital solution, customers will have the flexibility to easily schedule, modify, or cancel appointments.

Expected Benefits:

- Distributing customer arrivals evenly throughout the day, reducing peak-time congestion and minimizing waiting times;
- Helping offset operation costs with the introduction of a nominal booking fee, which also discourages no-shows and contributes to revenue stability;
- Modernizing the company, helping it distinguish itself from its competitors, with the implementation of the online appointment booking which will also cater to the preferences of tech-savvy customers.

These proposed changes will not only address the identified issue of long waiting times but also contribute to a more efficient, customer-centric, and financially sustainable vehicle inspection process at the Hesthals station.

Issue 2: Employees overwork

To minimize the overwork, it is important to reduce delays everywhere possible in the process and the uncontrolled overflow of clients that happen in the warmer months (demand is higher during those months).

The aforementioned online appointment system would greatly decrease the overflow of clients, and subsequently the delays, in the whole process. The goal would be to space clients in time throughout the day and year, in a way that would reduce waiting queues and, thus, the delays.

The reformulation of the check-in process mentioned in Issue 4 would help reduce overwork on the part of the receptionist.

Resolving Issue 5 would also speed up the inspection in Base 4, which is one of the causes of overwork in the process, as well as reducing delays there.

Expected Benefits:

- Ending, or at least greatly reducing, the overwork hours that the employees work;
- Saving money due to not needing to pay overtime;
- Improving work conditions for employees.

Issue 3: Customer's mistakes

In order to minimize the issue of customers unintentionally driving past Base 2, the solution would be to install more signs in the inspection hall. The proposed signals would give clear instructions for customers indicating where to stop, both in Iceland and in English. Along with the posters on the walls, there should be markings on the floor indicating where to stop.

Relatively to the issue of customers forgetting to leave the keys in the ignition, the solution would be for inspectors to take the customers keys once they arrive at Base 2. This way the customer wouldn't have to worry and the responsibility of asking for the keys would fall on the inspector.

Furthermore, during training, all staff should be encouraged to remind customers of these common mistakes in order to alert the more distracted clients.

Expected Benefits:

- Ending, or at least greatly reducing, the percentage of customers mistakenly driving into Base 3 and/or forgetting to leave the car keys in the ignition;

- Reducing of the average time spent in Base 2;
- Minimizing the number of times the inspector from Base 2 has to go over to the lounge to retrieve the keys.

Issue 4: Receptionist working multiple jobs

To deal with the serving of food and drinks, we proposed the purchase of a vending machine that would cost 2500$ and would make 500$ a month on average. Taking into account the cost of paying the vending machine maintainer that will replenish the stock, which we will pay 200$ a month, we can see that the vending machine will pay itself in close to 9 months, and from then on there will be a profit of 300$ a month.

For the other services, the best solution is to divide the customers between two queues, one queue for the clients that are there for the inspection (the majority of them), and one destined for the customers that want the other services. In conjunction with the reservation system mentioned above, this will make it so that there won't be an overflow of customers in the reception area. The customers for the inspection will have priority over the other ones.

This will allow the clerk to switch jobs less often, while taking away some tasks that can be automated without taking away the quality.

To not waste time in the collection of the completed documents from the inspection hall and the recording of the reports, we suggest every inspection form be online, and each inspector has a tablet with access to them. This would cost about 300$ for three tablets, and would not only save time, but also not distract the receptionist with another job. The finished inspection form would automatically be sent to the receptionist computer and to the customer's email.

Expected Benefits:

- Improving the quality of service;
- Reducing the hours the receptionist has to work;
- Reducing wait time for customers.

Issue 5: Hoist's size and speed limitations

To reduce the time lost due to hoist operation and the rejection of large vehicles, we recommend building pits below floor level and discontinuing the use of hoists. The estimated cost of this construction is around $30,000, and it would cut down the operation time to just 1 minute per vehicle, which accounts for the time taken to ascend and descend the pit steps.

Considering the proposed changes at the station, including the improved handling of vehicles, the need for inspectors to work overtime is eliminated. This results in a substantial cost saving, as the station no longer has to cover overtime pay, which amounts to $100 per day. Annually, this could lead to savings of up to $24,600 (considering that there are 246 working days per year). Even accounting for the temporary closure of each lane during pit construction, it's evident that the investment would pay for itself within a few years.

Expected Benefits:

- Speeds up the inspection process by eliminating the delays caused by the hoists;
- Accommodates larger vehicles, putting an end to size-related service refusals;
- Lessens the necessity for Base 3 inspectors to aid at Base 4, leading to more efficient workflow;
- The inspector previously dedicated to handling large-sized vehicles can now be redeployed to other tasks, enhancing overall productivity.

4.3. Alternative changes

Issue 1: Long waiting times

In addition to the proposed solutions outlined earlier, there are alternative strategies to consider in addressing the issue of long waiting times at the Hesthals station. One option considered was installing television monitors in the waiting area. However, this was not chosen due to concerns about potential distractions and visual impact.

