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PRODUCT DEVELOPMENT APPROACH FOR A STABILIZED AMBULANCE STRETCHER

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ISEP – School of Engineering

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KEYWORDS

Product Development, Emergency Stretcher, Vibration, Stabilization, Canvas Model, Business Plan, Financial Analysis.

ABSTRACT

The level of vibrations that a patient experiences during ambulance transport is often too high. The ambulance crew must take measures to reduce the effects of vibration. Currently, they do it by reducing the speed at which the ambulance transports the patients or by deviating from the shortest routes to routes that have better conditions for transport. The deviation in the route is required to avoid speed bumps, potholes and other obstacles that cause high vibration peaks. These vibrations are most severe in the vertical direction. The human body is most sensitive to vibrations in the range from 0.1 to 80 Hz, and it is within this range that the dominant vertical vibrations of an ambulance stretcher occur.

The vibrations experienced can be reduced by placing an active stabilization unit in between the stretcher mattress and the legs of the stretcher. This active system performs vibration compensation in real time. The system is controlled with a data logger which collects the vibrational information from the road and transfers that data to the control system. The system is based on a spring-motor configuration. The spring-based systems help to keep the mattress in position thereby reducing the effects of vibration and improving the comforts of patient transport. Since the stabilization unit increases the weight of the stretcher, currently this device cannot be employed for non-powered stretchers.

A business plan for the product launch is analyzed. The business plan provides the information to make this product market ready. A financial analysis is also performed to support the claims of the business plan. The business plan is focused on launching the stabilization device and then provides insight into developing stretcher solutions for the market.

PALAVRAS CHAVE

Desenvolvimento de Produto, Maca de Emergência, Vibração, Estabilização, Modelo Canvas, Plano de Negócios, Análise financeira.

RESUMO

O nível de vibrações que um paciente experimenta durante o transporte de ambulância é muitas vezes demasiado elevado. O pessoal da ambulância tem que tomar medidas para reduzir os efeitos da vibração. Atualmente isso é feito reduzindo-se a velocidade com que a ambulância transporta os pacientes ou desviando-se das rotas mais curtas para as rotas que têm melhores condições de transporte. O desvio na rota precisa ser feito para evitar lombas, buracos e outros obstáculos que causam altos picos de vibração. Essas vibrações são mais severas na direção vertical. O corpo humano é mais sensível a vibrações na faixa de 0,1 a 80 Hz, e é dentro dessa faixa que ocorrem as vibrações verticais dominantes numa maca de ambulância.

As vibrações no transporte de pacientes podem ser reduzidas colocando uma unidade de estabilização ativa entre o colchão da maca e a estrutura da maca. Este sistema ativo realiza a compensação de vibração em tempo real. O sistema é controlado por um processador de dados que coleta informações vibracionais da estrada e transfere esses dados para o sistema de controlo. O sistema atua através de uma solução dinâmica com um motor passo a passo. Os sistemas baseados em motores passo a passo ajudam a manter o colchão em posição, reduzindo assim os efeitos da vibração e melhorando o conforto do transporte do paciente. Como a unidade de estabilização aumenta o peso da maca, atualmente este dispositivo não pode ser empregado para macas não motorizadas.

Com base na proposta de produto concebido, um plano de negócios para o lançamento do produto desenhado. O plano de negócios fornece as informações para preparar o lançamento deste novo produto no mercado. Também foi realizada uma análise financeira para validar os pressupostos do plano de negócios. O plano de negócios foi construído com o foco no lançamento do dispositivo de estabilização e, em seguida, pressupõem extensões assentes no posterior para o desenvolvimento de soluções de maca integral a colocar no mercado.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

ABSC	Ambulância de Socorro
ABCI	Ambulância de Cuidados Intensivos
ABTM	Ambulância de Transporte Múltiplo
ACB	Actively Controlled Bed
AEM	Ambulâncias de Emergência Médica
B2B	Business to Business
B2C	Business to Customer
BOM	Bill of Materials
CAD	Computer Aided Design
CMVMC	Custo das Mercadorias Vendidas e Materias Consumidas
DOF	Degree of Freedom
FSE	Fornecimentos e Serviços Externos
HFAR	Hospital das Forças Armadas
IRR	Internal Rate of Return
NPV	Net Present Value
PCB	Printed Circuit Board
PEM	Postos de Emergência Médica
PID	Proportional–Integral–Derivative
PLA	polylactic acid
POM	Polyoxymethylene
R&D	Research and Development
RES	Postos Reserva
ROI	Return of Investment
SBV	Suporte Básico de Vida
SHEM	Serviço de Helicópteros de Emergência Médica
SIEM	Sistema Integrado de Emergência Médica
SIV	Ambulância de Suporte Imediato de Vida
TEPH	Técnicos de Emergência Pré-hospitalar
TIP	Transporte Inter-Hospitalar Pediátrico
UMIPE	Unidades Móveis de Intervenção Psicológica de Emergência
VMER	Viatura Médica de Emergência e Reanimação
VSAM	Veículo de Socorro e Assistência Médica

List of units

cm	Centimeter
G	g-force
kg	Kilogram
kW	Kilo-Watt
m	Meter
m/s	Meter per Second
mm	Millimeter
Ms	Milli-Second
N	Newton
N/A	Newton per Ampere
W	Watt

List of symbols

€	Euro
$	Dollar

GLOSSARY OF TERMS

Ambulance	A vehicle equipped for taking sick or injured people to and from the hospital, especially in emergencies.
Business model	A plan for the successful operation of a business, identifying sources of revenue, the intended customer base, products, and details of financing.
Business Plan	A business plan is a formal statement of business goals, reasons they are attainable, and plans for reaching them.
Customer	A person who buys goods or services from a shop or business.
EMS	EMS is the acronym for Emergency Medical Services. This term refers to the treatment and transport of people in crisis health situations that may be life-threatening. Emergency medical support is applied in a wide variety of situations from car accidents to drownings to incidents of a heart attack.
Patient	A person receiving or registered to receive medical treatment.
Paramedic	A person trained to give emergency medical care to people who are seriously ill with the aim of stabilizing them before they are taken to the hospital.
Product Development	The creation of products with new or distinctive characteristics that offer new or additional benefits to the customer.
Prototype	A first or preliminary version of a device or vehicle from which other forms are developed.
Stretcher	A framework of two poles with a long piece of canvas slung between them, used for carrying sick, injured, or dead people.
Vibration	Vibration can be considered to be the oscillation or repetitive motion of an object around an equilibrium position.

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INTRODUCTION

1. INTRODUCTION

1.1 Problem Statement

Vibrations are known to affect humans in many ways. One such occurrence is the vibrations that patients experience. Patients feel the effects of vibrations right from the moment they are placed on a stretcher to the point they are admitted to the hospital. In between being placed on a stretcher to being admitted to the hospitals, patients must be transported. Ground transport is the most predominant medium of transport.

During ambulance transport, patients experience vibrations and the effects are uncomfortable and at times discerning. It is important to reduce the vibrations of the stretcher mattress with the patient on it when the patient is being transported to the hospital.

One way of reducing the vibrational effects is by trying to place a damper in between the ambulance floor and the stretcher. Though this might be an effective solution, it can hamper the ergonomics of the ambulance. Another way is to place an active stabilization device between the legs and the mattress frame of the stretcher. Such a device provides the opportunity to provide vibration reduction while being potentially cheaper and with higher efficiency.

To develop the device, a spring-based linear motor system is used. The motors are actively controlled with a control system which is programmed to hold the bed in position. Holding the bed in position will provide comfort to the patients.

1.2 Objectives

The goal of this report is to provide an insight into the product development approach to develop solutions to counter the problem of vibrations. A business plan is made to show the strategy to develop the product from the prototyping stage to products being launched on the market. The business model is made using the Canvas model. In order to support the business model, a financial analysis was performed to see how feasible and sustainable this business proposal could be.

1.3 Methodology

The methodology follows the technical approach for new product development. First is the idea generation stage. In this stage, ideas were generated based on the sponsor requirements. Ideas were generated for the type of applications that could be targeted. Upon the idea definition, research and development were done. The research was performed based on a qualitative and quantitative approach. Qualitative research was done to understand the need for such a device in today's patient transport scenario. The Research mediums were personal structured interviews and online questionnaires. The research subjects were Paramedics, Bombeiros Porto, Doctors, Ambulance manufacturers/ modifiers. On field research gave insight into problems experienced during patient transport on a personal level while online research gave insight into the problems on a theoretical and statistical level. Online sources researched were google scholar, PubMed, NCBI. Problems experienced, existing solutions, theoretical papers, and patents were analyzed.

Post the research, the prototype, and product concept was developed. After the research and development, the business analysis was done to provide insights into the markets that could be explored and to devise a plan to launch the products into the market.

1.4 Thesis structure

In chapter 2, a literature review is made on the emergency medical services in Portugal. A study is made on the services provided, types of stretchers and the effects of vibrations on patients, paramedics, and test subjects. An insight is also provided on the available market solutions. The chapter is concluded with a summary of the research.

In chapter 3, the product concept is investigated. Insights are provided on the development process of the device to the prototyping stage. The prototype development method is also explained.

In chapter 4, a business plan to make the product market ready is analyzed. The business plan throws light on how to make the business sustainable. The business plan is followed by the market research and financial analysis. The objective of the financial analysis is to support the proposed business plan.

In chapter 5, the conclusions and further developments of this research are discussed.

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2 LITERATURE REVIEW

2.1 General Information

An Emergency Medical Service (EMS) can be defined as "a comprehensive system which provides the arrangements of personnel, facilities, and equipment for the effective, coordinated and timely delivery of health and safety services to victims of sudden illness or injury." The aim of EMS focuses on providing timely care to victims of sudden and life-threatening injuries or emergencies to prevent needless mortality or long-term morbidity. The function of EMS can be simplified into four main components; accessing emergency care, care in the community, care en route, and care upon arrival to receiving care at the healthcare facility [1].

The Franco-German model of EMS delivery is based on the "stay and stabilize" philosophy. The motive of this model is to bring the hospital to patients. It is usually run by physicians and they have an extensive scope of practice with very advanced technology. The model utilizes more of other methods of transportations alongside land ambulances such as helicopters and coastal ambulances [1]. Countries with the Franco-German system of emergency care include Austria, Belgium, Finland, France, Germany, Latvia, Norway, Poland, Portugal, Russia, Slovenia, Sweden, and Switzerland [2].

2.2 INEM

The Instituto Nacional de Emergência Médica (INEM), (National Institute of Medical Emergency), is the body of the Ministry of Health responsible for coordinating the operation, in the territory of mainland Portugal, to guarantee the patients or victims of sudden illness the prompt and provision of health care. The provision of emergency medical care at the place of occurrence, the assisted transportation of the victims to the appropriate hospital and the articulation between the various actors of the System are the main tasks of INEM [3].

2.2.1 INEM services

INEM provides a number of services depending on the patient condition and situation. Based on the requirement, the services provided are:

1. Ambulâncias de Emergência Médica (AEM)- Medical Emergency Ambulances (EMS).
2. Motociclos de Emergência Médica (MEM)- Medical Emergency Motorcycles.
3. Ambulâncias de Socorro sedeadas em entidades que são agentes de proteção civil e ou elementos do Sistema Integrado de Emergência Médica (SIEM)- Relief ambulances based in entities that are civil protection agents and / or elements of the Integrated Medical Emergency System.
4. Postos de Emergência Médica (PEM)- Emergency Medical Posts.
5. Postos Reserva (RES)- Reservation Post.
6. Unidades Móveis de Intervenção Psicológica de Emergência (UMIPE)- Emergency Psychological Intervention Units.
7. Serviço de Helicópteros de Emergência Médica (SHEM)- Emergency Medical Helicopter Service.

In addition to the means defined in Order No. 5561/2014 of April 23, the VMER (Emergency Medical and Resuscitation Vehicles) and Ambulances SIV (Immediate Support of Life) and the Pediatric Interhospital Transportation Ambulances (TIP) are also available. In order to fulfil its obligations under the SIEM, which are based on a complementarity between the various means of medical emergency, among them, the Medical Emergency and Resuscitation Vehicles (VMER), Ambulances of Immediate Life Support (SIV), Ambulances of Emergency Medical (AEM), Emergency Medical Motorcycles (MEM), Pediatric Interhospital Transportation Ambulance (TIP), the (UMIPE) and the Emergency Medical Helicopter Service (SHEM) [4].

Emergency Medical Ambulances- Ambulâncias de Emergência Médica-(AEM):

Emergency Medical Ambulances (EMS), formerly called Basic Life Support Ambulances (Suporte Básico de Vida) (SBVs), are part of a team of two INEM Pre-hospital Emergency Technicians (Técnicos de Emergência Pré-hospitalar) (TEPH). Their mission is the rapid movement of a prehospital emergency medical team to the place of the accident, the clinical stabilization of the victims of an accident or sudden illness, and assisted transportation to the emergency department that is most appropriate for their clinical condition [5]. Figure 1 shows the Emergency Ambulance used by INEM.

Figure 1 Ambulâncias de Emergência Médica (AEM) [5]

Emergency Medical Motorcycles-Motociclos de Emergência Médica-(MEM):

The emergency medical motorcycle is an agile medium, aimed at urban traffic, which allows you to quickly reach the place where the patient is. This vehicle carries an External Automatic Defibrillator, oxygen, airway adjuvants and ventilation, vital signs assessment and capillary glycemia and other Basic Life Support (SBV) materials [6]. The Emergency Medical Motorcycle can be seen in Figure 2.

Figure 2 Emergency Medical Motorcycle [7]

Emergency Relief ambulances- Ambulâncias de Socorro-(AS):

The mission of Relief Ambulances (AS) is to ensure the rapid movement of a crew with training in emergency medical techniques to the place of occurrence and in the minimum possible time, in complementarity and articulation with the other means of prehospital medical emergency as well as the possible transport to the health unit most appropriate to the clinical condition of the victim [8]. The Relief ambulance can be seen in Figure 3.

Figure 3 Ambulâncias de Socorro (AS) [8]

Unidades Móveis de Intervenção Psicológica de Emergência- Mobile emergency psychological intervention unit-(UMIPE):

The Mobile Units for Emergency Psychological Intervention (UMIPE) are activated by the Urgent Patient Orientation Center of INEM for the place of occurrence where it is considered necessary to intervene. Assistance to victims of accidents or their relatives and friends, support in the management of these occurrences are the functions of the UMIPE [9]. The Mobile Units for Emergency Psychological Intervention can be seen in Figure 4

Figure 4 Móveis de Intervenção Psicológica de Emergência (UMIPE) [9]

Serviço de Helicópteros de Emergência Médica -Emergency Medical Helicopter Service (SHEM):

Medical Emergency Helicopters are used to transport serious patients between health facilities or between the place of occurrence and the health facility. They are equipped with Advanced Life Support material and work 24 hours a day, 365 days a year. The primary mission is to place a medical team and equipment at the scene. As a rule, the patients are held-transported, however, Ambulance transportation is possible to the hospital, accompanied or not by the helicopter team. Their secondary mission is to carry critical patients between health units. Their third mission is to transport organs [10]. The Medical Emergency Helicopters can be seen in Figure 5.

Figure 5 Serviço de Helicópteros de Emergência Médica (SHEM) [10]

2.2.2 Paramedic Teams- Training and Skills

The EMS and EMS team consists of prehospital emergency technicians (TEPH), which are qualified with proper training and approved by INEM, which assigns them the necessary skills for the provision of emergency pre-hospital medical care and other procedures, acting in compliance with decision algorithms defined by INEM under the supervision of the coordinating doctor of the CODU.

The Ambulance Relief teams (PEM and RES) are and/or elements of SIEM that have specific training in pre-hospital emergency, defined and certified by INEM. The UMIPE consists of a team of TEPH and psychologist (senior technician) with specific in psychological intervention in crisis situations, approved by INEM.

SHEM includes a team of pilots (the commander and a pilot) and medical and a nurse), who are both in permanent physical presence with the aircraft. The physicians and the nurses who provide services at SHEM have specific training, a Flight Physiology and Safety Course in Heliports and a Medical Car Course Emergency and Resuscitation. They also have experience in Pre-hospital Emergency Care Intensive and/or Emergency Service [4].

2.3 Firefighters department Portugal (Bombeiros Portugal)

The firefighter's department works in collaboration with INEM. On receiving a distress call, INEM contacts the firefighters and they dispatch vehicles in the vicinity depending on the seriousness of the issue. The firefighter's department has its own fleet of vehicles:

Relief Vehicle and Medical Assistance - Veículo de Socorro e Assistência Médica - (VSAM) is a vehicle designed with equipment capable of medicalizing the rescue and manned by a doctor and specialized personnel, allowing the application of measures of Advanced Life Support [11]. The Relief Vehicle and Medical Assistance can be seen in Figure 6.

Figure 6 Veículo de Socorro e Assistência Médica (VSAM) [11]

Ambulance Relief - Ambulância de Socorro -(ABSC) is a single-person vehicle with equipment and crew that allows the application of basic life support measures (SBV), aimed at stabilizing and transporting a patient who needs assistance during transportation [11]. The Relief ambulance can be seen in Figure 7.

Figure 7 Ambulância de Socorro (ABSC) [11]

Intensive Care Ambulance - Ambulância de Cuidados Intensivos – ABCI is a single-person vehicle with equipment and crew that allows the application of advanced life support (SAV) measures, aimed at stabilizing and transporting a patient who needs aid during transportation. The use of the SAV equipment is the sole responsibility of a doctor, who must integrate the crew [11]. The Intensive Care Ambulance can be seen in Figure 8.

Figure 8 Ambulância de Cuidados Intensivos (ABCI) [11]

Patient Transport Ambulance - Ambulância de Transporte de Doentes - (ABTD) is a vehicle equipped for transporting one or two patients on stretcher or stretcher and transport chair, for medically justified reasons and whose clinical situation does not provide for the need for assistance during transportation [11]. The Patient Transport Ambulance can be seen in Figure 9.

Figure 9 Ambulância de Transporte de Doentes (ABTD) [11]

2.4 Types of stretchers

According to the Cambridge dictionary, a stretcher is defined as “a light frame made from two long poles with a cover of soft material stretched between them, used for carrying people who are ill, injured, or dead.” [12] Over the years, stretchers have moved beyond a light framed device. Modern-day stretcher manufacturing depends on factors such as economics, situational intelligence, patient condition and severity of the injury. Modern-day stretchers vary from simple scoop stretchers to highly advanced motorized stretchers. Mentioned below is a brief description of the types of stretchers:

Mobile hospital stretchers:

Mobile stretchers transport a patient safely and expediently within a healthcare facility. A mobile stretcher typically consists of a patient platform made of steel, aluminum, or plastic, mounted on a wheeled frame that may incorporate mechanical, electronic, or hydraulic devices for adjusting the platform's height. Fixed-height stretchers are lighter and less complex than adjustable-height models, but the latter can match the elevation of other surface levels, providing easier, safer patient transfers. Most stretchers can accommodate intravenous poles, patient monitors, oxygen tanks, articulating headpieces, and other equipment. They may also function as beds. Most stretchers provide mattresses, adjustable side rails, and straps.

The stretcher platform height can adjust in many ways: some use a hydraulic pump or an electronic control, while others use a mechanical hand crank or support bars that fit into grooves to raise or lower the platform. Most permit different platform positions (e.g., Trendelenburg, reverse Trendelenburg, Fowler, leg lift, knee flex). They typically have casters at least 20 cm (8 in) in diameter so that they can cross elevator and door thresholds smoothly. Most casters can swivel and are equipped with wheel locks and/or brakes to keep the table stationary for patient treatment. Stryker's Mobile hospital stretchers can be seen in Figure 10. Information about Mobile hospital stretchers can be seen in Table 1.