One potential approach involves the implementation of an online pre-screening process, where customers would be prompted to provide detailed information about their vehicles before their scheduled visit. This would enable inspectors to prepare in advance, streamlining the inspection process upon the customer's arrival.

Another alternative is the introduction of an additional inspection team during peak periods or the extension of inspection hours on specific days. This could help more efficiently distribute the workload, particularly during times of high demand, thereby reducing waiting times for customers.

Additionally, exploring partnerships with local auto workshops to conduct preliminary inspections before vehicles visit the station is another avenue to consider. This collaborative effort could potentially decrease the number of vehicles requiring extensive on-site inspections, contributing to smoother operations and shorter waiting times.

While these alternative approaches offer potential benefits, they were not included in the primary recommendations for specific reasons. The online pre-screening process may face challenges related to customer adherence and data accuracy. Introducing additional teams or extended hours may pose logistical and personnel challenges. Collaborating with external workshops could present coordination and standardization issues. Despite these considerations, these alternatives, when evaluated alongside the proposed measures, provide a comprehensive set of options to optimize the vehicle inspection process, aligning with our goal of enhancing both customer satisfaction and operational efficiency at Hesthals station.

Issue 2: Employees overwork

There are lots of ways to deal with the overworking of employees. One thing that would solve the issue would be to reduce the daily number of customers. Since, that would lead to a decrease in revenue, because the customers would go to the competition, that is not the desirable solution.

Issue 3: Customer's mistakes

An alternative measure to combat customer's mistakes at Base 2 would be to take the key from each customer entering into the reception, having one of the staff members bring the car to Base 2 afterwards. However, this solution was disregarded because the company is already struggling with staffing.

Issue 4: Receptionist working multiple jobs

We could consider that stopping to provide the other services (such as serving food and drinks, giving clients their license plates and attending customers there for driver testing) and only focusing on attending customers for the inspection would solve this issue. However, it is not the best solution, since the other services bring money to the company and, thus, have value. That justifies why we didn't choose this solution.

Issue 5: Hoist's size and speed limitations

An alternative to the construction of pits would be to simply upgrade the current small hoists with more advanced models that have a higher capacity and are specifically designed to handle larger vehicles. These new hoists could even be faster and more efficient, reducing operation time significantly. However, it's important to note that even with these advanced hoists, the speed of vehicle processing might not match the efficiency achievable with the proposed pit system.

4.4. *To be* process model

Our revamped general inspection model introduces significant enhancements, as detailed below (Figure 18). The inspection forms are now digitized and accessible on tablets, streamlining data handling and reducing paper waste. While the model still accounts for the Base 3 inspector assisting at Base 4, this is expected to occur less frequently, thanks to the increased efficiency at Base 4.

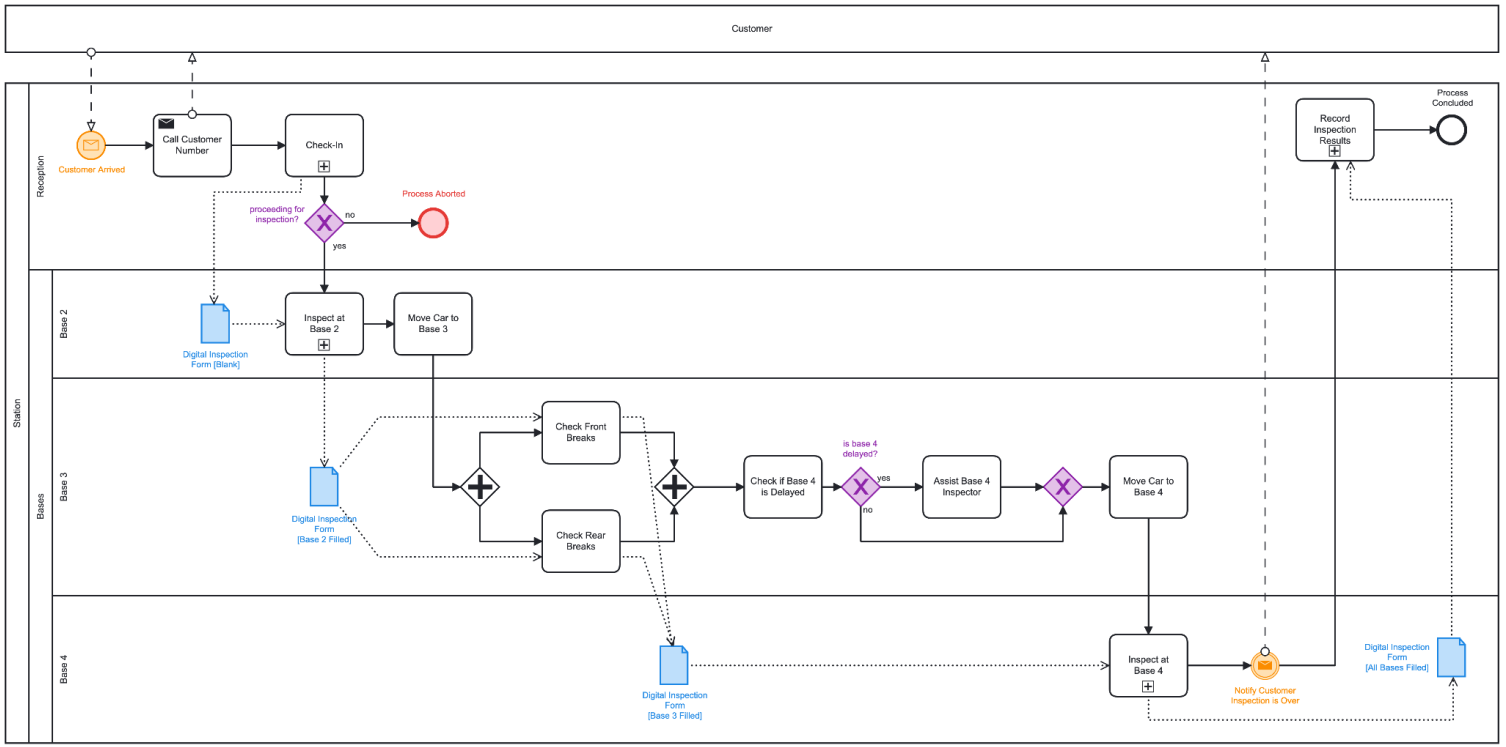

Figure 18 - BPMN diagram of the revised general inspection process (*to be* model).

The check-in process (Figures 19 and 20) has been upgraded to allow for scheduled inspections, expediting the procedure for customers with appointments. Those without prior appointments continue to follow the traditional check-in method, ensuring no customer is left behind.

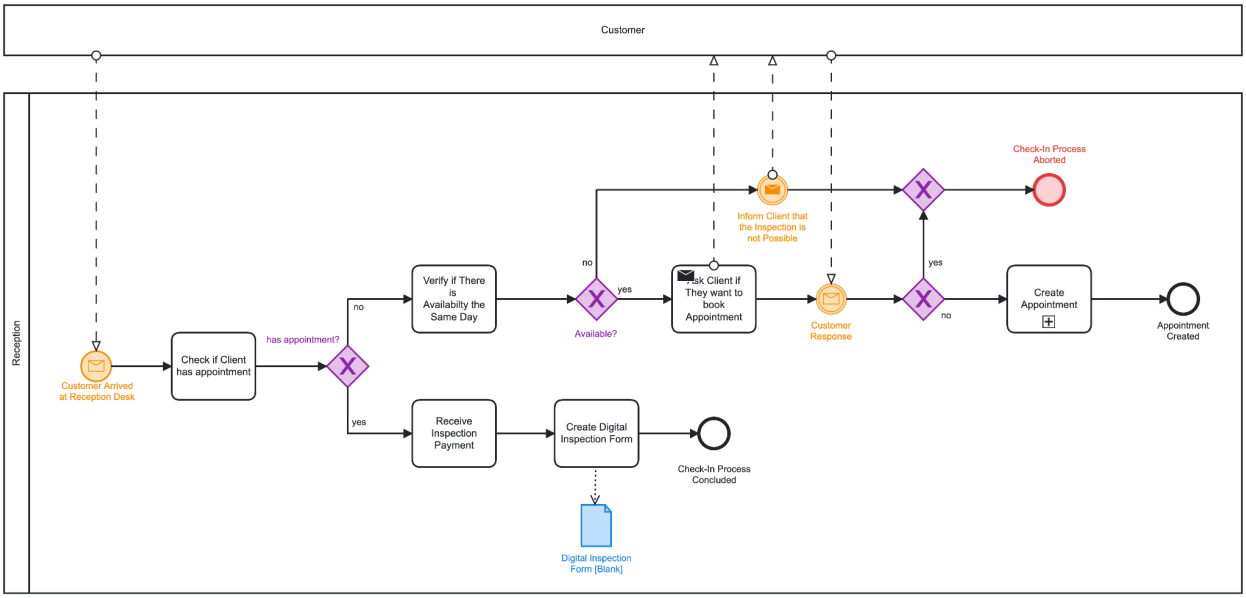

Figure 19 - BPMN diagram of the updated check-in sub-process.