Table 1 Information about Mobile hospital stretchers

Heading	Information
Issues	The most common problems encountered with mobile stretchers involve side rails unlocking, casters falling off, wheel locks and/ or brakes not functioning or engaged incorrectly, or frame/ structural components failing. Loss of a caster can cause the platform surface to tilt, spilling the patient onto the floor. Routine inspection of casters, \side rails, and other frame components can usually prevent these problems [13].
General Product specifications	Approx. dimensions (mm): [600-900] x 800 x 2000; the height should be adjustable to meet the caregiver's requirements / Approx. weight (kg): 125 / Price range (USD): 700-18,000 (6,500 typical); price covers all types and

	variations / Typical product life time: 15 years / Shelf life (consumables): NA.
Types and variations	Adjustable, Fixed-Height, Radiographic, Bariatric, Powered.
Manufacturers	Stryker [14] , Ferno [15] , Spencer [16] In Portugal: Auto Ribiero [17].

Figure 10 Stryker Transport Stretcher

Wheeled or mobile ambulance stretcher:

The wheeled or mobile ambulance stretcher is the most commonly used device to move and transport patients. It is a specially designed stretcher that can be rolled along the ground and weighs between 40 and 145lb (18 and 66 kg), depending on its design and features. Because its weight adds to that of the patient and any equipment needed for immediate patient care, it is in general not taken up or down stairs or to other locations where the patient must be carried for any significant distance. Moving a patient by rolling, using a stretcher or other wheeled device, is preferred when the situation allows and helps prevent injuries from carrying. A wheeled stretcher by EMS can be seen in Figure 11. Information about Wheeled or mobile ambulance stretcher can be seen in Table 2.

Table 2 Information about Wheeled or mobile ambulance stretcher

Heading	Information
General Product specifications	Approx. dimensions (mm): 520 x 300 x 1900 / Approx. weight (kg): up to 96 kg/ Maximum load: 150 kg / Consumables: NA / Price range (USD): 200-24000; price covers all types and variations / Typical

	product lifetime: 15 years / Shelf life (consumables): NA
Manufacturers	Ferno [15], EMS [18], Spencer [19].

Figure 11 EMS Mobile Ambulance Stretcher [18]

Portable stretchers:

A portable stretcher is a device consisting of a lightweight frame, or of two poles with a cloth or metal platform, on which a patient is carried. Portable stretchers do not have a second multi-positioning frame or adjustable undercarriage. Some models have two wheels that fold down about 4 inches (10 cm) underneath the foot end of the frame and legs of a similar length that fold down from the head end at each side. The wheels make it easier to move the loaded stretcher. The legs should not be used as handles.

Some portable stretchers is foldable in half across the center of each side so that the stretcher is only half its usual length during storage. Many ambulances carry a portable stretcher to use if a patient is in an area that is difficult to reach with a wheeled ambulance stretcher or if a second patient must be transported on the squad bench of the ambulance. A portable stretcher weighs much less than a wheeled stretcher and does not have a bulky undercarriage. However, because most of the models do not have wheels, medical stuff must support all of the patient's weight and any equipment along with the weight of the stretcher [20]. An example of a Basket Stretcher can be seen in Figure 12. An example of a Scoop stretcher can be seen in Figure 13. An example of a Foldable stretcher can be seen in Figure 14. An example of a Chair stretcher can be seen in Figure 15. Information about Portable stretchers can be seen in Table 3.

Table 3 Information about Portable stretchers

Heading	Information

Product specifications	Approx. dimensions (mm): 150 x 560 x 2130 / Approx. weight (kg): 6 / Maximum load: 150 kg / Consumables: NA / Price range (USD): 10-100 (50 typical); price covers all types and variations / Typical product life time: 15 years / Shelf life (consumables): NA
Types and Variations	Hand-carried, Basket stretcher, Two-fold stretcher, Pole stretcher, Scoop stretcher, Evacuation chair
Manufacturers	Ferno[21] [22], Promed [23], Globex [24].

Figure 12 Ferno Basket Stretcher [21]

Figure 13 Ferno Scoop Stretcher [22]

Figure 14 Promed Foldable Stretcher [23]

Figure 15 Globex Chair Stretcher [24]

2.5 Procedure

EMS personnel are required to handle the EMS stretcher either with or without the patients a minimum of seven times [25]:

1. Removal of the stretcher from the ambulance.
2. Movement of the stretcher to the location where the patient is found.

3. The movement to their own location, to the stretcher, or to temporary carry i.e. stair chair, Reeves' sleeve or stokes type baskets, or onto a full-length backboard.
4. Movement of the stretcher to the Ambulance, possibly over numerous steps, across rough, uneven, smooth, firm, or not so firm terrain.
5. Movement of the stretcher into the back of the ambulance.
6. Movement of the patient out of the ambulance at the healthcare facility.
7. Movement of the patient into the healthcare facility to the assigned room or waiting area.

2.6 Problems during ambulance transport

When on a call ambulance teams have two separate and equally important goals. In the back, patients must be treated with the best level of care, so they arrive at their destination in the best condition possible, while in the front the navigator and driver must ensure that the ambulance gets there as quickly as possible in a safe manner. There are certain factors greatly decrease both the patient's comfort level and the ability of the paramedics to provide care en-route [26].

According to the Bureau of labor statistics (United States Department of Labor), EMTs and paramedics have one of the highest rates of injuries and illnesses of all occupations. They must do considerable kneeling, bending, and lifting while caring for and moving patients. They may be exposed to contagious diseases and viruses, such as hepatitis B and HIV. Sometimes they can be injured by combative patients [27]. In addition to all this, the effects of vibration pose a whole different set of problems for the paramedics and patients alike.

2.7 Effects of vibrations

Most ambulances in use are designed so that the stretcher and patient are attached rigidly to a frame that is itself rigidly attached to the vehicle chassis. Therefore, the patient is effectively subjected to the same vibration as the vehicle chassis [28]. While vehicle suspension systems efficiently isolate vibration caused by road texture and short-wave roughness, they often amplify vibration at lower frequencies [29].

As described in ISO 2631, ride comfort and health are affected by shaking, bouncing and rocking whole-body vibration (WBV) at frequencies in a range from 0.5 to 80 Hz. Kinetosis, or motion sickness, is produced by slow motion at frequencies between 0.1 and 0.5 Hz [29].

Whole-body vibration occurs when a human is supported by a surface that is shaking and the vibration affects body parts remote from the site of exposure [30].

The effects of vibrations vary depending on the posture of the patient and the source of the vibration. Experience shows that whole-body vibrations, dependent on the kind, intensity, and duration, has various effects which can result in disturbances of wellbeing, the perception of pain, physiological reactions and a decrease in performance [31].

Road induced vibrations can be felt inside the patient compartment making it difficult to diagnose and treat patients. These vibrations can also cause pain and discomfort to patients being transported, especially those with spinal or neck injury and broken bones. [26] Road Surface induced vibrations to impact the patients care on two levels; it decreases the ability of paramedics to diagnose and treat. Additionally, it has the potential to affect the body's vital functions, which may already be compromised. Specifically, the cardiovascular system, skeleton, central nervous system, and respiratory system are all affected by road-induced vibrations [26].

Blood pressure is indicative of circulatory status accurate blood pressure measurements in the prehospital environment "are of paramount importance." It is believed that the noise and motion associated with transportation in an ambulance can exacerbate this difference [32].

The most commonly reported health effect of whole-body vibration is back pain. Despite this, other types of health effects have been observed. These include sciatica, digestive disorders, genitourinary problems, and hearing damage. Portuguese researchers have reported links between low-frequency noise and whole-body vibration with a variety of disorders, collectively termed as a vibroacoustic disease. These include thickening of cardiac structures and neurological and vascular disorders [33].

Vibrations during ambulance transport are also known to have caused stress. This stressful situation becomes evident by activation of the sympathetic nervous system: heart rate, blood pressure and plasma levels of stress hormones such as epinephrine (adrenaline), norepinephrine (noradrenaline), cortisol and prolactin increase within seconds and lasts for the duration of transportation [34].

There has been a lot of research done on the effects of vibration in a seated or standing position [35]. In the seated position, The comfort has been shown to be dependent on the magnitude of vibration, especially with the fully upright and fully reclined backrests [35].

Another test has shown Peak vibration values which newborns are exposed to (11.8 m/s (2)) are high when compared with the acceleration of gravity (9.8 m/s (2)); this can provoke repeated jerks. Environmental stress can easily alter the stability of an ill newborn and interfere with care maneuvers [36], [37], [38].

Investigated the effects of whole-body vibration on cognitive performance independent of the direct mechanical action of vibration or vision and manual control. 16 male Ss (aged 18–35 years.) completed a short-term memory task during exposure to 16 Hz sinusoidal whole-body vibration of 4 magnitudes. Results show a detrimental effect of vibration on performance when measured by mean reaction time (RT) and a number of attentional lapses. Response errors rose significantly during the lowest magnitude condition alone [39].

In a study conducted by Captain James G. Clark three young men, aged 19, 23, and 25, were subjected to horizontal vibrations for three-minute periods at frequencies from 4 Hz to 12 Hz. The results show a rise in heart rate, mean arterial blood pressure, and Cardiac index. This shows that experiencing induced sinusoidal vibrations increases the strain placed on the body's vital systems.[26]

The respiratory function has also been shown to be affected by induced vibrations. While the patient's increase in stress and vital statistics is a major concern with the road induced vibrations transferred to the patient compartment, the ability of the emergency medical support crew to perform the lifesaving tasks necessary is also hindered. Road surface induced vibrations to play a huge role in the ability of a worker to perform even the most standard tasks [26].

Reading numbers from vital equipment, reading, and writing of information, taking vital measurements and performing treatments can become almost impossible while traveling over some road surfaces [26].

The accuracy of EKG signals and blood pressure readings along with the ability to perform tests and treatments decrease as road vibrations increase[26].

The vision of a paramedic is crucial to their ability to diagnose and treat a patient's symptoms. Other Studies have shown that induced vertical vibrations have the ability to decrease the visual acuity of a person with frequencies as low as six or seven hertz depending on the distance between viewer and subject [26]. Noise pollution hinders patient comfort level and the ability of the paramedics to communicate [26].

2.8 Solutions to absorb vibrations

Vibration damping is a term that is used in industrial, electronic and ergonomic applications when there is a need to reduce the amount of energy that is produced by the system [40]. Active vibration damping is using appropriate sensors to measure the response at each instant and actuators to automatically apply forces which oppose the measured vibration response in a prescribed manner.[41] Over the years, plenty of research has been done on the vibration damping with regards to ambulances and stretchers used in ambulances. They can be broadly classified as:

1. Vibration damping/ vibration isolation devices.
2. Research papers on vibration damping stretchers and
3. Patents on vibration damping stretchers.

2.8.1 Vibration damping/ Vibration isolation devices

The vibration damping devices are the solutions available in the market. These solutions provide vibration damping solutions to reduce the effects of vibrations felt by the patients. Most of these devices are support devices that fit into the floor of the ambulance while the stretcher is placed on top of these support devices. Some available solutions are:

ERAS Germany:

ERAS is a company based in Germany. They develop solutions for active and passive vibration reduction. They developed an active isolation device for ambulance transport. The stretcher carrying the patient is connected to the vehicle floor via an active vibration isolation system. This active system prevents patients from shocks and vibrations during transport to a large extent and is automatic, intelligent and far more efficient than all conventional suspensions [42]. ERAS' product can be seen in Figure 16.

Figure 16 ERAS stabilization solution [42]

STEM technologies:

STEM technologies are a company based in Italy. They have developed a stretcher and incubator support with shock absorbers to reduce the effects of vibrations and impact during patient transport on rough terrains. It features a remote-control pad which performs the adjustments needed. The system developed enables the stretcher to unload even without power consumption [43]. STEM technologies product can be seen in Figure 17.

Figure 17 Stem Technologies stabilization device [43]

Nodin:

Nodin is a Norwegian company that develops medevac solutions for its customers. They develop Land, Aviation and Naval systems. Nodin has created a solution to reduce the impact of mine shocks. Two such products have been developed by Nodin namely: Mine shock and vibration damped stretcher rack and Shock and Vibration Damped Stretcher Rack/CASEVAC (NT-620). Both these devices are suspended from the roof and can also be implemented in a wall mounted bracket [44]. Nodin’s product can be seen in Figure 18.

Figure 18 Nodin's CASEVAC (NT 620) [44]

Promil 360 by FRESTEMS:

ProMIL 360 is a shock attenuating treatment base that offers premium level patient ergonomics even in the roughest terrain conditions, improving patient survivability. Suspension and vertical stabilization attenuate a wide range of vibration energy in health-critical frequencies. ProMIL 360 also enables also broad position adjustment range and highly ergonomic operation with electrically powered functions [45]. Promil 360 can be seen in Figure 19.

Figure 19 Promil 360 stabilization device [45]

2.8.2 Theoretical papers and prototypes

Parallel Robot for Ambulance Stretcher Active Suspension:

A special purpose parallel robot interposed between the ambulance frame and the stretcher, and a control strategy has been designed to compensate the road unevenness and the accelerations due to the ambulance trajectory. To perform both unevenness and trajectory compensation, five degrees of freedom are necessary: three translations and two rotations, pitch and roll; the yaw rotation must be avoided so that during motion the stretcher still is parallel to the ambulance longitudinal axis. This is obtained by connecting the stretcher frame to a purely translating platform through a universal joint, which allows pitch and roll [46]. The Parallel Robot for Ambulance Stretcher Active Suspension can be seen in Figure 20.

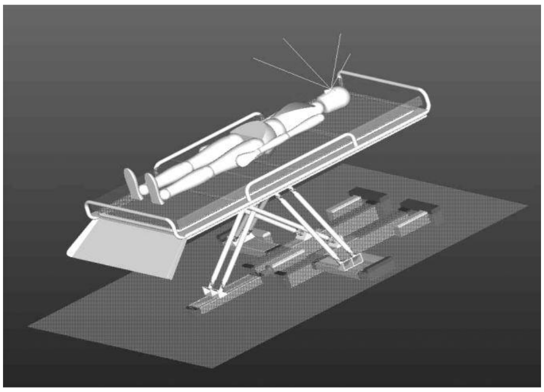

Figure 20 Parallel Robot for Ambulance Stretcher Active Suspension [46]

Actively-controlled Beds for Ambulances:

An actively-controlled bed (ACB), to absorb inertial acceleration in braking and curve driving which causes blood pressure variation or side-to-side body sway. By controlling the posture angle of a stretcher in real time, it can effectively reduce longitudinal and/or lateral acceleration on a patient in the frequency range from 0 to 1 Hz without slowing down an ambulance.

In 2004, [47] developed a 2-degree-of-freedom (2DOF) ACB, which controls pitch and roll angles of a stretcher, in cooperation with a Japanese ambulance manufacturer It was the first prototype of a full-size 2DOF ACB. The actively-controlled bed can be seen in Figure 21.

Figure 21 2-degree-of-freedom (2DOF) prototype of actively controlled bed [47]

Vibration isolation bed stage with Magnetorheological dampers for ambulance vehicles:

[48] propose a vibration isolation bed stage associated with magnetorheological (MR) dampers. The main purpose of this study is to design a vibration attenuation device which can control the vibration in both the stretcher holding the patient as well as that of the seat being used by the paramedic providing first aid to the patient. The Vibration isolation bed stage with Magnetorheological dampers can be seen in Figure 22.

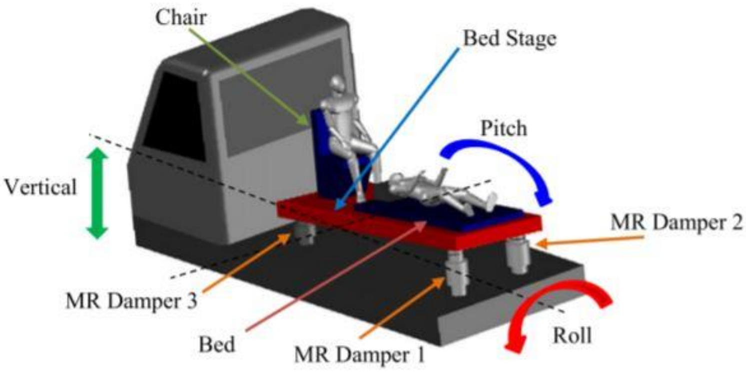

Figure 22 Vibration isolation bed stage with magnetorheological dampers [48]

Control System of One-Axis Vibration-Insulation Platform with Gyroscopic-Stabilizer:

A prototype of the stabilized plate consists of two rotating frames, Figure 23. The auxiliary base frame is placed on the floor. Upper frames are propelled by pneumatic springs. Pressures in both springs are controlled by electrical proportional valves. Two gyroscopes with a vertical rotation axis are mounted to the upper inner frame [49]. The One-Axis Vibration-Insulation Platform with Gyroscopic-Stabilizer can be seen in Figure 23.

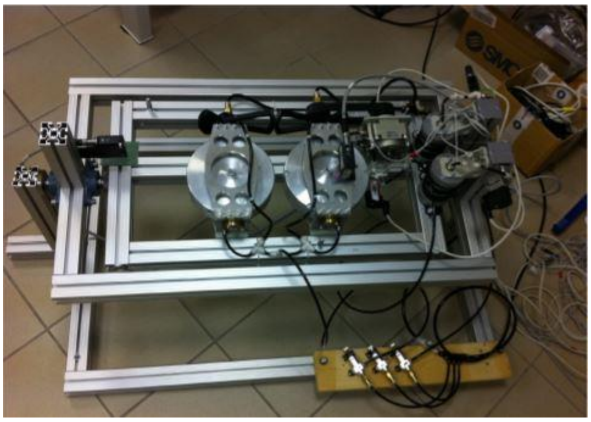

Figure 23 Control System of One-Axis Vibration-Insulation Platform with Gyroscopic-Stabilizer [49]

2.8.3 Patents

Construction of stabilized platform:

The platform is mounted for tilting about longitudinal and transverse axes, and a level sensor works, through an actuator control, to effect operation of an actuator to continually keep the platform in a horizontally stabilized position. The actuator is further mounted on a vertically extending variable height actuator which, through a motion sensor, keeps the platform at a constant height in space despite movement of the floor of the vehicle on which the platform may be mounted. Thereby a patient riding in an ambulance and lying on the platform is prevented from being subjected to various vibrations resulting from motion of the vehicle [50]. The patent drawing can be seen in Figure 24.

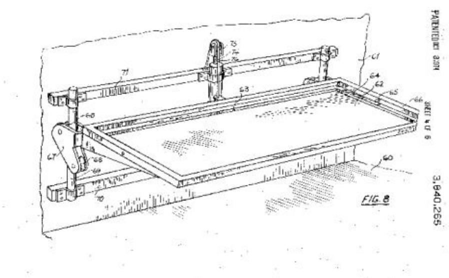

Figure 24 Construction of stabilized platform patent [50]

Shock absorbing transport frame:

The frame includes an inner frame and an outer frame capable of supporting a transportation device. The outer frame is secured to the inner frame in a manner that will control movement between the inner and outer frames. A four-bar linkage working between the inner and outer frame supplies the movement control. The frame includes a pneumatic self-adjusting mechanism to keep a constant gap between the inner and outer frame. The mechanism includes an air valve that adjusts air pressure to an airbag connected to the four-bar linkage, wherein changes in the distance between the inner and outer frame create changes in the pressure to the airbag thereby exerting a counteracting force to return the inner and outer frame to a neutral position [51]. The patent drawing can be seen in Figure 25.

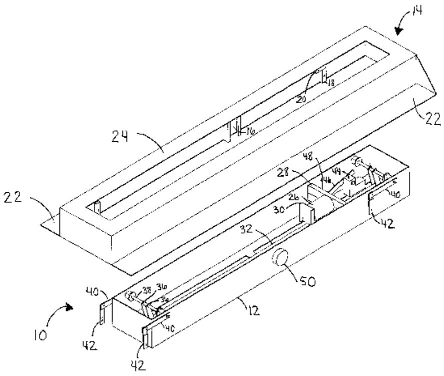

Figure 25 Shock-absorbing transport frame patent [51]

Vibration damping supports:

[48] patent relates to vibration damping supports and to a suspension unit for a stretcher. The stretcher support unit includes a rectangular base frame on which is supported, by a resilient support mechanism, a stretcher frame or carrier. The support mechanism includes a pair of cantilever arms inclined upwards in opposite directions and each pivotally mounted at its lower end on the base frame. The movements of the cantilever arms are controlled by respective gas-liquid suspension units, which are mounted between the base frame and an extension arm of each cantilever arm. The suspension units include, in one embodiment, a gas reservoir, a sealed liquid reservoir, a flexible diaphragm forming one end of the liquid reservoir and an actuator piston. This construction serves to damp the movements of the cantilever arms and hence the stretcher mounted on the carrier and enable the height of the carrier to be varied between a loading position and a position in which the stretcher rides. The patent drawing can be seen in Figure 26.

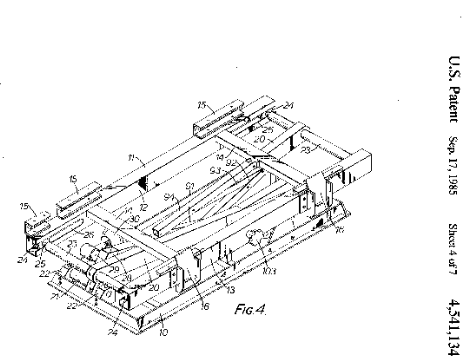

Figure 26 Vibration damping supports Patent [52]

Actuator arrangement for active vibration isolation using a payload as an inertial reference mass:

System for and method of active vibration isolation to isolate a payload from earth movements. The system has a body a mass supported by the body by at least one spring, a further mass supported by the mass by means of at least one further spring. A sensor senses a distance between the mass and the further mass and generates a distance signal. A controller receives the distance signal and generates a control signal based on the distance signal. An actuator actuates a position of said mass based on the control signal, whereas the further mass supports the payload to be isolated from the earth [53]. The patent drawing can be seen in Figure 27.

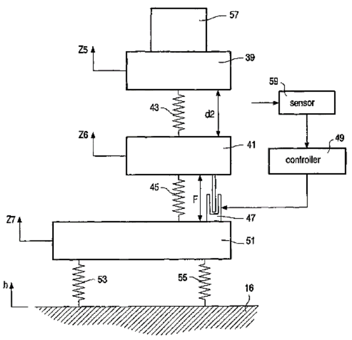

Figure 27 Actuator arrangement for active vibration isolation using a payload as an inertial reference mass Patent [53]

Vibration isolator having magnetic springs:

A vibration isolator is mounted on a floor of an ambulance and includes a lower frame movably mounted on the floor and an upper frame vertically movably mounted on the lower frame via a link mechanism. The vibration isolator also includes a plurality of magnetic springs interposed between the upper and lower frames and each having a plurality of permanent magnets with like magnetic poles opposed to each other. A vertical vibration of the upper frame is restrained by the plurality of magnetic springs, and the front side of the vibration isolator is lifted upon receipt of a forward acceleration [54]. The patent drawing can be seen in Figure 28.

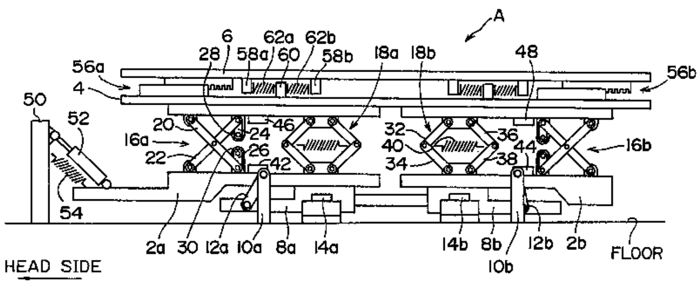

Figure 28 Vibration isolator having magnetic springs Patent [54]

Patient transport method and apparatus:

A transport method and apparatus are provided capable of reducing the accelerations encountered by an item or patient due to an external energy input to the transport device, by utilizing an active control system adapted to input a second energy to offset the effect of the external energy input [55]. The patent drawing can be seen in Figure 29.

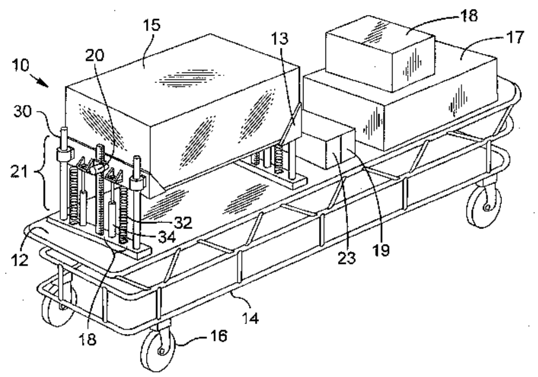

Figure 29 Patient transport method and apparatus Patent [55]

Vibration isolation arrangement:

A vibration isolation arrangement, for example for supporting a stretcher in an ambulance, includes a lever which extends between a base structure and a support frame. The lever can pivot about a fulcrum and is acted upon by a spring. The fulcrum is displaceable by an actuator along with a guide. Such displacement not only varies the stress of the spring but also alters the moment arm (h) between the spring and the fulcrum. When raising the support frame to a predetermined level, the mechanism automatically adapts to the load on the support frame to provide a constant natural frequency for the system, regardless of the weight of the patent being carried [56]. The patent drawing can be seen in Figure 30.

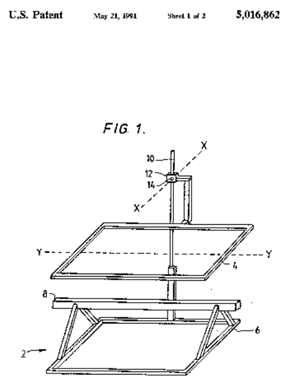

Figure 30 Vibration isolation arrangement Patent [56]

Upper frame position holding structure and ambulance vibration-proof rack having upper frame position holding structure:

An upper frame swingable between an inclined posture and a horizontal posture along a trajectory of movement of a four-bar linkage is held in the horizontal posture by a simple operation when necessary. A front link mechanism control gives an external force for pushing down an operation member to thereby control a front link mechanism to displace the upper frame rearward while lowering a front side of the upper frame. Since a displacement direction for bringing the upper frame into the substantially horizontal posture and an operation direction for locking the front link mechanism or a rear link mechanism by the operation of the operation member are substantially the same direction, it is possible to perform two movements, the displacement movements to the substantially horizontal posture and the locking movements, only by operating the operation member in a predetermined direction [57]. The patent drawing can be seen in Figure 31.

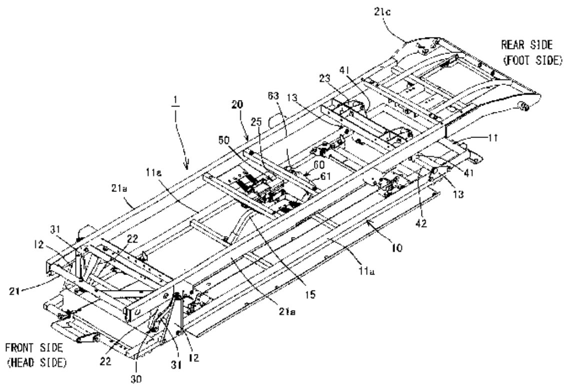

Figure 31 Upper frame position holding structure and ambulance vibration-proof rack Patent [57]

2.9 Canvas model

The Canvas model is a business model developed by Alexander Osterwalder. This business model is developed to provide the readers with ease of access. The business model fits on one page and gives the reader key insights into the business plan. The Canvas model consists of 9 blocks. Each of the 9 blocks describes the business model. The 9 segments are:

Customer Segment:

The Customer Segments Building Block defines the distinct groups of people or organizations an enterprise aims to reach and serve Customers make up the heart of any business model. Without (profitable) customers, no company can survive for long.

To better satisfy customers, a company may group them into distinct segments with common needs, common behaviors, or other attributes.

There are several types of Customer Segments. Some examples are:

1. Mass market.
2. Niche market.
3. Segmented.
4. Diversified.
5. Multi-sided platforms (or multi-sided markets).

Value Proposition:

The Value Propositions Building Block describes the bundle of products and services that create value for a specific Customer Segment. The Value Proposition is the reason customers turn to one company over another. It solves a customer problem or satisfies a customer need. Some of the types of value propositions are:

1. Newness.
2. Performance.
3. Customization.
4. Cost reduction.
5. Risk Reduction.
6. Accessibility.
7. Convenience/usability.

Channels:

The Channels Building Block describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition. Communication, distribution, and sales Channels include a company's interface with customers.

Channels serve several functions, including:

1. Raising awareness among customers about a company’s products and services.
2. Helping customers evaluate a company’s Value Proposition.
3. Allowing customers to purchase specific products and services.
4. Delivering a Value Proposition to customers.
5. Providing post-purchase customer support.

Customer relationships:

The Customer Relationship Building Blocks describes the types of relationships a company sets up with specific customer segments. A company should clarify the type of relationship it wants to show with each Customer Segment. Customer relationships are driven by the following motivations:

1. Customer Acquisition.

2. Customer retention.
3. Boosting sales (upselling).

We can distinguish between several categories of Customer Relationships, which may co-exist in a company’s relationship with a Customer Segment:

1. Personal assistance.
2. Dedicated personal assistance.
3. Self-service.
4. Automated services.
5. Communities.
6. Co-creation.

Revenue Streams:

The Revenue Streams Building Block stands for the cash a company generates from each Customer Segment. There are several ways to generate Revenue Streams:

1. Asset sale.
2. Usage fee.
3. Subscription fees.
4. Lending/Renting/Leasing.
5. Licensing.
6. Brokerage Fees.
7. Advertising.

Key Resources:

The Key Resources Building Block describes the most important assets needed to make a business model work Every business model needs Key Resources. These resources allow an enterprise to create and offer a Value Proposition, reach markets, keep relationships with Customer Segments, and earn revenues.

Key Resources can be categorized as follows:

1. Physical.
2. Intellectual.
3. Human.
4. Financial.

Key activities:

Key Activities are the activities that need to be performed to achieve the value proposition. Some of the key activities are:

1. Production.
2. Problem-solving.
3. Platform/network.

Key Partnerships:

The Key Partnerships Building Block describes the network of suppliers and partners that make the business model work. Companies create alliances to perfect their business models, reduce risk, or get resources.

We can distinguish between four types of partnerships:

1. Strategic alliances between non-competitors.
2. Coopetition: strategic partnerships between competitors.
3. Joint ventures to develop new businesses.
4. Buyer-supplier relationships to assure reliable supply.

Cost Structure:

The Cost Structure describes all costs incurred to run a business model. This building block describes the most important costs incurred while running under a business model.

Types of the cost structure:

1. Cost-driven.
2. Value-driven.

Cost Structures can have the following characteristics:

1. Fixed costs.
2. Variable costs.
3. Economies of scale.
4. Economies of scope [58].

2.10 Research Summary

The literature review presents information about the effects of vibrations on the human body. The literature also presents information about the road induced vibrations and the suspension systems used in ambulances. Even though there is research work available, it only gives some input about the issues. More intensive research is needed to truly understand the effects of these vibrations.

The research shows that very few solutions are available on the market which improve the transport conditions of the patients. Most of the products available fit into the ambulance. This causes ergonomic issues in an already cramped ambulance.

Most of the other solutions available are research papers or patents. Very few solutions consider adopting a device that would fit into a stretcher. Some solutions suggested using suspensions for the stretchers [46]. Other solutions suggested using Magnetorheological dampers [48] or to use gyroscopic stabilizers [49].

The research shows that even though theoretical solutions are available, there is still a need for a product that compensates the effects of vibrations in real time. Even though achieving the solution can be tricky, research has shown that there is a possibility to make such a product.

PRODUCT CONCEPT

3 PRODUCT CONCEPT

3.1 Project Host Institution-Porto Design Factory

Porto Design Factory is a laboratory of ideas based on interdisciplinary work, applied research and industrial collaboration. Porto Design Factory (PDF) is part of the Design Factory Global Network (DFGN), composed of 20 institutions from four continents. This network enables the exchange of students and teachers between the different nuclei, in addition to the exchange and sharing of knowledge and collaboration in projects [59]. The PORTO DESIGN FACTORY project consists of an integrated set of activities whose main objective is to establish efficient and effective mechanisms for communication and transfer of R & D results from Universities and Research Centers to the business fabric, assuming that this interaction is absolutely fundamental in the process of business innovation and in the correct implementation of Cohesion policy [60].

3.2 Product Development Project

The product development project is a program at the Porto design factory in collaboration with Aalto University and the Aalto design factory in Helsinki, Finland. This program is aimed mainly at undergraduate and/or master's degree students in engineering, industrial design and communication and for the companies that are interested in the development of products or consumer goods [61]. Since 1997: More than 150 different sponsors, 300 projects and 2890 students have been part of PdP. A new set of around 16 projects are started every academic year. The results of these projects are presented to the public at the annual Product Design Gala in mid-May. The duration of the course is 9 months starting from October to May in the following year [62].

3.3 Sponsor Information- Murata Manufacturing

Murata Manufacturing is a Japanese company that is a world leader in the design, manufacture, and supply of advanced electronic materials. Akira Murata founded Murata. He started Murata Manufacturing as a personal venture in Kyoto-shi, Japan in 1944. He started the company in a small factory of 150 m^2 where he started the production of titanium-oxide ceramic capacitors with heterodyne radios being the primary application for these products. Murata was incorporated on the 23rd of December 1950. Since then Murata has done business worth 1,371,842 million yen as of March 31, 2018. (consolidated basis amount) and has a common stock worth 69,444 million yen.

Murata's philosophy was created by the founder of Murata- Akira Murata in 1954. Their philosophy is to contribute to the advancement of society by enhancing technologies and skills by applying the scientific approach and creating innovative products and solutions. Murata innovations can be found in a wide range of applications from automobiles to mobile phones to medical devices to smart home solutions.

Murata is headquartered in Kyoto, Japan and has a global network of customers, suppliers and sales support. Murata has its presence in Japan (Kyoto, Tokyo, Kanagawa, Fukui and Shiga among others), greater China and East Asia (Seoul, Shanghai, Tianjin, Beijing, Taiwan and Sichuan among others) southeast Asia and South Asia (Singapore, India, Malaysia Vietnam, Philippines and Thailand among others), Americas (USA, Mexico, Brazil and Canada) and Europe (Netherlands, United Kingdom, Spain, France, Germany, Hungary, Finland and Italy).

They deal in products such as Multilayer Ceramic Capacitors, SAW filters, Ceramic Resonators, Piezoelectric sensors, ceramic filters, Piezoelectric buzzers, short-range wireless communication modules, multilayer ceramic devices, connectors, isolators, power supplies, circuit modules, EMI suppression filters, Inductor coils, sensors, and Lithium-Ion Batteries [63]. Murata's logo can be seen in Figure 32.

Figure 32 Murata Logo [63]

3.4 Sponsor Requirements

The brief given was: "To create an innovative future application using Murata motion sensing technology!". The only requirement that the sponsor had was that the application must highlight the capabilities of the sensors in a way that it fits Murata Finland's strategy and product portfolio and that the application must have a social impact as it aligns with the company values.

3.5 Product Requirements

3.5.1 Sensor Information

Along with the brief, the team was provided with Murata's accelerometers, gyro meters and a combination sensor of accelerometer and gyro meter. The team was also provided with technical information (data sheets) about the sensors which defined the best features and qualities of the sensors. The data sheet helped the team understand the sensors better and gave insights to the kind of applications that could be targeted. Figure 33Figure 33 is the image of an SC-2100 sensor [64].

Figure 33 SC 2100 sensor [64]

In order to characterize the main features of the sensor, the features are:

1. Single axis X or Z-axis gyroscope with ±125°/s or ±300°/s measurement range.
2. 3-axis accelerometer with ±2g or ±6g measurement range.
3. Extensive self-diagnostics features.
4. SPI digital interface.
5. User selectable low pass filter via SPI.
6. −40°C…+125°C operating range.
7. 3.0V…3.6V supply voltage.
8. Size 12.1 x 15.0 x 4.35 mm (w x l x h).
9. Product platform qualified according to AEC-Q100 standard and compliant to the ISO26262 standard.

Benefits:

Some of the benefits that this sensor provides are:

1. Complete product platform for acceleration and angular rate detection in all three sensing axis directions. With the newly introduced Z-axis gyroscope enables implementation of a 6DOF sensor solution on one application PCB.
2. Excellent bias stability, low noise level, and good vibration robustness.
3. Field proven reliability and high performance in very demanding applications.

Applications:

SCC2000 series is targeted at applications demanding high stability with tough environmental requirements. Typical applications include:

1. Inertial Measurement Units (IMUs) for highly demanding environments.
2. Platform stabilization and control.
3. Machine control systems.

4. Electronic Stability Control
5. Hill Start Assist.
6. Rollover detection.
7. Navigation systems.

3.5.2 Problem definition

Patients suffering from injuries such as major bone fractures, internal bleeding, spinal or head injuries, need to be stabilized to prevent further pain and trauma. Research shows that it can be exceedingly difficult to stabilize the patients before and especially during patient transport. Due to lack of proper stabilization, some of the following issues can occur:

1. Delay in the transport of the patient
2. Risk of causing more injuries
3. Increase in trauma
4. The decrease in patient comfort
5. The decrease in the ability to provide better care for the patients.

In the case of patients with minor injuries, patients can suffer from more pain and discomfort due to the shakes and jolts that patients experience while being transported to the hospital.

3.5.3 Possible applications

Initially, three practical solutions were considered. The three possibilities were:

1. To develop a solution where the entire floor was stabilized in an emergency vehicle.
2. To develop a solution where the patient's bed also known as the stretcher was stabilized.
3. To develop a solution that would stabilize the stretcher and the floor of the emergency vehicle.

Some of the issues that we could address with our solutions were:

1. Better stabilization of patients.
2. Better ride conditions.
3. The possibility of faster transport.
4. Possibility to perform more operations on the patient during emergency transport.
5. Reduction in trauma.

With these solutions in mind, the project moved into the research phase to validate the feasibility of the solutions.

3.5.4 Research on Possible Solutions

The product focus was on human-centered innovation hence, the approach to conducting the research was more qualitative based. The on-field research approach was to conduct unstructured qualitative interviews to capture genuine perceptions and feelings towards current patient transport solutions, the problems faced and the validity of our solution concept.

Planned interview subjects:

1. Existing and potential stakeholders.
2. Equipment manufacturers.
3. Hospital and ambulance company administrative workers.
4. Ambulance maintenance workers.
5. Paramedics (Main users) and
6. Patients (User experience).

The research was done in 4 countries:

1. Finland
2. India
3. Poland and
4. Portugal.

Research in Finland:

Interviewees: Ambulance crew.

Interview Location: Helsinki.

Research focus: Kind of stretchers used in Finland and how they function.

Key findings:

1. Most common model in Finland was the basic Stryker with no batteries.
2. The "basic model" costs around 8000€.
3. The Battery powered versions cost around 32,000€ (source: HUS transportation officer).
4. The Stretcher "Dock" (base where stretcher attaches to ambulance floor) is attached to the chassis.
5. Stretchers and docks are crash tested and currently must withstand 10G. Nothing is supposed to fly around in the ambulance in case of a crash. (10G limit may increase in the future).
6. Ambulances are equipped with inverters (sizes: 800W, 1000W bigger ones are used in special vehicles).