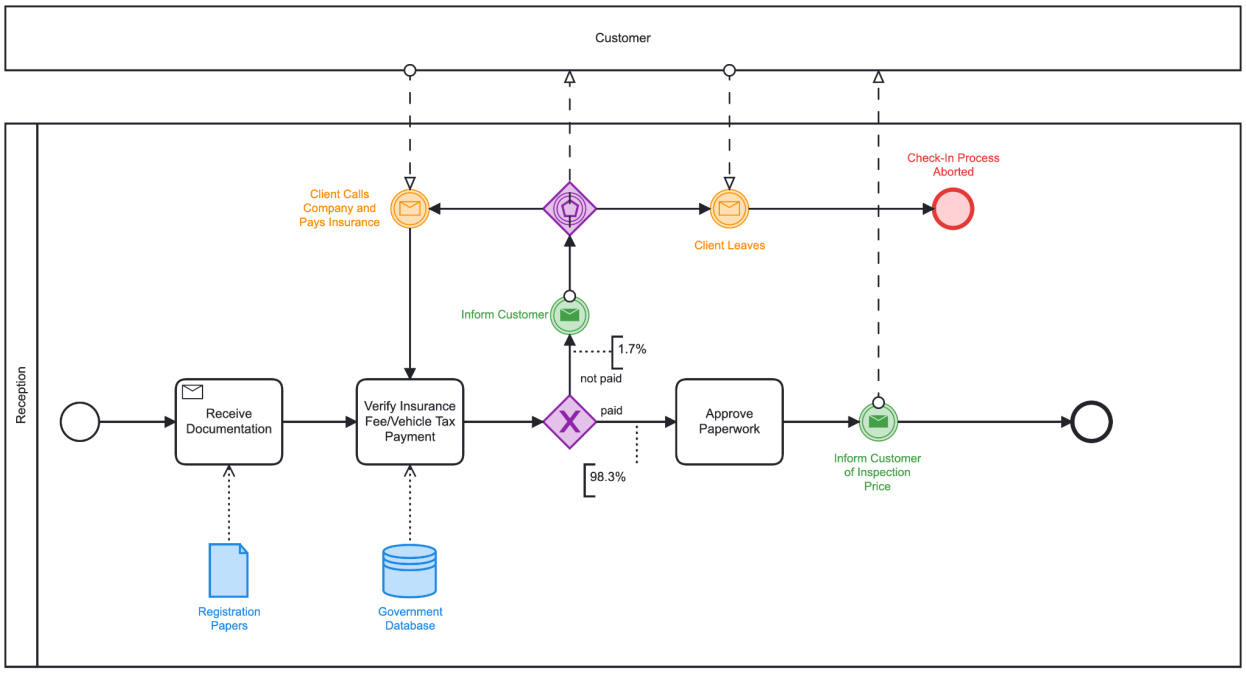

Figure 20 - BPMN diagram of the create appointment sub-process.

The inspection process at Base 2 remains practically unchanged (Figure 21), with the exception of using digital inspection forms and inspectors no longer needing to retrieve keys from customers.

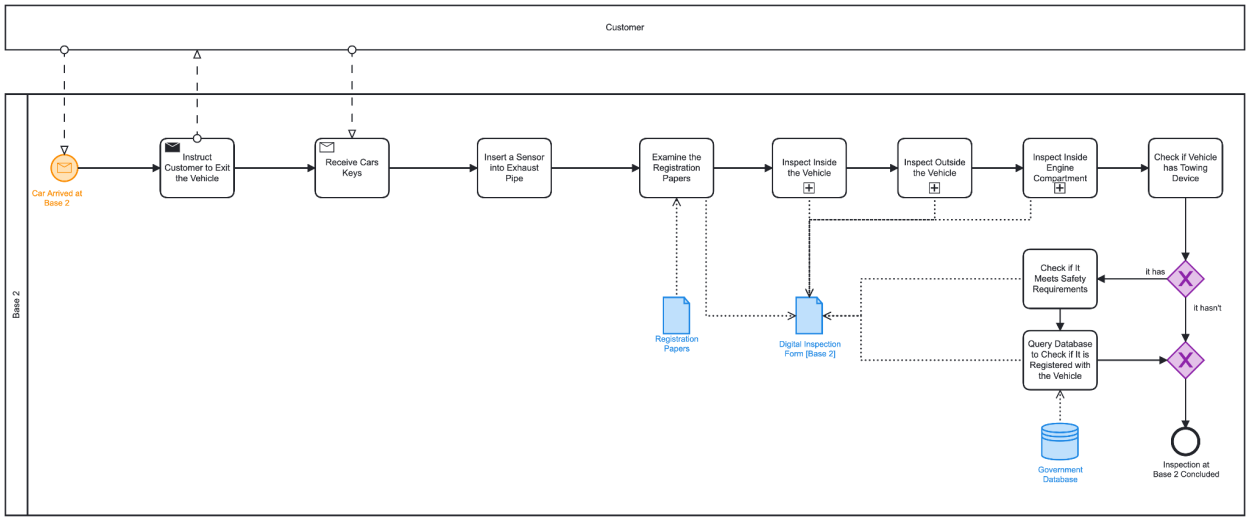

Figure 21 - BPMN diagram of inspection at Base 2 sub-process.

A major shift has occurred at Base 4 (Figure 22), where hoists have been replaced with pits. This alteration addresses the previous challenges with large vehicles and is expected to significantly speed up the inspection process for all vehicle types.