7. Stretcher and the bed must be easy to clean. At least the bed may have to be washed multiple times a day. The interiors of an Ambulance in Helsinki can be seen in Figure 34. Figure 35 shows the common stretcher used in Finland.

Figure 34 Ambulance in Finland (Self Elaborated)

Usability:

1. The bed must be detachable.
2. Lifting positions are not always optimal and cause back pain for operators.
3. Ability to have different positions for bed is important (comfort and some of the patients must sit up).
4. Washability.
5. Rough terrain can cause extra pain to the patient.

Dimensional limits:

1. Length: about 2,5 m.
2. Width: 0,85 m (basic ambulance, from cabinet to chairs), 1 m (special vehicle).
3. Height: about 0,55 m (dock + base + stretcher + extra that is manageable regarding treatment).

Figure 35 Stretcher in Finland (Self Elaborated)

Ergonomic issues:

1. The most common health-related issues with paramedics were wrist, elbow, shoulder and back pain. These are caused by lifting patients to the stretcher in all kinds of scenarios where best lifting posture is not always possible.
2. Another lifting movement that paramedics had to constantly do was to load the stretcher into the ambulance. The current Stryker stretcher provided good lifting handles for average height paramedics, but taller and shorter users could suffer.
3. The Stryker model leg releasing buttons are positioned so that paramedic had to lift the stretcher with palms facing down while pressing the buttons. Using your thumb while trying to lift heavy objects reduced the arms strength. Palms facing down grip was also not the strongest grip for lifting. This caused stress to wrists.
4. Shorter paramedics also suffered from shoulder pain as they had to lift more with their shoulders to get the bed to the desired level.
5. Another problem was the height of the blood bag holder. The holder was not high enough to make the blood (or other liquids) flow well enough.

Effects of vibrations on patients:

1. In Helsinki city center there is a certain kind of pavement made of rocks. Driving on those rocks causes a lot of high-frequency vibration that can be dangerous. In cases where patients have bleeding (internal or external), the vibration makes the bleeding faster. So high-frequency vibration causes extra pain and can be life-threatening in case of bleeding.
2. Bigger bumps on the road also cause pain but can make the bone or spine injuries worse.
3. Overall road vibrations and bumps make paramedics job harder and cause pain in patients.

Research in India:

Interviewees:

1. A government hospital doctor who was also the head of an ambulance service in the city.
2. A Paramedic in a Private Hospital Ambulance service and
3. An Owner of a private medical ambulance service.

Interview Location: Puducherry, India.

Key findings:

In India, there are 3 grades of ambulances:

1. The government ambulances.
2. The corporate ambulances and
3. The private ambulances.

1. The government ambulances:

1. The doctor felt our idea of creating a stabilized floor was good and it could help the patients quite a bit.
2. The ambulances are barely equipped.
3. These ambulances are used only during emergencies and are mostly used to travel short distances around the city and from a local hospital to local hospital.
4. At a time, there is a paramedic, a driver and up to 2 attendants along with the patient.

Figure 36 is an image of the government ambulance in India.

Figure 36 Government Ambulance in India (Self Elaborated)

2. Corporate ambulances:

1. The Paramedic felt that such a floor system would be useful due to the road conditions and the weight of the vehicle leading to more vibrations.
2. The corporate ambulances are fully equipped ambulances.
3. These ambulances cost 5 times than the government ambulances.
4. The total weight of the ambulance with all the equipment is about 3 tons. This is for the non-ac ambulances.
5. Depending on the patient requirement, sometimes a doctor accompanies the paramedic.
6. These ambulances are used for long-distance transport of patients usually a distance of over 100 kilometers at least.
7. An inverter is used along with the batteries.
8. An air suspension system is used.
9. The bed can be converted into a wheelchair, fully-flat and semi-flat system.
10. The vehicle is fully equipped for basic treatments and also has life support systems, monitors, ECG's and is equipped with 3 oxygen tanks (2 full-size tanks and 1 portable tank).

11. The max patient weight the bed can handle is 200 kilos.
12. The driver has no issues with traveling the distance at what speed they need.

Figure 37 is an image of a corporate ambulance in India.

Figure 37 Corporate Ambulance in India [65]

3. Private ambulances:

1. Private ambulances are like the corporate ambulances.
2. These are used on-call basis and are used for intercity and for long distance, transport depending on the call.
3. The suspension system used is the leaf spring system.
4. These ambulances are fully equipped.
5. The patient is accompanied by a paramedic and 2 attendants at most.

Figure 38 is an image of a private ambulance in India.

Figure 38 Private Ambulance in India (Self Elaborated)

Research in Poland:

Interview 1 Interviewee: 2 ambulance related personnel. One of them worked in an ambulance while the other one did not.

Interview 2 Interviewee: Paramedics at Warsaw Emergency Centre.

Interview Location: Warsaw.

Key Findings from the 1st interview:

1. They had different opinions. First one, who did not work in an ambulance said that stabilized floor is a better idea because it would be great facilitation for paramedics, e.g. to make an injection.
2. The second one who worked in the ambulance was more into a stabilized stretcher. Due to the experience of this paramedic, the focus is on the research findings for a stabilized stretcher.

Effects of vibration:

1. The paramedic thought that stabilized stretcher is much better because it would reduce the risk of secondary injuries and complications, especially related to spinal injuries.
2. The paramedics are used to shakes during the ambulance ride and it is not a big problem for them to administer an injection or anything else to help the patient.
3. The focus must be to immobilize the patient.
4. There are only a few different ways to get to every hospital and drivers must choose the best one depending on patient status, so sometimes they chose the longest way by road without holes to avoid shakes, but it takes more time.
5. Floating stretcher which stabilizes patient already exists, but there are few ambulances equipped with it (at least in Poland), the system is old and does not work well, so the 'journey' is uncomfortable for patients.
6. In ambulances, there is a space for regulating the vertical position of the stretcher. In big ambulances there is also a place to regulate the horizontal position – it means that it is possible to put the stretcher on left or right side in an ambulance, depending on from which side they want to help the patient. He mentioned that we must think if we want to stabilize patient by stretcher or platform on which stretcher is placed in ambulances.

Key Findings from the 2nd interview:

1. Stretchers consisted of three parts. First was the part that was fixed to the floor. The second was the portable part of the stretcher which was used to transport the patient to and from the ambulance. This part has its own wheels. The third part was like a sedan chain and was used in narrow terrains.
2. The part which is fixed to the floor is partially stabilized for the comfort of the paramedics to give easier access to the patient. It is not precise, and the main stabilization system is the ambulance suspension.
3. The stretcher platform can move sideways. This is especially important when there is a need for more people near the patient.

4. Two upper parts namely the sedan chain and the truck are lighter than expected. They weigh around 10 kilograms but even an additional of 5 kilograms will not be well received by the paramedics. This is because every kilogram matter and it affects the ergonomics of the stretcher. sometimes the paramedics must carry the stretcher during the whole course of the day.
5. The cost of such a stretcher (two upper parts without the platform) is about 1000-3000€.
6. The stretchers can fold in many places:
    a. Near the head
    b. Under the legs and
    c. Sometimes in complicated positions.
7. The different folding positions can be an issue for fixing our stabilizing mechanism on such stretchers.

Figure 39 is an image of a stretcher used in Poland.

Figure 39 Stretcher in Ambulance in Poland (Self Elaborated)

8. The sirens in ambulances are loud. Hence, additional sounds from such a system would not be an inconvenience.
9. The ambulance that was shown to the researchers had two big batteries and an alternator. The first battery is connected to the ambulance circuit just like in a normal car. The second battery is only for medical purposes. During the breaks, the second battery is connected to the main socket and is always kept for charging. There are some medical devices such as the defibrillator which is connected all the time.
10. There are a lot of procedures done in the ambulance during the ride and its relationship is 1:1 between only the transporting patients to the hospital with monitoring them and conducting procedures during the ride to the hospital.
11. Giving injections is not an issue for the paramedics even if there are some shocks.
12. Transporting patients who have suffered a spine injury is a difficult case because the patients need to be mobilized. Keeping the patients stabilized is especially important and exceedingly difficult. It is a challenge especially for the driver to

choose the best route without bumps and must drive extremely carefully also keeping in mind that time is of the essence.

13. The paramedic's opinion is that stabilizing the stretcher should be the focus of our project to improve transport conditions especially in cases like the spine injuries.

Research in Portugal:

Interviewees: Firefighters, Paramedics.

Interview location: Porto, Vila do Conde.

Key findings:

1. Effects of Vibrations:

1. There are a lot of vibrations involved.
2. The paramedics usually go standing up, so they do not feel as much as the patients feel the vibrations. The patients feel it a lot.
3. Medics do have a lot of issues with the vibrations.
4. The vibrations do cause more pain and discomfort to the patient, especially if it is a traumatic accident (example: broken bones).
5. The sensation of vibration is more intense not only because of the state of the ground but also because the bed is right above the wheel axles.

2. Other findings:

1. The paramedics in Portugal are very restricted to work on the patients but can perform any kinds of treatments including advanced care.
2. Medics can be there in an ambulance during patient transport.
3. Inside the city, it does not take too long to get to the hospital but sometimes, when the patient is outside the city it takes longer to transport the patient and the roads do not help the case of the patients, especially the curvy roads.
4. Most ambulances are fully equipped.
5. Usually, just one paramedic goes with the patient.
6. The overall weight of the ambulance when the patient and paramedic is inside is around 3000 kilos.
7. All the devices in the ambulance are supported by a standby battery.
8. No special suspension system is present in the ambulance.
9. The bed with the patient on it is so heavy that paramedics develop back problems.
10. By norm, normally paramedics do not give anything while in movement. They do it before getting into the ambulance or while the ambulance is stopped.
11. The stretcher with the patient on it makes it heavy and so the paramedics develop back problems.
12. By norm, normally paramedics do not administer anything during transport. They do it before getting into the ambulance or while the ambulance is stopped.
13. View of the paramedic: It would be helpful to have such a system. But the focus should be on the patient.

3. Observations based on personal experience:

There were shakes from the point where the stretcher was on the ground to the point where the stretcher was placed into position inside the ambulance. Figure 40 is an image extract from the personal experience on a stretcher in Porto.

Figure 40 Personal Experience on a Stretcher in Portugal (Self Elaborated)

1. Once the ambulance ride began, the effects of vibration could be felt.
2. The vibrations were minimal at first and slowly increased as the speed of the ambulance increased.
3. After a while, the vibrations started to create a sense of irritation and discomfort even at low speeds.
4. Overall the experience was uncomfortable.

Figure 41 is an image of the stretcher placed inside the ambulance.

Figure 41 Stretcher being moved into the Ambulance (Self Elaborated)

3.5.5 Observations and findings from the research

Based on the research, a solution that would stabilize the whole floor of an ambulance or a medical helicopter was considered. In addition to the benefit for the patient, this would have allowed the paramedic staff and doctors to perform operations during transport. Although the whole floor stabilization initially sounded more useful than a stretcher, some of the following findings objected to it:

1. Technical implementation feasibility: Stabilizing the floor would not help during car turns. It would be necessary to stabilize the whole volume of the medical transport box, which would lead to a large construction.
2. The price of the system: Consequently, the whole volume stabilizing system would get out of the most common B category ambulances and need purchasing of the larger vehicle.
3. Low need for the whole volume stabilization system: The situation when the surgery should be conducted not directly in the accident place and not in the stationary hospital, are infrequent. Much more common are bone fractures that need just patient stabilization. For the most frequent small interventions, such as an injection, we could just temporarily attach the hand of the paramedic to the stabilized stretcher, using e.g. soft vise.
4. Focusing on the patient is more important than focusing on the paramedics since they are ones who need the attention and require a change in ride conditions.
5. There is no fixed standard ambulance or stretcher used around the world. It depends on a lot of factors and hence a change in design is required.
6. There is a need for such a system as it does not exist on the market yet.

3.6 Project vision/goals

Post the research phase and understanding the requirements better, the patient stretcher was validated as the more useful and versatile option for the stabilized treatment platform.

The vision of the product developed from the research conclusions. The vision statement read as follows “Our vision is to develop an actively stabilized stretcher which compensates the vibrations from the road in real time using Murata’s advanced MEMs sensors.”

The vision for future development is shown below in Figure 42.The stabilized stretcher is named ATARUM 2020. The full concept design considers everything from vehicle restrictions to paramedic ergonomics.

Figure 42 Product Vision (Self Elaborated)

3.6.1 Product outlining

Upon scope and product vision validation, the next phase was the product outlining phase. In this phase, different options for the mechanical and electronic design for the prototype were evaluated. Product Outlining Information can be seen in Table 4.

Table 4 Product Outlining Information

Product Possibility	Advantages and Potential Issues
Actively Stabilized Stretcher with Patient treatment platform.	Advantages: The benefits of this solution lay in the understanding that in addition to patient stabilization, the paramedics could also be stabilized by standing on this platform and hence perform minor procedures such as administering injections. It was a midway solution with respect to money and complexity compared to our first idea of stabilizing the entire floor of the emergency vehicle and stabilizing only the stretcher. Potential Issues:

	Such a system would have a problem of offsetting the weight distribution and it could cause imbalance.
Actively stabilized stretcher without the attached platform.	Advantages: Such a system would help in stabilizing the patient outside the emergency vehicle right from the location of the accident. The solution is cost-effective in comparison to stabilizing the entire floor of the ambulance. Potential Issues: Weight management of the system would be a critical point.

Consideration was given to the type of system that could be developed for the stabilization system. Some of the options considered were:

1. Stabilization system based on Pneumatics.
2. Stabilization system based on Hydraulics and
3. Stabilization system based on springs and electronics.

The types of Systems- Advantage and Disadvantages can be seen in Table 5.

Table 5 Types of Systems- Advantage and Disadvantages.

System	Advantages and Disadvantages
Stabilization unit based on Pneumatics	*Advantages:* 1. Quick control ability of the system. 2. The system would be clean. Example: No risk of leakages. *Disadvantages:* 1. The compressors needed for such a solution are very loud and heavy.
Stabilization unit based on Hydraulics:	*Advantages:* 1. Powerful system. 2. Fast vibration compensation.

	Disadvantages: 1. The system would be very heavy. 2. Relatively expensive. 3. Would need high power usage.
Stabilization system based on Springs and Electronics	*Advantages:* 1. Springs were the most economical and best suited to dampen the small vibrations. 2. PID tuning would be easy. 3. Low power usage as high-frequency oscillations doesn't need power.

3.6.2 Product concept

As mentioned in the product vision, the aim was to develop a solution for an actively stabilized stretcher which would compensate for the vibrations in real time. One of the concept parameters was to provide relief to the patients as soon as possible. Hence it was decided to develop a system that would fit into the stretcher.

The main idea was to use springs and electronics to dampen the system based on the reasons stated in the previous section. The logic behind this system was to let the springs filter the vibrations and use the electronic control to prevent the oscillations from resonance.

The weight of the patient would reside on the springs. The springs would be controlled by the linear actuators which would help to keep the bed of the stretcher in position thereby actively compensating for the vibrations. The actuators were controlled by the control electronics also called as the drives.

3.7 Prototyping

The prototyping phase began right after the research and product outlining were completed. The different types of prototypes built during the during of the project have been described below:

3.7.1 First prototype

The first prototype was built using simple modules such as simple motors, springs, batteries and a circuit board. The aim of building this prototype was to understand the capabilities of the sensors and to visualize the response and capabilities of the sensors. The first prototype can be seen in Figure 43.

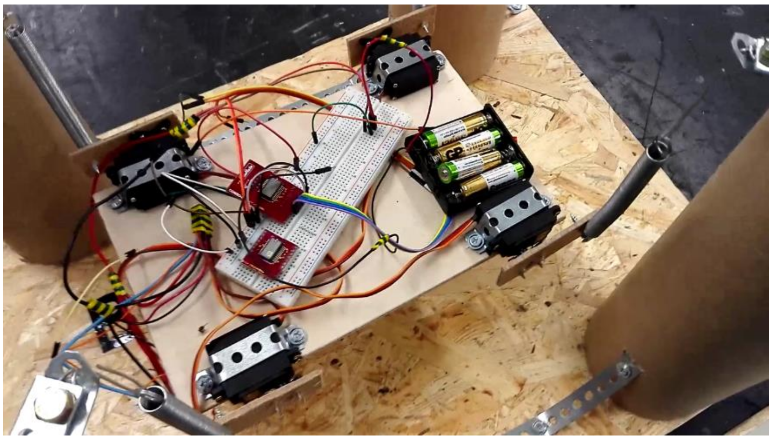

Figure 43 First Prototype (Self Elaborated)

3.7.2 Full-scale concept mock-up

The full-scale concept mock-up served as a tool to solve some mechanical and user experience design issues. This was an important prototype because it solved the purpose of perception creation of what would be a full-scale model of the product. Prior to this, other prototypes had been done as well ranging from Lego models to more elaborate non-functional designs. The full-scale concept mock-up Prototype can be seen in Figure 44.

Figure 44 Full-scale concept mock-up Prototype (Self Elaborated)

3.7.3 Small-scale functional prototype

This prototype served as a testing platform for the data logger that had the Murata sensor incorporated. This prototype was built to see if the sensor was able to bring the bed back into position. The small-scale functional prototype can be seen in Figure 45.

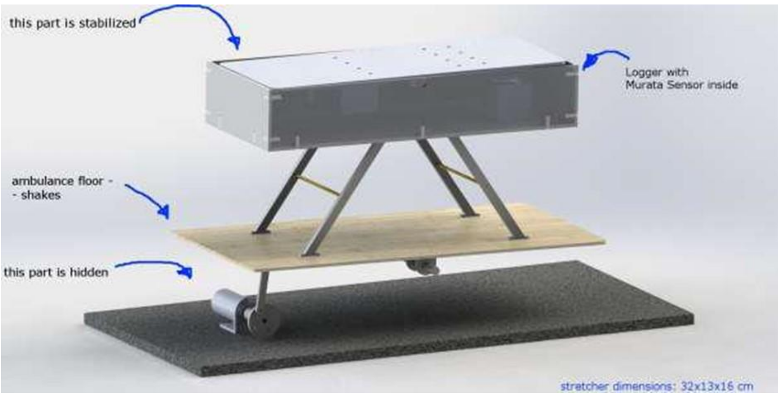

Figure 45 Small-scale functional prototype (Self Elaborated)

3.7.4 Final functional prototype

The final prototype was a stretcher with the built-in stabilization section. The stabilization section is located under the mattress frame and above the legs of the stretcher. as mentioned before, once the patient lies down on the stretcher, the weight of the patient would fall on the springs. The springs would hold the bed in position while the active compensation of the vibration from the road bumps would be performed by the fast and powerful linear motors/actuators.

Overview of the Technology:

Objective:

The aim of the system is to minimize the acceleration experienced by the patient. Once the acceleration is reduced, the vibrational effects on the patient will be reduced as well. Due to a limited movement range, if the bed hits the end position, high forces will be transferred to it which can cause a lot of discomfort to the patient. Hence, keeping the bed in the middle of the movement range is also a secondary aim. This ensures that the bed has room to move in either direction if necessary.

Prototype Constraints:

1. The prototype development only deals with the stabilization of the movement along the vertical axis. Further R&D can adapt the system to stabilize along the other axes as well.
2. Another design constraint was that both ends of the bed needs individual control by the system. This would allow the compensation for tilting along the x-axis direction which is the relative vertical movement of head and feet.

Traditional suspension system vs spring-based system:

A traditional suspension system consisting of a spring and a shock absorber that is normally present in ambulances would not work very well in this kind of a context since the shock absorber would transfer the quick vibrations it absorbs straight upwards to the bed of the stretcher where the patient would lie. Just using a spring system would be much better as all the small amplitude vibrations would be completely absorbed. The reasoning behind this system was that only the amplitude of the vibrations affected the forces transferred to the patient.

Possible issues faced with a Spring-based system:

1. The issue faced would be that the spring would overshoot resulting in unnecessary forces when the bed returns to the middle position resulting in jerks to the stretcher.
2. Resonance would become a problem, making the bed's movement range much greater than the amplitude of the vibrations.

To overcome the issues with a Spring-based system:

1. An active compensation system should be used to prevent the overshoot of the springs.
2. A well-tuned PID controller would help control the forces applied to the bed and would help remove short-term vibrations and keep the bed in the center of the movement range on a long-term basis. To achieve this, the active system needed to apply the same forces to the bed regardless of the movement of the bed.
3. In this case, no rapid movements would be transferred to the bed. Most types of actuators are designed to stay in the position they are set to regardless of external movement or forces which made them unusable for this application.

If the power requirements had not been a concern, the springs would not have been necessary. A powerful motor with an ideal control algorithm would be enough to handle the tasks of vibration compensation. The role of the spring was to keep the bed in the middle position as that would be the point of equilibrium. The reasoning behind keeping the bed in the equilibrium position was that when no vibrations are experienced, the active system did not need to work. Moreover, the spring would also add a force towards the center position when the bed was offset from it. This meant that the forces created by the spring system would always be relatively close to those created by the ideal motor. The role of the actual motor would be to just correct the difference.

The springs had to be set up such that the point of equilibrium was in the middle of the movement range. With patients of different weight, the point of equilibrium moves, however, this movement had to be somehow counteracted. The solution to that was to add a secondary spring compensation motors to each spring, handling this offset. They only needed to be able to set a position and stay in it, so a typical linear actuator would work fine for this task. They also do not need to be extremely fast, as during the ride the weight of the patient can be assumed to remain the same. The compensation can take multiple seconds without a problem.

The movement of the bed is to be actively controlled in the vertical direction, but the movement of the system must be locked along the horizontal axes. This could be achieved in many ways but allowing for the tilting simultaneously restricted the ways considerably. A piston system in the middle of the bed was considered. The piston was retractable, allowing for vertical movement while freezing the other directions. With a turning joint, the rotation could be freed.

Transferring the forces from the compensation system to the bed was an issue faced. The motors, springs and compensatory motors were too big to fit vertically in the limited space below the bed and so they had to fit horizontally. This meant that the force had been transferred through an angle of 90 degrees. The first possibility was to use sliding bars that would lift the bed by turning vertical, lower it down by turning to a greater angle. This had the problem that the movement range must be comparably small, otherwise, the changing angle would affect the force multiplication factor to a higher degree.

A Simulink model of the entire stretcher was created. It simulated the independent movement of the ends of the bed, complete with springs, main motors, compensatory motors, and their controls. Even the way a patient sat onto the bed was simulated to see how the control reacts to the sudden change of load. The simulation was used to gain a better understanding of the system, to develop the spring-motor configuration and to develop the control algorithm.

Mechanical design:

The mechanical design was initiated by focusing on figuring out how the mechanisms would work and what components would be needed to implement the mechanism.

How the components should be fitted into the frame to minimize moment forces was given due consideration. The sketches were very helpful in the concept design phase and allowed the visualization of the early concepts. Detailed design could be started only after the critical components, including the linear motors, the springs, and the motion transferring mechanism were selected. A used stretcher was obtained to have a better understanding of the outer dimensions and limitations. This stretcher was also was in the development of the prototype.

Design parameters of the prototype:

The main design parameters of the prototype are mentioned below:

1. Width: 56cm.
2. Length: 200cm.
3. The height of the bed frame and mattress: 15 cm.
4. The height of legs with wheels: 18 cm.
5. Target total stretcher height: 75 cm.
6. Active stabilization range: ±12 cm.
7. The movement range of the platform: 24 cm (±12 cm from nominal position in the middle) (The maximum that motor & shaft allows is ±26.5 cm).
8. Patient weight range: 50-150 kg.

Design Targets:

The primary design targets set for developing the prototype were:

1. Maximum vertical acceleration of bed < 0.3g (1 min) (ISO Human comfort tolerance limit).
2. System total weight < 60 kg.
3. Prototyping cost < 7000 €.
4. The height of technology layer < 150 mm.

Material Selections:

The material selection had to be done for some of the components. Material selection was done based on requirements, availability, and strength among other factors. The Material Selection Parameter Description can be seen in Table 6.

Table 6 Material Selection Parameter Description

Material Selection parameter	Description
Frame material	Aluminum was selected for the frame and other supporting structures due to its lightweight, strength and non-magnetic nature since the permanent magnet stators create a powerful magnetic field.
Chain guide material	Polyoxymethylene (POM) was used for the chain guides, stator clamps and the flanges for connecting the forcer support structure to the round rails. POM was chosen because it is a strong plastic that could be machined to create precise customized shapes.
Chain Material	The chains and the end support of the springs were 3D printed from polylactic acid (PLA), which enabled the creation of otherwise challenging contours. The springs, rails, and bolts were sourced in steel. The other component didn't need manufacturing or material selection decisions. Most of the components were easily available.

Chain design:

One of the critical design tasks was to solve how the horizontal motion of the linear motors could be transferred to vertical motion. To counteract this, a chain that could bend only to one side was developed.

The chain became maybe the most iterated component in our system. After testing the chain bending, a double chain was developed to ensure rigidity. Some of the iterations are shown below in Figure 46 and Figure 47. The final design iteration can be seen in Figure 48 while the 3D printed chain can be seen in Figure 49:

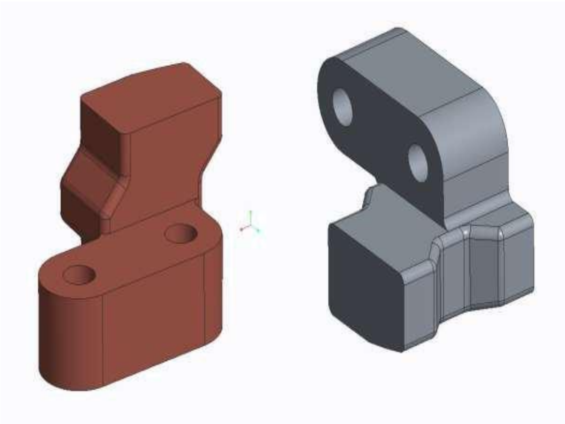

Figure 46 Chain Design Iteration (Self Elaborated)

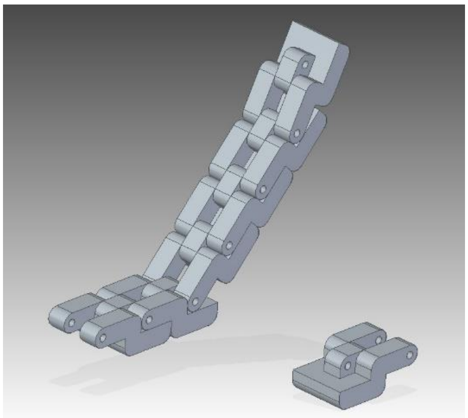

Figure 47 Chain Design Iteration 2 (Self Elaborated)

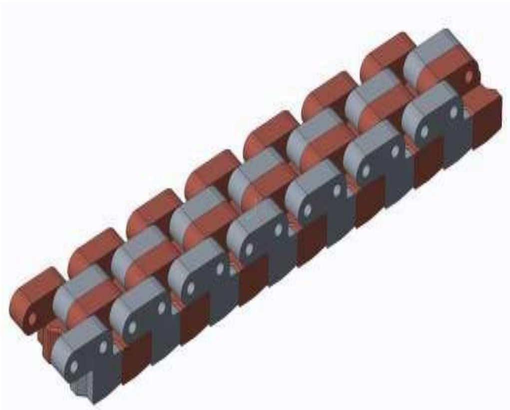

Figure 48 Chain Design final Iteration (Self Elaborated)

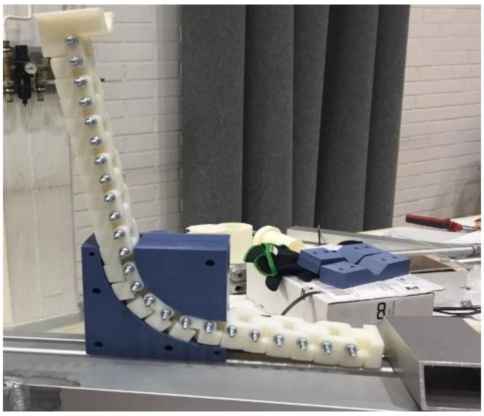

Figure 49 3D Printed Chain Iteration (Self Elaborated)

Selection of the Springs:

The selection of the springs was based on calculating the needed spring coefficient by optimizing the mathematical model in Simulink. After simulations, the desired length for the springs was established. Four standard choice springs close enough to the desired feature values were sourced.

Motor selection:

The type of motor to be used was a critical parameter. Hence it was important to understand what factors were considered for the motor selection. The factors considered for the motor selection are presented in Table 7:

Table 7 Motor Selection Parameter Description

Motor Selection Parameter	Description

Operation conditions	The motor should not break, nor create a rigid connection when the acute road bumps were confronted. Therefore, the screw linear actuators and electric cylinders were not viable options. Preferable options were belt linear actuators and linear motors.
Maximum velocity	The higher the maximum velocity, the more acute bumps the system could compensate. The selected motor could move with the speed of 3 m/s when the loss in torque started to show up.
Reaction time	The delay of operation in the bump's compensation was crucial, especially for the acute bumps, which, in case of their high amplitude, are the most dangerous and traumatizing. Therefore, the inertial mass of the forcer (or rotor) had to be kept minimal. The time that passed between the command input and the filling of the motor windings by ⅔ of the maximum current was 2 ms for the selected model. The inertial mass of the linear motor forcer was relatively high (2.8 kg). It was, however, relatively small when compared to the mass of the patient and the frame with the mattress.
Suspended weight	If the high-amplitude acute bump appears, the motor had to be capable of temporarily "holding" the weight of the patient. Therefore, the peak force of the selected motor was 736N. Two motors can hold 150.2 kg patient for one second until the acute bump ended.
Power consumption	The power consumption of the prototyping motor was 780 W for continuous operation and 3.12 kW for peak operation. This allowed testing the motor from the standard wall-plug.

Energy effectiveness	Energy effectiveness was described by the parameter “Force constant”, measured in Newtons per Ampere. Generally, slower motors provide better energy efficiency. The force constant of the selected motor was 77 N/A, which represented the compromise between its maximum speed and the force it could output to hold the patient.
The weight of motors	The weight of the motors was one more of the limiting factors. Total weight of the two motors, including the stator permanent magnet rods, was 17.1 kg. We should minimize the weight of the stabilizing system to make the stretcher more mobile.
Length of the stator permanent magnet rod	The length of the stator rod was determined by the sum of the following functional segments: 1. Length of the stator: For the selected motor LMTC4, the stator is 28 cm. The rod had to be longer than that to allow movement. 2. Active compensation range: it was at least 24 cm (±12 cm to each direction). 3. Clamps length: Depending on the rod length, its recommended value was either 5 or 10 cm. Clamps had to be applied from both ends. 4. Altogether, the minimum length of the permanent magnet stator rod was 62 cm. To investigate the possibility of tilting of the whole system, while maintaining the ability to provide active compensation, as long as possible rods were placed. For the stretcher with the length of 2m, the standard size that fit was two rods of 91 cm each.

3.7.5 Data Logger

Objective:

The data logger was the device that collected the vibrational information from the roads and this information was used to develop the software for the control of the system. The goal was to mount the data logger to the ambulance (Figure 50) and to get real-time data about the road vibrations and the feedback the system was receiving. The data logger had to be mount to the stretcher to get as realistic data as possible about the acceleration of the patient.

Figure 50 Data logger mounted to the stretcher (Self Elaborated)

Development process:

The data logger was custom designed. The loggers supplied the vibrational information to develop the software. Vibrational data was recorded from self-owned cars on different road conditions, in ambulances, and in the three different countries.

To develop the data logger, the printed circuit board (PCB) was custom designed with custom lines of code. It had the possibility to communicate with many devices at the same time and process a vast amount of data quickly. Batteries enabled the logger to be completely autonomous and independent of the main power.

With the logger, it became possible to collect essential data about vibrations and shock impact on the patient. Reliable data about the patient's experience during the transportation was crucial in the development process. The custom designed datalogger can be seen in Figure 51.

Figure 51 Custom printed circuit board for the data logger (Self Elaborated)

3.7.6 Bill of Materials (BOM)

The Bill of Materials is shown in Figure 52 and Table 8:.

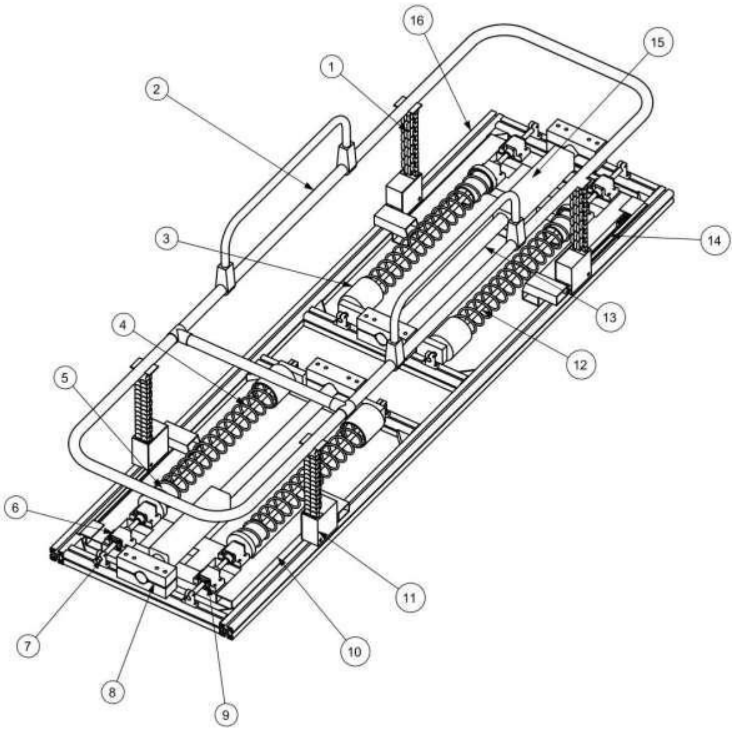

Figure 52 Bill of Materials (Self Elaborated)

Table 8 Bill of Materials

S.No.	Description	Quantity
1.	Double chain	4
2.	Used stretcher bed	1

3	Spring outside the head cap	4
4	Springs	4
5	Spring inside head cap	4
6	Flange unit housing	8
7	Shaft mount	8
8	Stator clamp	8
9	Flanged bearing unit	12
10	Support structure	2
11	Chain guide	4
12	Linear rail shaft	4
13	Stator rod	2
14	Linear rail and rail block	4
15	Forcer	2

3.7.7 Final CAD Model

The image below presents the mechanical design of the prototype. This model was the final CAD model designed and the prototype was built based on this design. The blue parts are manufactured from POM and the white parts and the chains are manufactured from PLA. The Isometric view (Figure 53), Top view (Figure 54), Side view (Figure 55) and Final CAD rendered model (Figure 56) can be seen below:

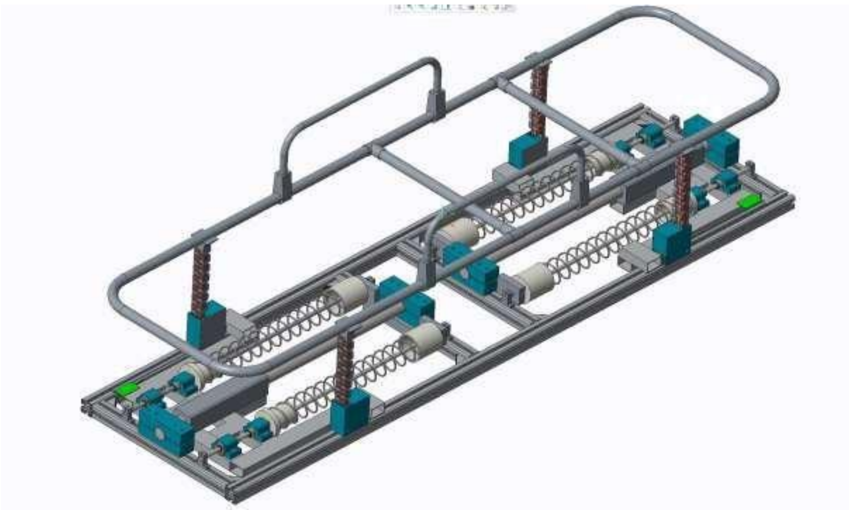

Figure 53 Final CAD model (Self Elaborated)

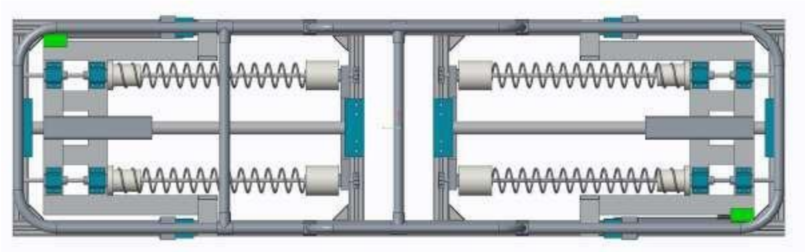

Figure 54 Final CAD model top view (Self Elaborated)

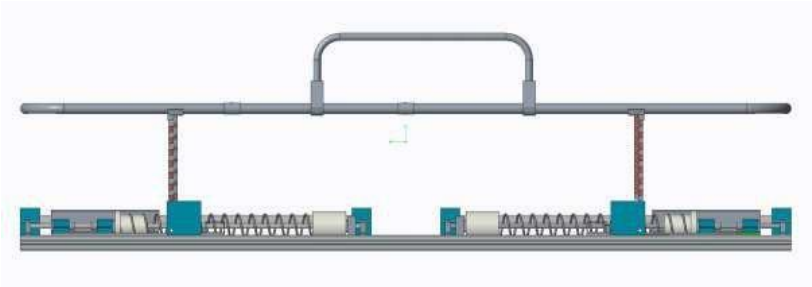

Figure 55 Final CAD model Side view (Self Elaborated)

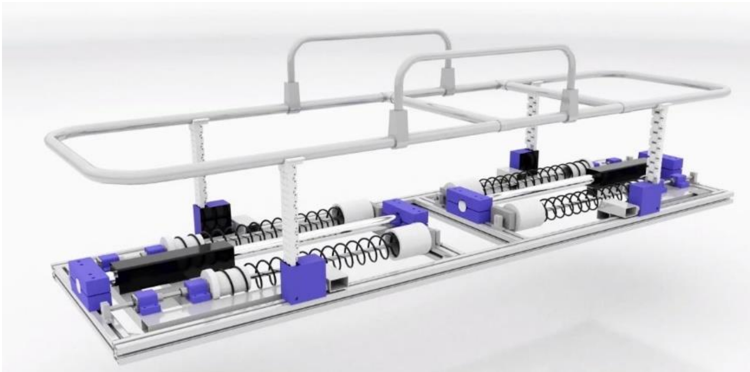

Figure 56 Final CAD model Rendering (Self Elaborated)

3.7.8 Prototype construction

The product prototype was built after all the components were received. Hence shown below is the construction of the prototype from the stretcher to stabilized stretcher. The prototype construction can be seen in the following steps:

1. Used stretcher (Figure 57),
2. Prototype frame and Springs arrangement (Figure 58),
3. Linear Motor Drive (Green) and 3D printed chain arrangement (Figure 59),
4. Stretcher Mattress placement (Figure 60),
5. Stretcher Mattress placement on Chain system (Figure 61),
6. Prototype setup (Figure 62),
7. Prototype full set-up (Figure 63).