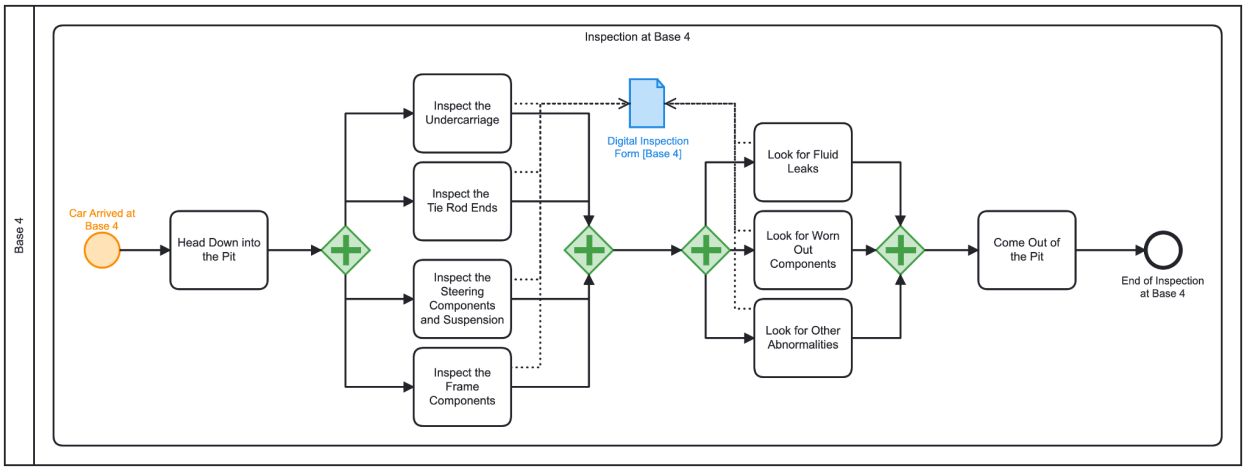

Figure 22 - BPMN diagram of the new inspection at Base 4 sub-process.

The final step of recording inspection results has undergone a digital transformation (Figure 23). Inspectors now submit reports directly through a digital system at the end of each inspection, eliminating the need for clerical recording and enhancing the accuracy and efficiency of data collection.

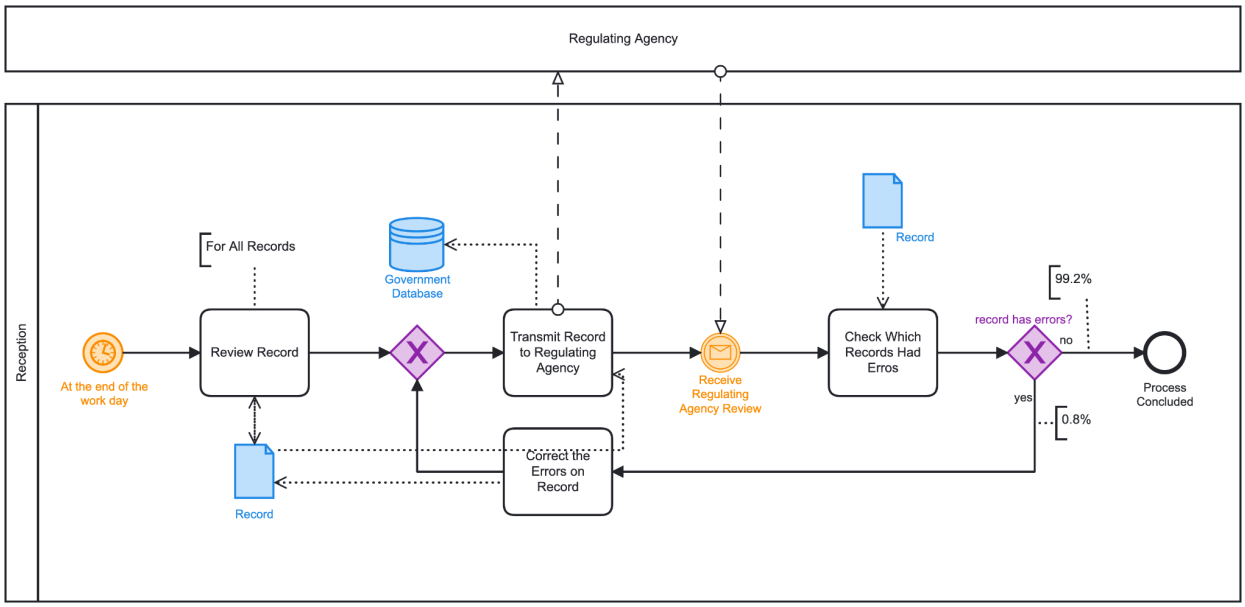

Figure 23 - BPMN diagram of the digitized process for recording inspection results.

4.5. Simulation results

To address the issue of prolonged waiting times, the modification in the BPMN was implemented specifically at the check-in stage. Here, we streamline the process by checking for prior appointments. If an appointment exists, physical submission of documents is unnecessary, as they are submitted online. We proceed to check availability, offer appointment scheduling, and promptly verify the submitted documents if the customer chooses to schedule. If the customer opts not to schedule, the check-in process is promptly aborted, with the assumption that, in cases of unavailability, customers will leave.

An adjustment in the BPMN was driven by the inherent size of the hoists. While the implementation of pits reduces the frequency of assistance required from Base 3 to Base 4, it alters the simulation by decreasing the instances requiring help from 30% to 5%.

For the full results, refer to Annex C.

Bizagi simulation results:

Wages:

Table 10 - Bizagi simulation results showing the wage of each worker.