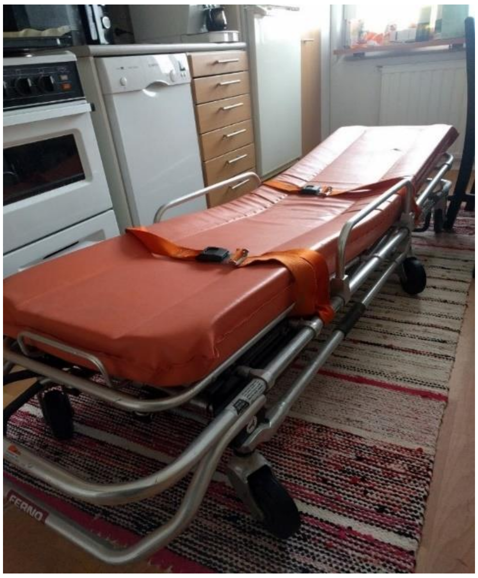

Figure 57 Ferno Stretcher (Self Elaborated)

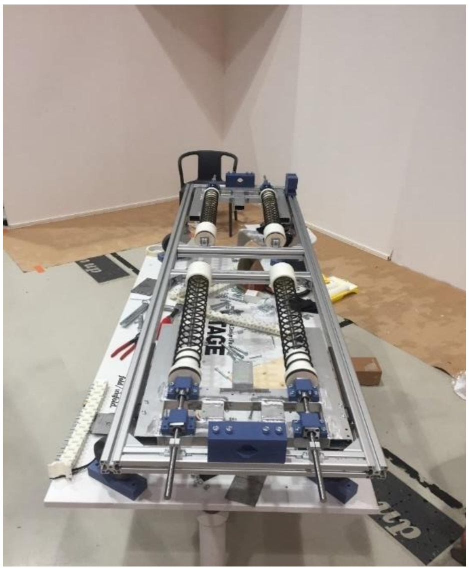

Figure 58 Prototype frame and Springs arrangement (Self Elaborated)

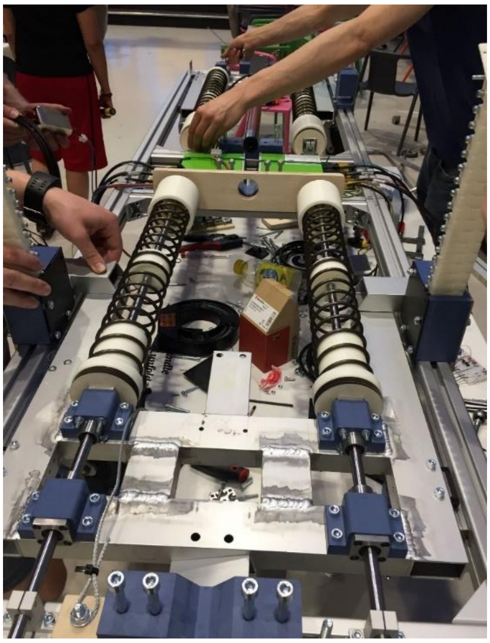

Figure 59 Linear Motor Drive (Green) and 3D printed chain arrangement (Self Elaborated)

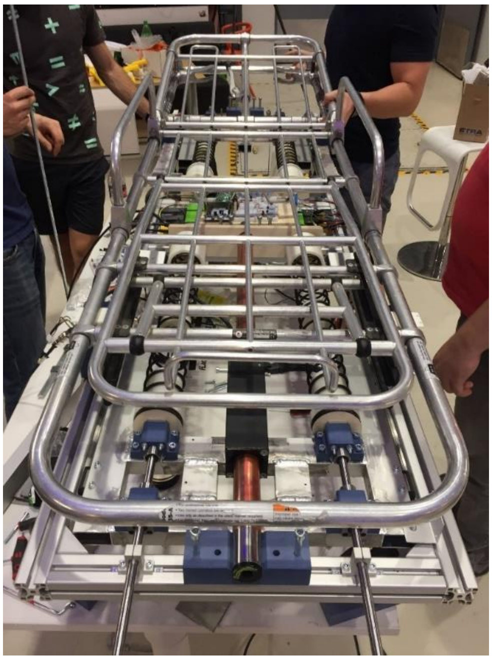

Figure 60 Stretcher Mattress placement (Self Elaborated)

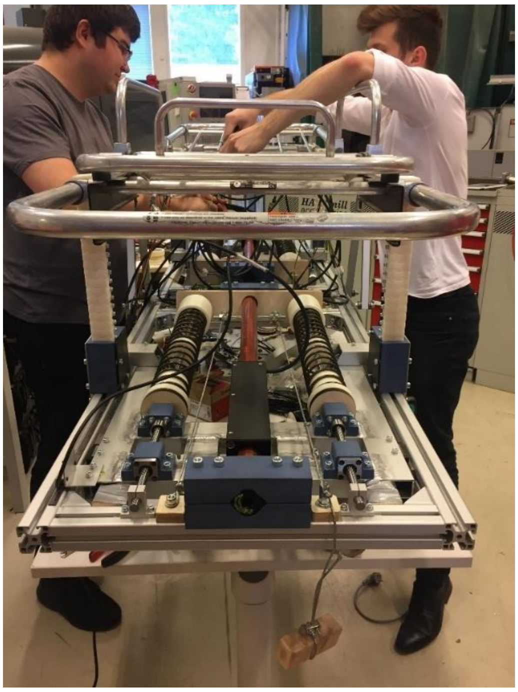

Figure 61 Stretcher Mattress placement on Chain system (Self Elaborated)

Figure 62 Prototype setup (Self Elaborated)

Figure 63 Prototype full set-up (Self Elaborated)

3.7.9 Simulation

For the motor selection, the catalog of HIWIN was used. To determine the exact model, the performance in the region if interest (±12 cm) of various linear motors models was investigated.

Results of the simulation:

Motors accelerated forward for half of the simulation time (35 ms) and then decelerated for the second half. The simulation showed how much distance the motors could cover and then fully stop in a given period. The simulation results can be seen in Figure 64 and Figure 65.

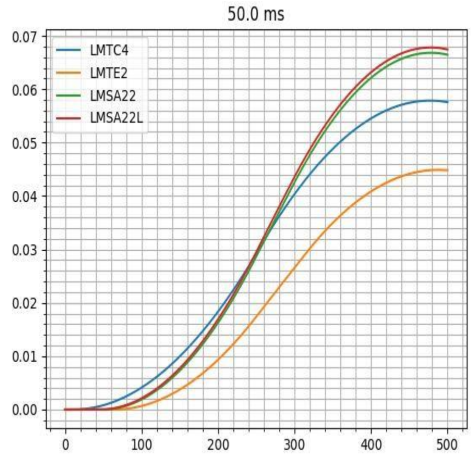

Figure 64 Motor Reaction at 50 ms (Self Elaborated)

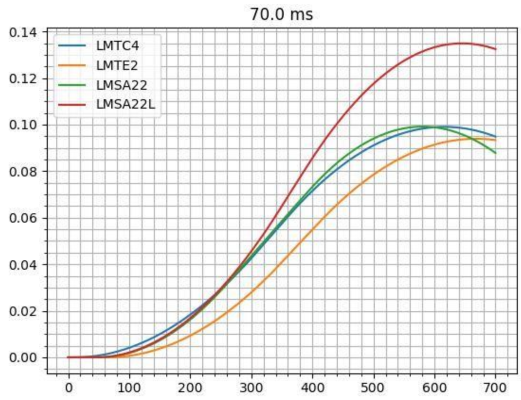

Figure 65 Motor Reaction at 70ms (Self Elaborated)

For 90 ms (40% increase in operation time), motors covered twice the distance. LMSA22L looked like the better choice for the target interval of 12 cm. the simulation result can be seen in Figure 66.

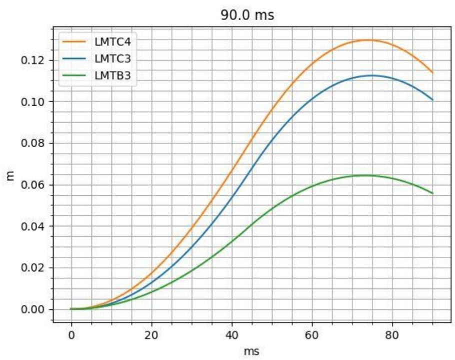

Figure 66 Motor reaction at 90 ms (Self Elaborated)

The simulation also outputted the data for power consumption:

LMTC4: 760500 J

LMTE2: 2252250 J

LMSA22: 2106000 J

LMSA22L: 4752000 J

The power consumption of the LSMA22L was six times higher, compared to the LMTC series model, with results being comparable.

LMTC4: 760500 J

LMTC3: 760500 J

LMTB3: 380250 J

The LMTB3 was twice smaller, twice weaker and twice less power hungry than LMTC4. It would need four of those motors to do the same work as two LMTC4. Considering that each motor needed a drive to operate it, two extra drives would cost ~1000 €. Separate magnetic stator rods would add about the same. With these constraints along with financial constraints, the first prototype was constructed with two LMTC motors and tilting across one axis. In the LMTC series, the LMTC4 showed better results, compared to the colleagues, such as LMTC3, therefore it was chosen.

3.7.10 Stress Analyses

Stress analyses were performed using the integrated Simulate feature in the Creo Parametric 3 software. Given below are two samples of the analyses performed:

Analysis 1:

The round rails were initially intended for housing the end supports of the springs and maintaining the air gap of the linear actuators at precisely 1 mm. However, the stress analysis for the rails revealed that with the operational 25 N load, it would split into two flanges, the maximum displacement being 0.8 mm. Therefore, the second set of rails would be implemented to carry the load and the round rails would only serve as shafts for the spring equipment. Analysis 1 can be seen in Figure 67.

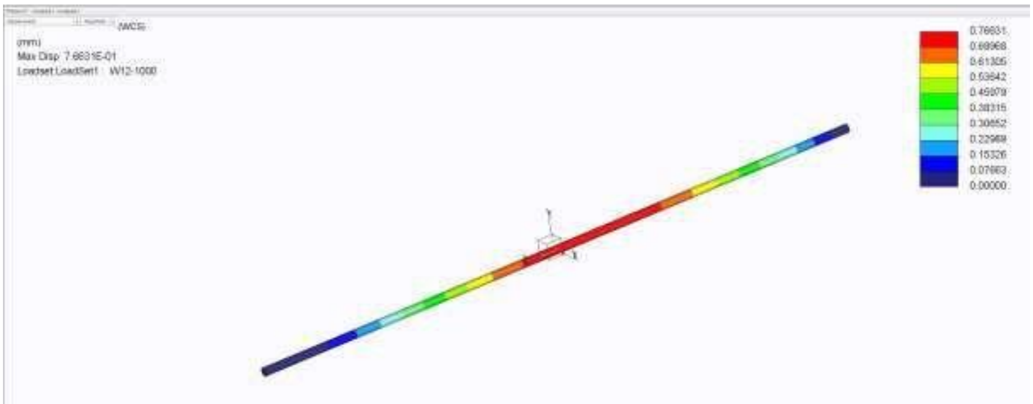

Figure 67 Round rail displacement analysis under design load. (Self-Elaborated)

Analysis 2:

The support structure connected the forcer to both rails and actuated the chains and encoders. The part that was connected to the end of the chain bore a load of 500 N and a sufficient aluminum profile was selected to limit stresses and displacements to acceptable levels. The selected 50x30 cm profile endured a maximum relevant displacement of 0.5 mm, which was further reduced by an additional beam that is missing from the picture. Analysis 2 can be seen in Figure 68.

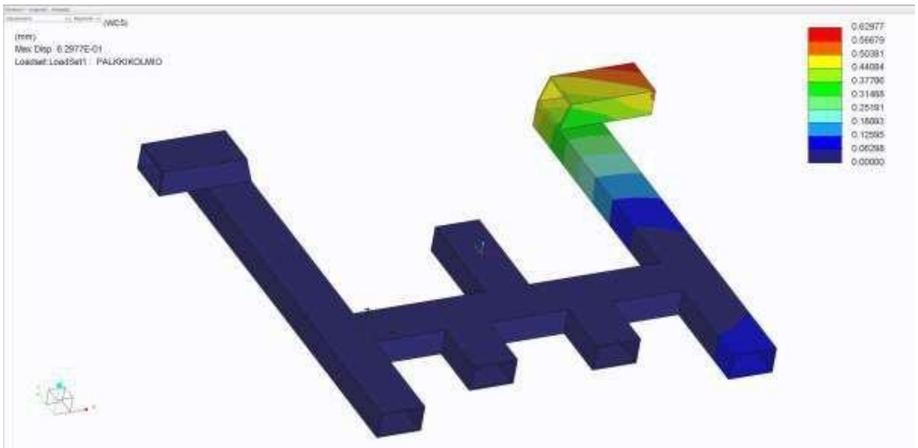

Figure 68 Support structure displacement analysis under design load (Self Elaborated)

3.7.11 Quality Management, Testing & Measurements

Critical measurements:

1. Spring maximum buckling displacement under design load (500 N), limit: 5 mm.
2. Round rail dynamic bending displacement during maximum operational forcer acceleration (2g), limit: 0.5 mm.
3. Encoder vertical movement during maximum operational forcer acceleration (2g), limit: 0.1 mm.
4. Mean sound level during operation, limit: 55 dB.
5. Maximum sound level during operation, limit: 60 dB.

Testing plan:

1. Design load test.
2. 100 kg patient.
3. Maximum forcer acceleration (1.3g).
4. Visual inspection of mechanical integrity.
5. Voltage test.
6. Separate voltage measurements for the bed frame and tech frame during operation.
7. Performance test.
8. Acceleration measurements at both ends of the tech frame and both ends of the bed frame during operation.

3.7.12 Control algorithm

With the help of the MATLAB/Simulink simulations, it was enough for the control algorithm to try to keep the bed in the middle position. The motors are would not be able to create significant accelerations for the patient, so the main aim was to prevent the overshoot when the bed would approach the middle position with relatively high velocity.

To some extent, this could be achieved with a simple PID controller, for which the feedback signal would be the positional error of the bed. The spring acted as the P-component since its force is always proportional to the displacement. The compensatory motors handled the I-component since they correct any long-term errors that got introduced to the system. Hence, only the D component was left for the main motors to handle. According to the simulation, it did result in decent action.

3.7.13 Prototype testing

The energy consumption of the prototype motors (1.6 kW each) was relatively high for the mobile application. With such energy consumption, it will need 1.6 kWh of stored energy to run the system with 2 motors for half an hour. The existing energy storage module systems are heavy.

Since the motor drive units performed vector control (they turn input 3- or 1-phase AC to DC, and then create PWM sine for the motors), it is possible to feed them straight with high-voltage DC. For example, for the 230V AC RMS with a 325V peak to peak level from the wall plug, the equivalent would be just feeding 325V DC from batteries source.

To reach the level of ~330V DC, we would need to stack 89 cells into a single column (89*3.7V=329.3V). The discharge current limit would be the same as from a single cell, ~10A for e.g. Sony Li-ion. That means ~5A to each motor, which is around half of the peak motor current of 9.6A. To supply the peak current for both motors (19.2A for 1 second), it is possible to store some charge in the capacitors and shortly use when needed.

The weight of such cell's column would be approximately 1.3 kg. It would require 2 to 3 of such columns to ensure the uninterrupted work from the batteries (one battery pack is in use, while the other two are charging).

3.8 Concept design

The concept design was developed following many iterations. The concept design was interdependent on the technical concept design and the user requirements. The Design concept shows the current vision of the finished product. It is shown below in Figure 69:

Figure 69 Final Design Concept (Self Elaborated)

Final concept design steps:

The final concept was developed based on the following steps:

1. Sketching
2. CAD modeling
3. 3D rendering
4. Final product design

Sketching:

Sketches were developed based on the ergonomics and paramedic needs. All components were sketched to get a better understanding of how the product would look like. Some of the sketches developed are shown below in Figure 70,Figure 71 and Figure 72:

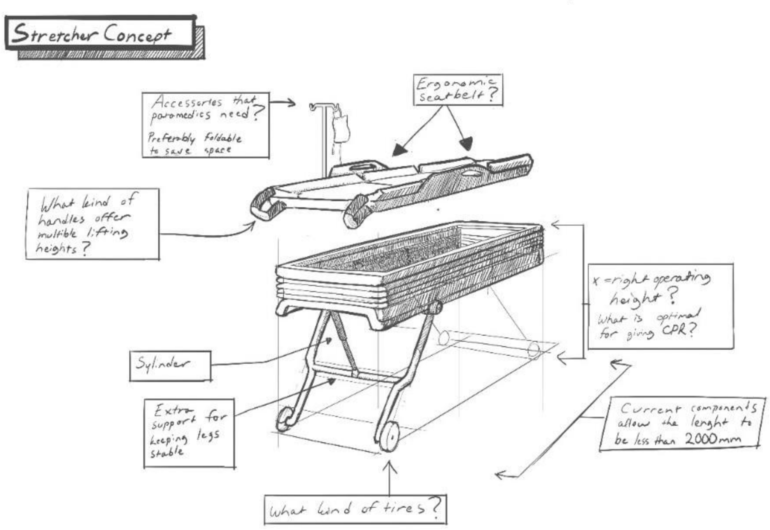

Figure 70 Full model sketch Iteration 1 (Self Elaborated)

Figure 71 Full Model sketch Iteration 2 (Self Elaborated)

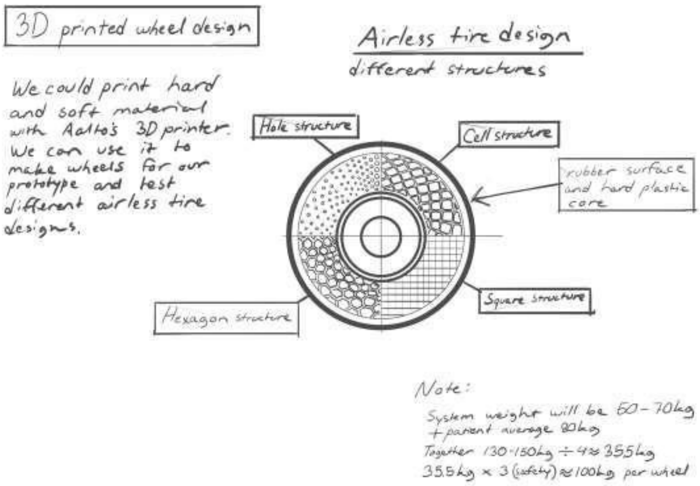

Figure 72 Stretcher Wheel Design Concept (Self Elaborated)

CAD modeling of Mechanical design:

Based on the sketches, the CAD model was developed. The software used was PTC Creo. Some of the iterations are given below in Figure 73 and Figure 74:

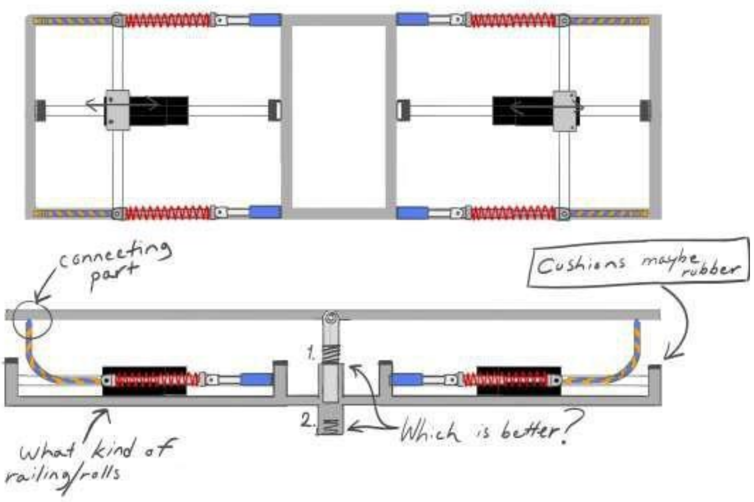

Figure 73 Mechanical Design Iteration 1 (Self Elaborated)