Resource	Utilization (%)	Total fixed cost ($)	Total unit cost ($)	Total cost ($)
Inspector Base 2	1.74	0	109.5	109.5
Inspector Base 3	0.93	0	58.5	58.5
Inspector Base 4	1.74	0	109.5	109.5
Receptionist	0.60	0	37.5	37.5
	Total:	0	315	315

**Note: Due to *Bizagi* limitations, this table isn't fully accurate, because it is only counting the active work times. For example, the Receptionist is responsible for the Check-in and the Record Inspection Results, that summed take in Total 2h 32min. However, the Receptionist still has to stay 8 hours because the customers arrive all throughout the day.

Activities:

Table 11 - Bizagi simulation results showing the time of each task.

Task Name	Instances Completed	Total Time Waiting Resource	Min. Time	Max. Time	Avg. Time	Total Time
Station	75	1h 25m 39s	2m	26m 39s	16m 57s	22h 25m 39s
Check-in	75	0m	2m	2m	2m	2h 30m
Base 2 Inspection	73	1m 39s	5m	6m 39s	5m 1s	6h 6m 39s
Move Car to Base 3	73	6m	1m	6m	1m 4s	1h 19m
Check Front Brakes	73	1m	1m	2m	1m	1h 14m
Check Rear Brakes	73	1h 15m	2m	3m	2m	2h 27m
Assist Base 4 Inspector	3	1m	5m	6m	5m 20s	16 min.
Move Car to Base 4	73	0m	1m	3m	1m 1s	1h 15m
Base 4 Inspection	73	0m	6m	6m	6m	7h 18m
Record Inspection Results**	1	0m	2m	2m	2m	2m

** Note: Due to *Bizagi* limitations, we couldn't successfully model that the Record Inspection Results task happens only once at the end of the day, so in the full results it says it is completed 0 times when it should be 1.

By fixing **Issue 5: Hoist's size and speed limitations** with the new pit installation, Base 4 Inspection went from taking, on average, 8m per car, to just 6m and all cars are able to be inspected in Base 4, while also needing much less help from the Base 3 Inspector (went form 30% of the time to 5%).

Fixing **Issue 4: Receptionist has too many jobs,** by automating the selling of food and drinks service and the collecting and recording of inspection forms, as well as separating the queues between inspection and other services, we saw a decrease in the wait time reception. This went together with Fixing **Issue 1: Long waiting times,** reintroducing the appointment system, would space out customers, as to divide them better during the day and even year, with the goal of not having a big overflow of clients that can't be attended quickly and not forming huge queues. Both of these solutions made the wait time in the reception go from an average of 8 minutes to 1min.

Fixing **Issue 3: Customer's mistakes,** that happen in Base 2, by having better signalization telling the customer where to stop, and by taking the keys immediately after the client steps out of the vehicle, we were able to reduce to mean time in Base 2 Inspection from 7minutes to 5min.

All of these solutions together led to the Fixing of **Issue 2: Employees Overwork.** As we can see by the simulation results, the Receptionist has jobs of Check-in and the Record Inspection Results, now takes in total 2h 32min (however, the Receptionist still has to stay 8 hours because the customers arrive all throughout the day). The Base 2 Inspector, responsible for Base 2 Inspectiona and Driving the Car to Base 3, now takes 7h 25m 19s (6h 6m 39s + 1h 19m). Base 3 Inspector that works on the Checking Front Brakes, Checking Front Brakes, Assist Base 4 Inspector and Moving the car to Base 4, has a total active time of 5h 12m (once has stayed 8 hours because of having customers all through the day). Base 4 Inspector, has the job of Base 4 Inspection and that now takes 7h 18m.

As we can see, no employees need to overwork.

5. Conclusion

The aim of this project was to analyze and model the business process for vehicle inspection in the Hesthála station, located in Reykjavik. The motivation behind this report was to contribute to the implementation of the quality strategy of Frumherji Ltd. and the achievement of the goals and key performance indicators for the company's vehicle inspection department.

The modeling of the vehicle inspection process carried out in Chapter 2 was key to understanding the *as is* process, translating it into BPMN and delimiting the assumptions. The model obtained was organized into a high level model that contained the subprocesses occurring in the station, namely, the check-in, inspection at Base 2 and Base 4, and check-out. Additionally, in this chapter, a process landscape model was built for the Frumherji Ltd.' vehicle inspection process, identifying the core, support, and management processes.

Then, in Chapter 3, a qualitative and quantitative analysis of the process model was conducted. Qualitatively, from the value-added analysis, some NVA steps were identified, particularly those tied to handoffs and, from the waste analysis, the most inefficiencies were found in motion and over processing categories. Considering a quantitative point of view, the average time for the overall process was estimated to be 29m 44s, inspecting about 75 cars per day. After studying the process as a whole, an issue register was built for following the five main issues: long waiting times, employees overwork, customer's mistakes, receptionists working multiple jobs, and hoists' size and speed limitations.

Finally, in Chapter 4, the *to be* process was modeled. To do this, measures were defined according to the issues aforementioned and implemented in the BPMN model. Some of these proposed changes include the reintroduction of an appointment system, the installation of signboards in the inspection hall and a vending machine in the lounge, the use of tablets to avoid paperwork, and the substitution of the hoists by pits below floor level. The simulation taking into account the upgraded model resulted in an average time of 16min57s per car for the same daily flow of cars, which corresponds to clear improvement over the *as is* scenario.