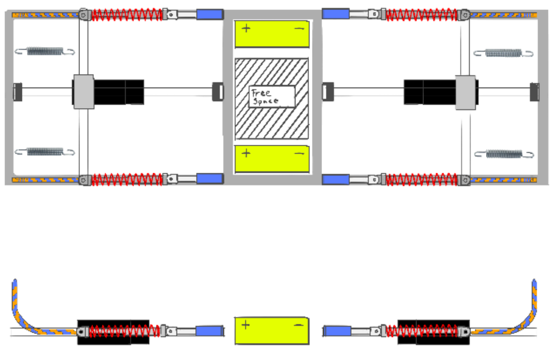

Figure 74 Mechanical Design Iteration 2 (Self Elaborated)

3D rendering:

The 3D renderings gave a better perspective and visual detail on the product assembly. It also provided insights into how the prototype would look like. Some of the iterations are shown below in Figure 75 and Figure 76:

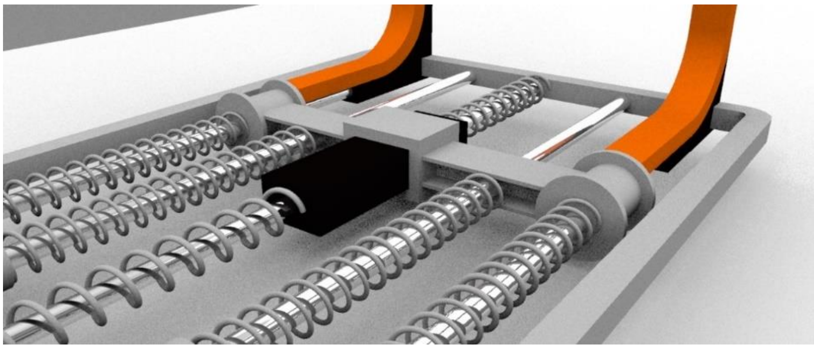

Figure 75 3D rendering Iteration 1 (Self Elaborated)

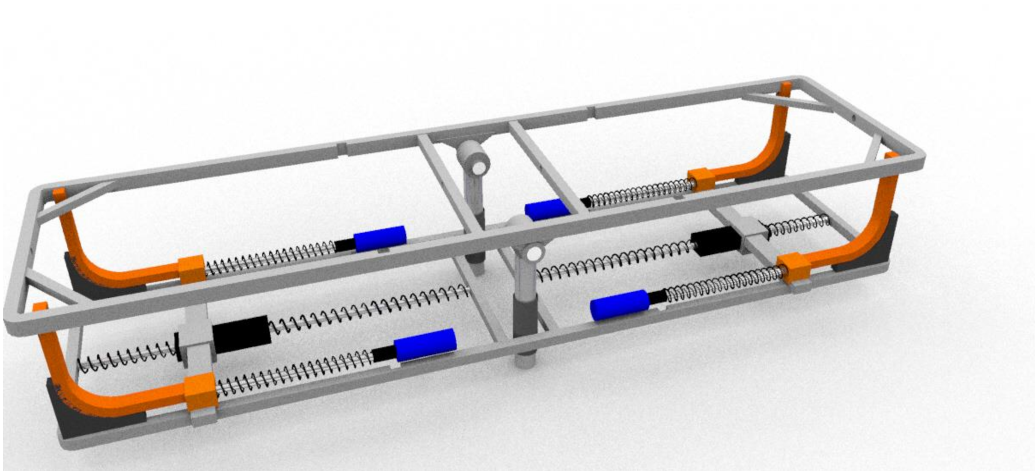

Figure 76 3D rendering Iteration 2 (Self Elaborated)

Final Product Concept:

The final product concept was developed based on the sketches and renderings. The final product concept is shown below in Figure 77:

Figure 77 Final Product Concept (Self Elaborated)

The final product concept shows a stabilized stretcher which will help compensate for the vibrations in real time. By compensating the vibrations, the patient ride conditions will improve, and the patients can have a more comfortable journey to the hospital. The stretcher is also designed to help the paramedics by improving the handle design and by having a powered system so that the paramedics do not have to endure more back strain and injuries.

BUSINESS PLAN

4 Business plan

4.1 Business plan overview

This chapter deals with the business aspects of the new products to be launched on the market. The focus is on the canvas model development and the financial aspects associated with the business model. Each block of the business canvas will be analyzed in detail followed by the business plan analysis. Each block will be analyzed based on some questions that will be answered.

4.2 Definition of initial and future applications

To progress from the product concept and prototyping stage to product development, a business plan is devised. The strategy is to develop two products in the first 6 years to be sold in Portugal. The first product is a stabilization device which will fit in between the legs of the stretcher and the mattress frame of the stretcher. The stabilization device is custom designed as per our customer needs. Custom designed solutions enhance customer relationships.

There is a big scope for future applications where along with improving transport conditions for patients, the conditions of the paramedics can be improved by improving the ergonomics of the stretcher and improving the conditions for ambulance drivers with road condition monitoring.

The second product is an actively stabilized stretcher. This product is an upgrade to the stabilization device. This product will help improve ride conditions of the patients even more. The product has an ergonomic design to help the paramedics as well (Example: Improved handle design).

Future applications in this market segment also include targeting air ambulance transport and water ambulance transport. Any application where vibration compensation and stabilization are a requirement is a potential market segment. By reversing the software algorithm, markets, where destabilization is needed, opens a new window of opportunity for business. Considering both these cases, the added market segments are endless. There are many firms who deal with multiple sectors of stabilization. After the 6 years, plans could be made to venture into these sectors. To mention a few, Some of the possible market segments are:

1. Automotive industry. E.g.: Road condition monitoring.
2. Drone technology industry. E.g.: drone stabilization.
3. Blood bank industry. E.g.: stable transport of blood bags.

4. Alcohol and beverages industry. E.g.: De-stabilization of whiskey to speed up the maturation process.
5. Chemical industry.

4.3 Executive Summary

Market need:

Research has shown that the level of vibrations that a patient is subjected to in an emergency medical ambulance is often too high. The vibrations felt in the ambulance can be very disturbing for the patients and can cause trauma and duress to the patients.

Due to these reasons, a market need is set up:

Modern-day stretchers do not have the capacity to reduce the vibrational effects. There are powered stretchers (Example: Stryker Power-PRO XT [14], Ferno POWERFlexx+® Powered Cot [66]) which help the paramedics but even those stretchers do not have vibrational compensation features. There is a need for a product which can reduce the effects of vibration and improve the transport conditions for the patients.

As in the case of modern ambulances, they too do not help solve in reducing the vibrations as the only vibration compensation they can achieve is through their shock absorbers which are built-in during the time of manufacturing.

Devices that help compensate the vibrations are not currently available in the medical technology/device industry.

How products support overall business strategy:

The stabilizing unit developed helps to create value in society by bringing ease to the patients during pre-hospital, intra-hospital and inter-hospital transfers. After a period of three years, the stabilization device will evolve into a full-scale stretcher which will supply support to patients and paramedics alike. The medical device industry thrives on value creation products. Hence the overall business strategy is supported by this product and the generations of products that will follow.

Market opportunity:

We can enter a new market where there are no comparable products available. We could be a pioneer in this field. Other markets where there is a need to stabilize or destabilize can also be explored as potential future market targets.

Key elements of a product launch- marketing, technology, and manufacturing strategy:

To market the product, Murata's well-established marketing channels can be used to set up a client base. Extensive awareness creation marketing strategy needs to be employed to create customer outreach. More R&D must create a sustainable technology. The stabilization device will only be assembled in Portugal while all the components will be obtained from other locations locally and internationally. When the stretcher development process is complete, manufacturing and assembly will be done in-house.

Target Customers:

The first product is a stabilizing unit that fits into the modern-day stretchers and the stretchers of the future. Hence the stretcher manufacturers are the primary target customers. Our other target customers are the stretcher manufacturers, ambulance modifiers, Military, and international suppliers. The stabilized stretcher will target more customers such as Hospitals and Private clinics too.

Competitive Position:

The competitive advantage is that products like these are not currently available in the market and it opens a new market segment. We could launch a product which is of high impact value. Since unique products are being offered, it presents a clear competitive advantage to us.

4.4 Canvas model

The canvas business model proposed can be seen in Figure 78:

<table>
<tr>
<td rowspan="2">Key Partners
• Murata/ sensor manufacturer/supplier
• PCB manufacturer (Data logger)
• Component suppliers</td>
<td>Key Activities
• Research and Development of the product.
• Product assembly.
• Software developing.</td>
<td rowspan="2">Value Proposition
• stabilization unit to be fitted into the stretchers.
• Stabilized Stretcher.
• Maintenance and repair contracts.</td>
<td>Customer Relationships
• Selling of product.</td>
<td rowspan="2">Customer Segments
• EMS services.
• Military medical services.
• Hospitals.
• Firefighter departments.
• Private ambulance services.
• Stretcher manufacturers.
• Ambulance modifiers.
• Military services.
• International suppliers.</td>
</tr>
<tr>
<td>Key Resources
• Hardware labor resources.
• Software developers.
• Assembly infrastructure.
• Maintenance and repair teams.</td>
<td>Channels
• Company website and partner website.
• Web sales.
• Salesforce communicating with customers.
• Online enquiries.
• Murata supply chain.
• Supply chain of Stretcher manufacturers.
• Ambulance conversion companies.</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Research and development costs.
• Labor costs.
• Assembly costs and facility cost.</td>
<td colspan="2">Revenue Streams
• Product sales.
• Maintenance.
• Repair costs.</td>
</tr>
</table>

Figure 78 Canvas Model

4.4.1 Customer Segments

Our products, the stabilization device, and the stabilized stretcher create unique customer segments. The stabilization device fits into modern day stretchers and the stretchers of the future while our stretcher will be futuristic stretcher. The device falls under the Business to Business (B2B) framework while the stretcher follows the Business to Customer (B2C) framework. These stretchers will fit into the ambulances which are the vehicles primarily used in patient transport services on the ground level.

Value creation segmentation:

Many entities that run in the emergency medical services have their own fleet of ambulances. Hence the product creates value for the following institutions/service providers:

1. EMS services.
2. Military medical services.
3. Hospitals.
4. Firefighter departments.
5. Private ambulance services.

1. EMS services:

The EMS service in Portugal as mentioned before is primarily ran by INEM-Instituto Nacional de Emergência Médica. INEM supplies funding to the firefighter's department so that the firefighters can invest their money to get new ambulances depending on the requirements of the said department. INEM also has at least one ambulance per municipality and plans to renew its fleet of ambulances.

2. Military Medical Services:

The Portuguese Military has its own medical service that is supplied for the Army, Navy, and Airforce. The service is extended to the family members of the personnel and disabled personnel as well. HFAR- Hospital das Forças Armadas is a military hospital, which is a backbone of the military health system in support of operational health, consisting of the Lisbon Polo and the Porto Polo [67]. The Military has its own medical vehicles. Since products of this kind improve the ergonomics of the vehicles and improve ride conditions for the Military personnel, the Military is a potential customer to be considered.

3. Hospitals:

Every hospital needs a good fleet of stretchers. Sometimes the patient needs to be rushed to the operation theatre and the doctors/nurses cannot always consider if the vibrations will worsen the condition of the patients when it comes to life or death situations. Our products can help cut all doubts in the heads of the doctors and nurses with regards to the vibrational effects.

Another aspect to be considered is the inter-hospital and intra-hospital transfers. Not all hospitals can perform operations. Sometimes the patient needs to be transported to other hospitals which have the facility to perform operations that the other hospitals cannot. Even if the patient being transported is not critical anymore, they can still feel the effects of vibrations which cannot be ignored.

4. Firefighters department:

The firefighter's department works in tandem with INEM. They are funded by INEM every year and they are free to obtain ambulances as per their requirements. Depending on the requirement, they contact ambulance manufacturers/ ambulance modifiers and say their requirements.

5. Private ambulance services:

Private ambulances in Portugal are abundantly available. An ambulance service of this kind is primarily used for non-emergency vehicle transport. These services pride themselves in the kind of facilities they provide. Hence there is a wide range of services they provide, some of them even dealing with luxury services where patient experience is their selling factor.

Some of the private ambulance services have partnerships with the Portuguese Firemen's League- Liga dos Bombeiros Portugueses. Example: ACP- Automóvel Club de Portugal [68] while some of the other services have partnerships with INEM and IMT such as Tagus Ambulâncias based in Lisbon [69]. The paramedics are trained to perform the functions of patient transport.

Target Customers:

Even though the products create value for the above-mentioned segments, the target customers are slightly different from the customer segments. The target customers we intend to focus on are:

For the stabilization device:

1. Stretcher manufacturers.
2. ambulance modifiers.
3. Military services.
4. International suppliers.

For the stabilized stretcher:

1. Hospitals.
2. Military.
3. Private ambulance services.
4. Ambulance Modifiers.
5. International Suppliers.

1. Stretcher manufacturers:

Our biggest customer base is the Stretcher Manufacturers. There are 2 kinds of stretcher manufacturers:

1. Manufacturers who supply stretchers locally. Example: Auto Ribeiro-Porto [17].
2. Manufacturers supplying stretchers locally and globally. Example: Stryker [14].

To begin with, we focus on selling our products locally around Portugal and then slowly expanding operations abroad.

The stabilization device will lead to an increase in the weight of the stretcher. The increased weight will lead to injuries for paramedics if the stretcher is non-powered. Therefore, it cannot be employed with non-powered stretchers. Hence the focus is on stretcher manufacturers who supply powered stretchers.

2. Ambulance Modifiers:

Ambulance modifiers are automobile manufacturers who supply emergency vehicles to firefighter's department and hospitals. These manufacturers change van chassis depending on customer needs and equip them with state-of-the-art equipment. Some of the applications are:

1. Mobile health units
2. The isothermal/ refrigeration unit
3. Mobile library
4. Mobile technical units.

These manufacturers either do the transformations themselves or they outsource it to some other manufacturers. An example in Portugal being Renault vans giving the transformation rights to Auto Ribeiro which is a stretcher manufacturer based in Porto [70]. Tying up with these modifiers can help ease business.

3. Military Services:

Military services as mentioned above in customer segments is another potential customer. Since Military hospitals and their fleet of ambulances need custom stretchers, our products can fit into their stretchers and ambulances.

4. International suppliers:

The international suppliers are online vendors who sell a wide range of products ranging from fully equipped ambulances (Example: Mascus Portugal [71]) to small medical devices catering to all kinds of medical requirements (Example: Medicalexpo [72]). Through these suppliers, our products can be sold without us having the issue of documentation and registration of the product across international borders. This gives us a scope to expand beyond the Portugal territory.

4.4.2 Value proposition

Problems experienced:

Patients undergo a lot of vibrations while they are being transported to the hospitals. These vibrations can be extremely dangerous for the patients. Some of the effects of vibrations are:

1. Patient trauma or anxiety can increase.
2. Complications can arise.
3. The transport times can be longer.
4. Deaths of patients in the ambulances.
5. Not enough vibrational compensation happens.
6. Delay in the transport of the patient.
7. Risk of causing more injuries.
8. The decrease in patient comfort.
9. The decrease in the ability to supply better care for the patients.

Vibrations affect the paramedics in other ways. Depending on the level of vibrations, the vision of the paramedics can get distorted. The vibrations prevent the paramedics from performing simple functions such as administering injections. The level of noise also prevents the paramedics from effective communication. Even though the vibrations affect the patients and the paramedics, the focus is on developing products that improve the ride conditions of the patients.

Reasons for such occurrences:

1. Stretchers are not equipped to reduce the vibrational effects.
2. Ambulances are not equipped with devices to reduce the vibrational effects.
3. The ergonomic focus has been on paramedic health due to paramedic sustainability issues.

Our products:

Our first product is an active vibrational compensation system that compensates the vibrational effects of the terrain in real time. The first product is a stabilization unit that is fit into the stretcher in between the bed/mattress and the legs of the stretchers. Our second product planned is an actively stabilized stretcher which will compensate for the vibrations in real time and supply relief to the patients. The ergonomic design will help paramedics too.

Value delivery:

In terms of business:

1. Stabilization unit to be fitted into the stretchers.
2. Stabilized Stretcher.
3. Maintenance and repair contracts.

1. Stabilization unit to be fitted into the stretchers:

The main value that we create for the customers is the stabilization unit which is our product. This product can be fit into the new stretchers that they will deliver to their customers. With this product, the customers will be able to supply vibrational compensation features on their stretchers.

2. Stabilized Stretcher:

Once a market has been set up, we offer another value proposition which an actively stabilized stretcher is. This stretcher is an upgrade to the stabilization device. The strategy is to launch the stretcher 3 years after the stabilization device is launched on the market.

3.Maintenance and repair contracts:

Along with the product, we will provide maintenance and repair based on contracts signed with the customers. Depending on the needs of the customer, the contracts can be changed.

In terms of product benefits:

1. Increase in comfort by a reduction in vibrations felt by the users.
2. Better stabilization of the patients.
3. Reduced trauma.
4. Better transport conditions.
5. The possibility of faster transport.
6. Possibility to perform more operations on the patient during emergency transport.

Product features:

The stabilized stretcher will have the same features as the stabilization device. Some of the features of the stabilization device are:

1. Battery powered and Replaceable batteries.
2. Portable (Stabilization device feature only).
3. User-friendly.
4. Easy maintenance.
5. Robust.
6. Superior vibration absorption.
7. Increased comfort.
8. Fast charging and
9. Automated guidance vehicle (Stretcher feature only).

Primary and Secondary Focus and Other Potential Opportunities:

The primary focus is to do comprehensive Research and Development for the design, manufacture, and assembly of the products. The secondary focus is the marketing for the products and spreading the awareness of the technology.

There are plenty of other potential opportunities. With proper R&D, we can reduce the size of the device, making the device more compact. There is potential to reduce the weight of the device. There is also an opportunity to redesign the stretcher to make it more ergonomic. These are some of the potential opportunities present that can be explored. Alongside the R&D for the device, the development process for the stabilized stretcher needs to be done to launch it in a period of three years.

4.4.3 Channels

The channels that the customers would be reached with is a combination of own channels and partner channels alike. It is important to get the right mix of channels so that the value proposition is properly met.

The following list of channels is proposed to reach our customers:

Own channels:

1. Company website
2. Web sales.
3. Salesforce communicating with customers.
4. Online inquiries.

Partner channels:

1. Murata supply chain and Murata's website.
2. The supply chain of Stretcher manufacturers.
3. Ambulance conversion companies.

Own channels:

1. Company website:

A company website helps to put the company on the digital platform. Having an online presence in today's market scenario is of utmost importance. The company website falls under the Directly owned channels.

Some of the advantages of having a company website are:

1. The company website can have information about the products and services offered.
2. It can also provide information about further developments and associations with partner companies.
3. It provides information on how other clients can contact us.
4. It also helps clients to request for quotations and place orders for the product.
5. As and when new products will be developed, it can be updated on the website.

2. Web sales:

Web sales are about placing orders directly on the company website. This kind of a sales channel supplies a direct link between the clients and us. There is no requirement of a middleman or a negotiator for the business [73]. Some of the advantages and disadvantages of web sales are:

Advantages:

1. Easy access to market
2. Reduced overheads
3. The potential for rapid growth
4. Widen your market/export

5. Customer intelligence

Disadvantages:

1. Website Costs
2. Infrastructure costs
3. Security and fraud
4. Legal issues
5. Advertising costs
6. Customer trust [74]

3. Salesforce communicating with customers:

Since the products are new on the market, it needs to be marketed properly. It is imperative that knowledge about the existence of the stabilization device is well known to customers. Hence it is important to have a dedicated sales force to communicate with customers. This will help build credibility and sales of the product across Portugal. Through later marketing, the knowledge about the stabilized stretcher can also be achieved. Salesforce channel falls under the directly owned channels.