It's crucial to take into consideration that modeling processes, like the vehicle inspection in the Hesthála station, simplify the real world through assumptions and data constraints. Furthermore, the tools used, both *Camunda* and *Bizagi*, have limitations that hinder the modeling process. All of these factors translate into a model that may not be an exact mirror of reality but can be a helpful tool to help stakeholders make better decisions. This being said, the

results obtained should be reviewed by a team of domain experts and process analysts before being implemented.

In conclusion, this case study allowed us to deepen our understanding in the field of business process modeling and management. It also promoted awareness and sensitivity to the inherent complexity of these projects and to their real-life implications in a business context.

References

Thorbjornsdottir, B., Brown, K. (2011) *Frumherji Ltd., Reykjavik: The Vehicle Inspection and Emissions - Testing Process*. Thunderbird School of Global Management.*

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of Business Process Management*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-56509-4

Support material for the theoretical classes made available by the course's faculty

*Note: all citations in the document are from this document.

Annexes

Annex A

Table A.1 - *Bizagi* simulation results showing the wages of each worker (*as is* model).

Resource	Utilization	Total fixed cost	Total unit cost	Total cost
Inspector Base 2	12.17 %	0	150	150
Inspector Base 3	7.00 %	0	86.25	86.25
Inspector Base 4	12.17 %	0	150	150
Receptionist	12.30 %	0	151.5	151.5
	Total	0	537.75	537.75

Table A.2 - *Bizagi* simulation results showing the time of each task (*as is* model).

Name	Type	Instances completed	Instances started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource	Avg. time waiting for resource	Standard deviation waiting resources	Total time waiting resource	Total fixed cost
Station	Process	75	75	27m	39m 2s	29m 44s	1d 14h 25m 43s					2h 34m 43s	0
Customer Arrived	Start event	75											
Call Customer Number	Task	75	75	0	0	0	0	0	0	0	0	0	0
proceeding for inspection?	Gateway	75	75										
Process Aborted	End event	0											
Move Car to Base 3	Task	75	75	1m	1m	1m	1h 15m	0	0	0	0	0	0
Move Car to Base 4	Task	75	75	1m	1m	1m	1h 15m	0	0	0	0	0	0
Notify Customer Inspection is Over	Intermediate event	75	75										
Process Concluded	End event	75											
Give a Copy of the Documents to the Customer	Task	75	75	0	0	0	0	0	0	0	0	0	0
Check-In	Task	75	75	8m	15m 2s	8m 35s	10h 44m 43s	0	7m 2s	35s	1m 40s	44m 43s	0
Base 2 Inspection	Task	75	75	7m	7m	7m	8h 45m	0	0	0	0	0	0
Base 4 Inspection	Task	75	75	8m	13m	8m 28s	10h 35m	0	5m	28s	1m 27s	35m	0
Check Front Breaks	Task	75	75	1m	1m	1m	1h 15m	0	0	0	0	0	0
Assist Base 4 Inspector	Task	24	24	5m	5m	5m	2h	0	0	0	0	0	0
Is base 4 delayed?	Gateway	75	75										
ExclusiveGateway	Gateway	75	75										
ParallelGateway	Gateway	75	75										
Check Rear Breaks	Task	75	75	2m	2m	2m	2h 30m	1m	1m	1m	0	1h 15m	0
Check if base 4 is Delayed	Task	75	75	0	0	0	0	0	0	0	0	0	0
ParallelGateway	Gateway	75	75										
(Record Inspection is done only 3 times a day)	Gateway	75	75										
ExclusiveGateway	Gateway	75	75										
Record Inspection Results	Task	3	3	2m	2m	2m	6m	0	0	0	0	0	0

Annex B

Table B.1 - Identification of issues in the vehicle inspection process and correspondent citation.

Issue identified	**Citation**
Clients missing their turn when their number was called	*"In some cases, people fell asleep in their cars and were not ready to drive into the inspection hall when their turn came"*
Customers mistakenly drove into the wrong lane	*"(...) vehicle owners proceeded past Base 2 and directly to Base 3 because there was no sign indicating where to stop"*
Lack of signals	*"the only sign in the inspection hall (...) guided customers to the exit"*
Customers forgetting to leave keys in the ignition at Base 2	*"Sometimes drivers mistakenly took their car keys with them to the lounge and the inspector had to retrieve them"*
Long waiting times	*"(...) people were generally dissatisfied with the long waiting times"*
Employees overwork	*"When inspectors worked overtime, the clerks had to work additional overtime to finish data entry after the inspectors left the worksite"*
Uncertainty in demand	*"there was a high degree of variation in demand by month, by day of the week, and by time of day"*
Customers having to be turned away due to the high demand	*"Customers who arrived before 16:30 usually received service that day, but some had to be turned away"*

Difficulty to maintain sufficient staffing levels	*Due to "shortage of qualified mechanics", "high employee turnover rate" and "compensation limitations"*
Facilities not prepared to deal with the increasing numbers of large vehicles	*"Inspection station doorways and lanes were too narrow and the elevators (hoists) too small to accommodate some of these larger vehicles easily"*
Delays in the check-in due to receptionists having to do multiple jobs	*"There could be delays in the reception area, even when there were no cars in the inspection hall, because the receptionists also had to serve customers who were there for other services such as driver testing, picking up their license plates, and buying drinks and sweets"*
The inspections having to continue inspecting the cars even when the cars fail at Base 2	*"On average, 15.23 percent of vehicles failed the inspection at Base 2. Those failing at this station still moved forward to Base 3 for further inspection"*
Vehicles delayed at Base 3	*"(...) a few vehicles were delayed at Base 3 because the vehicle at Base 4 was not finished"*
Manual errors in paperwork which might have to be redone	*"(...) Umferðarstofa would return a document identifying the errors in the reports (about 0.8 percent of reports had errors). The supervisor of the reception area would oversee the process of correcting the errors"*
Mismatch in documents collected at exit (customer might collect somebody else's documents)	*"(...) a few vehicles were delayed at Base 3 because the vehicle at Base 4 was not finished. In those instances, the Base 3 inspector assisted the Base 4 inspector in completing necessary inspection tasks"*

Customers not bringing all the necessary documents	*“Once all of the paperwork was approved (...)”*
Wasting time raising the car with the car elevator	*“At Base 4 (...) the inspector drove the vehicle to the hoist, where the next inspector raised it to a height that allowed him to inspect the undercarriage (...)”; “(...) noted that a few vehicles were delayed at Base 3 because the vehicle at Base 4 was not finished.”*
Not having a system to estimate waiting times	*“(...) people were generally dissatisfied with the long waiting times. For example, a young woman and her husband had waited 90 minutes and, in her words, “used both of our lunch hours and coffee breaks that day.””*
Idleness when an inspector is waiting for the next car, because the it is still being inspected at the previous base	*“(...) a few vehicles were delayed at Base 3 because the vehicle at Base 4 was not finished. In those instances, the Base 3 inspector assisted the Base 4 inspector in completing necessary inspection tasks”*
Doorways and hoists too narrow/small to accommodate larger vehicles	*“One recent problem stemmed from the increasing numbers of large vehicles imported to Iceland. Inspection station doorways and lanes were too narrow and the elevators (hoists) too small to accommodate some of these larger vehicles easily.”*

Annex C

Table C.1 - *Bizagi* simulation results showing the wages of each worker (*to be* model).

Resource	Utilization	Total fixed cost	Total unit cost	Total cost
Inspector Base 2	1.74 %	0	109.5	109.5
Inspector Base 3	0.93 %	0	58.5	58.5
Inspector Base 4	1.74 %	0	109.5	109.5
Receptionist	0.60 %	0	37.5	37.5
	Total	0	315	315

Table C.2 - *Bizagi* simulation results showing the time of each task (*to be* model).

Name	Type	Instances completed	Instances started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource	Avg. time waiting for resource	Standard deviation waiting resources	Total time waiting resource	Total fixed cost
Station	Process	75	75	2m	26m 39s	16m 57s	22h 25m 39s					1h 25m 39s	0
Customer Arrived	Start event	75											
Call Customer Number	Task	75	75	0	0	0	0	0	0	0	0	0	0
proceeding for inspection?	Gateway	75	75										
Process Aborted	End event	2											
Move Car to Base 3	Task	73	73	1m	6m	1m 4s	1h 19m	0	5m	4s	35s	6m	0
Move Car to Base 4	Task	73	73	1m	3m	1m 1s	1h 15m	0	2m	1s	13s	2m	0
Process Concluded	End event	73											
Check-In	Task	75	75	2m	2m	2m	2h 30m	0	0	0	0	0	0
Base 2 Inspection	Task	73	73	5m	6m 39s	5m 1s	6h 6m 39s	0	1m 39s	1s	11s	1m 39s	0
Base 4 Inspection	Task	73	73	6m	6m	6m	7h 18m	0	0	0	0	0	0
Check Front Breaks	Task	73	73	1m	2m	1m	1h 14m	0	1m	0 s	6s	1m	0
Assist Base 4 Inspector	Task	3	3	5m	6m	5m 20s	16m	0	1m	20s	28s	1m	0
Is base 4 delayed?	Gateway	73	73										
ExclusiveGateway	Gateway	73	73										
ParallelGateway	Gateway	73	73										
Check Rear Breaks	Task	73	73	2m	3m	2m	2h 27m	1m	2m	1m	6s	1h 14m	0
Check if Base 4 is Delayed	Task	73	73	0	0	0	0	0	0	0	0	0	0
ParallelGateway	Gateway	73	73										
(Record Inspection is done once at the end of the work day)	Gateway	73	73										
ExclusiveGateway	Gateway	73	73										
Notify Customer Inspection is Over	Intermediate event	73	73										
Record Inspection Results	Task	0	0	0	0	0	0	0	0	0	0	0	0