Since the products have a social impact, highlighting the benefits these products will have and the impact they will create can help increase the awareness among hospitals, doctors, paramedics, stretcher manufacturers, and ambulance services.

Partner channels:

1. Murata's website:

A collaborative effort with Murata will help launch the device. Murata has a lot of clients in the medical device industry. Marketing the product on their website helps create a greater outreach. The aim is to set up a market in Portugal and then move onto the other European markets through online export. Making the most of this collaboration will help the business immensely.

2. The supply chain of Stretcher manufacturers:

Developing good customer relationships will give us access to the supply chain of stretcher manufacturers also. Having access to this supply chain increases our outreach to other potential customers leading to higher sales of the device.

3. Ambulance conversion companies.

Ambulance conversion companies have their dedicated supply channels which can be targeted.

4.4.4 Customer Relationship

Our main customer relationship is product sales which are also known as asset sales. We keep good customer relationships by delivering top quality products which will be custom designed for each customer (for the stabilization unit). The customer can request for custom features so that they can integrate their equipment with our device (example: the plug-in feature can be used to connect road condition monitoring devices). Such a partnership helps improve overall value for the customers.

What type of relationship does each of our Customer Segments expect us to set up and keep with them?

Initially, to set up relationships, personal aid will be provided. This is helpful to understand customer requirements better and to improve the quality of our product.

Over the course of time, customers can place orders via the website of our company. This would be a self-service type of relationship with online customer aid as and when needed. The website will supply all the contact information such as telephone numbers, distributor contacts, and even a contact form to ask for quotations and further information about our products.

Potential for retrofits/upgrades and linkage to next-generation products and technology product/service/technology roadmap:

If the customer opts to buy the stabilizing unit, they will need to buy the upgrades eventually in time. Regular software updates will be provided. Based on customer relationships, mutual deals can be signed for better offers for the stabilized stretchers.
There can be a buyback choice or a replacement for a lower price option too as and when the new products come out into the market. The stretcher will not have immediate upgrades. The upgrades for the stretchers will only be new product or variations in the stretcher for different models of the stretcher.

4.4.5 Revenue Streams

For what value are our customers willing to pay?

1. Value creation.
2. Social impact products.
3. A new product on market.

1. Value creation:

The medical device industry is a value-based industry. Every medical device manufacturer thrives to create value-enhancing products. Our products enable the customers to create more value by solving problems for paramedics and patients alike. Hence, customers will be willing to pay for this product.

2. Social Impact:

Our products are social impact products. There is always a willingness to pay for products that create a social impact especially in markets like these.

3. A new product on the market:

Our customers have an opportunity to explore a new product market that they could use to market their products too. Marketing their stretchers with a new stabilization device to compensate vibrations leads to better marketing and more sales, not only for them but also for us. The stabilized stretcher will also be a new product on the market since no stretcher manufacturer currently manufactures actively stabilized stretchers.

For what do they currently pay?

Product sales:

The sales model considered is the asset sale model. In the beginning, it is a B2B business. customers can buy the stabilization unit from us and then use it in their stretchers to sell to their customer base. This is like the automotive industry where the automobile manufacturers procure a lot of components from other manufacturers to be used in their vehicles. The stabilized stretcher will incorporate B2C business where the customers such as hospitals will buy the stretcher from us and use it in their hospitals.

Maintenance:

Over the course of time and depending on the usage of the device, maintenance will be needed. Signing periodic contracts of six months depending on the customers will help generate revenue for us. For the first two years, the customers will not have to pay for maintenance. After the two-year period, the customers will start paying for the maintenance of the devices. This is part of the product launch process idea to foster better relationships with the customers.

Repair costs:

There are possibilities that the device and the stretcher would need repairs depending on the usage of the products. If the products are damaged, they can either be replaced or repaired. Hence, repairs are also revenue generating sources

Pricing mechanism:

The pricing mechanism adopted will be the fixed pricing. This is like the fixed menu concept where a customer pays for the product based on product features provided.

4.4.6 Key Resources

What Key Resources do our Value Propositions need?

1. Hardware labor resources.
2. Software developers.
3. Assembly infrastructure.
4. Maintenance and repair teams.

1. Hardware labor resources:

To assemble the device in-house, a team of hardware labor resources is needed. The hardware labor will handle the assembly of the device. They will also handle quality testing and knowledge management. For the stretcher most of the components will be obtained from suppliers and only a few components such as the chains will be manufactured in-house via 3D printing.

The hardware team will have to be trained on how to assemble the product. They will need to be trained on the concepts of JIT and lean as well so that we have an efficient storage system. We do not want to stock excess products or components for the products. Hence proper training is essential.

2. Software developers:

The software developers will handle the software development of the device and the stretcher. They will also handle testing, tuning and debugging the software. This role is a continuous developmental role where recent updates would be required to fine tune the system. There is also a possibility to deliver the updates via apps for the or Wi-Fi in the future development course. The software developers will have to sign a contract to avoid copyright infringement issues in the future.

3. Assembly infrastructure:

Even though no manufacturing will take place, we will need a rental space to initially set up our stabilization device. For the first two years, the set up will be in a company nest which are like incubators for startups. This company nest will supply the space needed for assembly of the device and office space. In the first two years, we will only need to pay the rent for space. The rent will also include the electricity, water and security bills.

In the third year when the expansion into the stretcher industry happens, a new assembly infrastructure will be needed. This assembly infrastructure will have even the office spaces and expansion zones. The infrastructure will also have a small warehouse to stock the required components as and when needed.

To have security measures, security cameras will be installed and there will be security personnel at the gates. The infrastructure will be well lit and will have proper ventilation installed.

4. Maintenance and Repair teams:

The maintenance and repair teams will handle post-sales duties. The customers will be provided with routine maintenance and repair contracts and the team will handle keeping the products to the highest quality.

4.4.7 Key Activities

What Key Activities do our Value Propositions need?

To deliver the value proposition to our customers, some key activities need to be performed. The key activities are:

1. Research and Development of the product.
2. Product assembly.
3. Software developing.

1. Research and Development:

A lot of emphases must be made on the research and development of the products. R&D must transform the product from prototyping phase to a full-scale device and from a full-scale device to a stabilized stretcher ready to be launched into the market. R&D is also needed to make the product more robust and versatile so that it can fit into stretchers of all kinds without hindering the performance and ergonomics of the stretchers. This will open a new market for us over the course of time.

2. Product Assembly:

To deliver the value proposition, we need to assemble the products. Product assembly will be done in-house. The device will be assembled based on the customer's stretcher designs and requirements.

The device will be developed in Portugal. No major manufacturing will be done except for the chains which will be 3D printed. Rest of the components are obtained from our partner suppliers and the assembly is done in-house. To assemble the device, we need all the components to arrive beforehand and on time. Hence having good supplier relationships is important. If not, there could be delays in the assembly of the product. Product assembly will follow JIT concepts.

The key technologies needed are the linear motor with its drives and the data loggers. Both these components will be outsourced. The data loggers will have our custom design and the PCB is custom designed as well. For the stretchers, apart from the components needed for stabilization, the hydraulics will be a key technological resource.

3. Software Developing:

Software developing is the 3rd key activity that needs to be done. The software will do the stabilization of the product. Hence a group of software developers will be needed. To prevent violation of intellectual property, the software will be developed in-house.

4.4.8 Key Partners

Who are our Key Partners?

1. Murata.
2. PCB manufacturer (Data Logger).
3. Component suppliers.

1.Murata:

Murata is our most important partner. There are different possibilities to form this partnership with Murata:

1. Forming a strategic alliance between non-competitors or
2. Joint ventures to develop new businesses.

Forming a strategic alliance with Murata is beneficial. Murata will supply the sensors for the products. Murata will also help set up a supply chain and provide marketing through their websites.

Another key partner is the PCB manufacturer (Data Logger). the datalogger software development will be done in-house, but the manufacturing will be outsourced. A suitable location to outsource the manufacturing is China since the manufacturing costs are cheap. Protecting intellectual property would not be a major issue since the manufacturer would not know for what application the data logger was being built. Hence the data logger manufacturing can be outsourced.

Who are our Key Suppliers?

Our key suppliers are the part suppliers. We will need suppliers for all the components mentioned in the bill of materials and the later components needed for the stretcher. Most of these components such as the springs, connecting rods, can be found easily and hence forming alliances with these suppliers will be easy. Due to the availability of the components, a decent price can be quoted to obtain the components are low prices.

The most vital part is the linear motor and the drives for the linear motors. Hence finding the right supplier for this part is crucial to the business aspect since the linear motor is also the most expensive part in the device. For the stretcher, hydraulics will be a key factor.

Which Key Resources are we buying from partners?

The key resources we would buy from our partners are the data loggers which would have the sensor from Murata fitted on it and the linear motor with its drives. These are the key resources we would buy.

4.4.9 Cost Structure

The focus is to create value. Hence the cost structure is value driven and not cost driven. We will have both fixed costs and variable costs to our business. They are mentioned below:

1. Research and development costs.
2. Labor costs.
3. Assembly costs and
4. Infrastructure cost.

1. Research and development costs:

R&D is a sector that will incur a lot of costs. Since we focus on value creation, more research and development are needed to enhance this value. This is a variable cost entity. Investing money in R&D will be beneficial and can lead to further business development opportunities.

Labor costs:

Labor costs are fixed costs. We will incur direct and indirect labor costs. The direct labor costs are the salaries paid to the personnel who are involved in the development and the production of the product. Other costs also include the advertising costs when the marketing employee will have to go by foot to create product awareness.

The indirect labor costs will be paid to the personnel who are not directly involved in the production process. This includes the salaries and benefits paid to the cleaners, security, supervisors, and accounting. These costs fall under the overhead costs. These costs will be considered only in the third year when the expansion into stretcher assembly takes place.

2. Assembly costs:

Assembly costs are the cost related to the assembly of the products.

Component costs: It includes the price of getting the components needed to assemble the device.

Variable overhead costs: variable overhead costs are the costs that increase or decrease as the quantity produced increases or decreases. An example being the cost of electricity that would be involved in the assembly of the product. Since electricity will be paid for the whole plant, this cost cannot be added to a specific cost model.

3. Infrastructure costs:

Infrastructure costs are the costs incurred in relation to the assembly line and office space. This includes the maintenance costs, insurance, property taxes, electricity, heating, water costs. We will also have infrastructure setup costs which include setting up of assembly lines, office space, and plant surroundings. Buying assets such as tables, chairs, printing equipment, computing equipment, electronics, security, lights, ventilation also fall under infrastructure costs. The infrastructure costs will be low during the first two years and then would increase during the expansion period.

4.5 Product launch requirements

Launching a medical product in Europe is not as straightforward as it seems. The medical device needs to be compliant with the European medical directive. The European medical directive to launch a medical device in Europe is 93/42/EEC. Only if a medical device follows this directive, it can be launched on the market. Even though the directive is a law to all the 27-member states within the European Union, each member state has its own directive within the country. The countries can add regulations to the directive and create local legislation.

Portugal requires in addition to the CE marking (as opposed to the essence of the CE marking which is “Free Circulation of Goods”), that Class IIb and III medical devices to be placed on the Portuguese market will go through a Device registration process. This process is like the pre-market notification requirement for Class I Medical Devices (as stated in the European Directive MDD 93/42/EEC Article 14) only in Portugal it is applicable for Class IIb and Class III. The devices must be registered online to the Portuguese Competent Authorities according to n. º 3 of l' article 8º-C of the Order in Council nº30/2003 February 14.

In addition to this registration and in accordance with the Decree-Law n. º 273/95, of 23rd of October, all manufacturers of active and non-active Classes of IIb and III medical devices will need to communicate their device details to the Portuguese Competent Authorities through their legal entity, including labeling and Instructions for User information (which are required to be in Portuguese).

Class I medical devices are not exempt. While they do not have to fulfill all the requirements of the Class IIb and III devices, Class I devices are required to complete the registration sheet and Declaration of Conformity on the Portuguese database [75].

Our device falls under the class I medical device where there is no contact with the patient. As for future applications, the stretcher to falls into the same category since the contact that the stretcher has with the patient is contacted with intact skin. To complete these requirements, the Authorized Representative will need to be presented with the following:

EC Declaration of Conformity

1. CE Certificate.
2. Labeling (must be in Portuguese).
3. Instructions for Use (must be in Portuguese).
4. Technical file.

CE Marking is CE the symbol. The letters "CE" are the abbreviation of French phrase "**C**onformité Europééne" which means "European Conformity". The term initially used was "EC Mark" and it was officially replaced by "CE Marking" in the Directive 93/68/EEC in 1993. "CE Marking" is now used in all EU official documents.

Apart from the CE marking, we will need a quality system to be set up. This is also a requirement to launch medical devices into the market. Europe needs a quality system be established to meet the medical device regulations (and/or IVD regulations). Many medical device companies choose to implement a quality system, and have it certified to ISO 13485:2016 to satisfy EU needs.

After the CE marking registration and the quality management system establishment, our device is ready to be launched on the market.

4.6 Identification of risks and mitigation strategy

Some of the risks and their mitigation strategies are:

- Cost of the Product

(Risk) - The prototype built costed about €7500 (Research costs included) which in terms of commercial aspect is on the higher end.

(Risk) - Depending on the final weight of the product, exporting the product to various locations with packaging (Air or Sea) costs must be kept in mind. Charges in the sea are lesser since it is in cargo basis but, it's very time-consuming. On Air, it's faster but expensive. All of these include in the total product cost.

(Mitigation) - If made in commercial terms i.e. making it through limited 'local' suppliers, these individual parts of the product can be bought in bulk and hence there would be a reduction of prices due to economies of scale. Also, thinking of outsourcing the manufacturing of the product in countries which have lower labor costs and making charges will help improving profit margins and to reduce the overall cost of the product.

- Installations of the product after Launch

  (Risk) - Since it is a new product worldwide, adaptation and acceptance of people in the Stretcher Industry is necessary to make the product successful.

  (Mitigation) - Marketing in terms of exhibitions, campaign drives, advertisements, field visits etc. will help to educate the need of the product and the impact it creates.

4.7 Market Analysis

Market category:

The product falls under a niche market category. The niche market deals with products and services that cater to specific needs of the customers. This market segment has a specialized segment of customers.

The five key characteristics of niche markets:

1. the customers in the niche have a distinct set of needs;
2. they will pay a premium price to the firm that best satisfies their needs;
3. the niche is not likely to attract competitors;
4. the niche marketer gains certain economies through specialization; and
5. the niche has size, profit, and growth potential [76].

While there is no clear and consistent definition for niche marketing, it is fair to assert that it is portrayed in the literature as a form of "pull" marketing – first finding the market and then developing a product for it. It is related to market segmentation in the fact that it is a further segmentation of market segmentation. However, based on Kotler's (2003) characteristics of a traditional niche market, there is an opportunity for success using a “push” approach – developing a product and then looking for a market for it [76].

Success factors:

One of the most crucial factors in the success of niche marketing is relationships. Researchers stress that strong, long-term relationships can help build a barrier to deter potential competitors and sustain long-term profitability as well as customer retention. Another concept of major importance to a niche marketing company is reputation. It is been pointed out that niche strategies depend on word-of-mouth communication. People’s opinions play a crucial role in a product’s success. In niche marketing, a company not only markets their product but also their business (Dalgic and Leeuw, 1994).

Besides relationships and reputation, Michaelson (1988, p. 23) believes that the first rule of a niche market strategy is “to offer the customer a clearly differentiated product that fills (or creates) a need.” He asserts, in Raynor (1992), that true niche marketing must be based on the ability to supply products that meet actual customer needs. The niche must be real, and the product must satisfy the needs [76].

4.7.1 Global Market Research

According to a new market report published by Transparency Market Research "Hospital Stretchers Market (by Types: Fixed-height, Adjustable, Bariatric, Radiographic Stretchers and by Applications: Intra-hospital Transport, Day Care Surgery Department, Emergency Department and Others) - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast, 2013 - 2019," the global hospital stretchers market was valued at USD 1.3 billion in 2012 and is expected to grow at a CAGR of 3.9% from 2013 to 2019, to reach an estimated value of USD 1.7 billion in 2019.

Steady growth in the market was seen due to the long average lifespan of stretchers (7 years to 10 years), availability of refurbished equipment and lack of innovation in this field. However, growing demand for technically advanced stretchers, rising number of surgical procedures and increasing prevalence of chronic disorders are major factors expected to fuel the market growth. Globally, the rise in elderly population is also being considered as one of the major factors that are likely to boost the demand for hospital stretchers as the aged population is more susceptible to many disorders and require effective care.

Based on technology, electrical or motorized stretchers accounted for more than 25% revenue share of the global hospital stretchers market. Moreover, during the forecast period, the technology is expected to increase its market share and appear as the fastest growing segment, reporting a CAGR of over 7% by 2019. On the other hand, the market for non-motorized stretchers during the forecast period would be driven by demand from low budget hospitals that prefer to purchase low-cost equipment [77].

With the slowdown in world economic growth, the Emergency Stretcher industry has also suffered a certain impact, but still maintained a relatively optimistic growth, the past four years, Emergency Stretcher market size to maintain the average annual growth rate of 4.90% from 1230 million $ in 2013 to 1420 million $ in 2016, Market analysts believe that in the next few years, Emergency Stretcher market size will be further expanded, we expect that by 2021, The market size of the Emergency Stretcher will reach 1720 million $ [78].

4.7.2 Market Need Survey

A quantitative research was done to understand if there is a potential market for such a stabilization device. The survey was made only for the stabilization device because it is the first product offered in this market segment. The quantitative research was done via google forms and responses were collected from doctors, paramedics, and nurses. A total of 22 responses were obtained- 20 online responses and 2 on field responses. The survey summary is described below. Samples of Individual responses can be viewed in the Annex

Annex A- Market analysis.

Survey structure:

The survey was a questionnaire with 5 questions to get a basic understanding of market response. The questions were based on:

1. Product need.
2. Product Acquisition.
3. Product cost and
4. Product features.

Product Need:

86% of the respondents felt that there is a need for such a product. The results are in Figure 79:

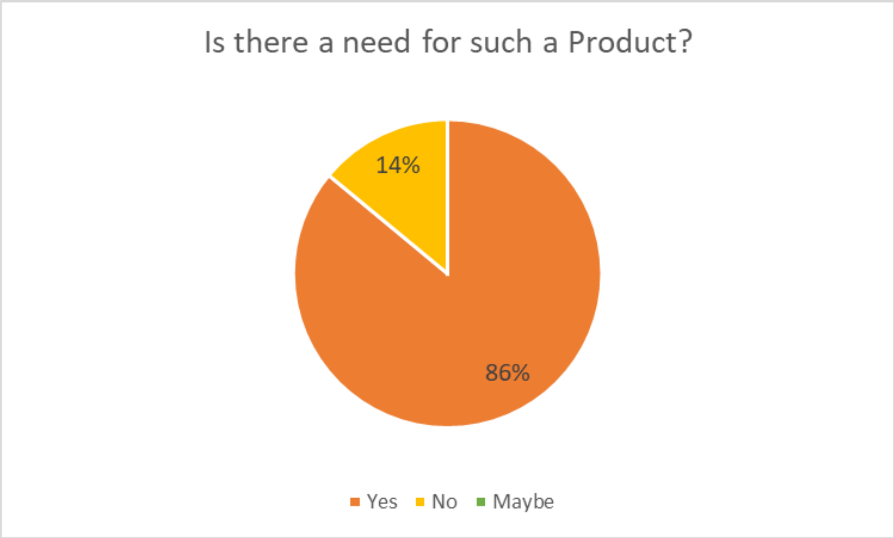

Figure 79 Product need joint survey results

Product acquisition:

65% of the respondents were willing to buy such a product while 27% considered it a possibility. The results can be seen in Figure 80:

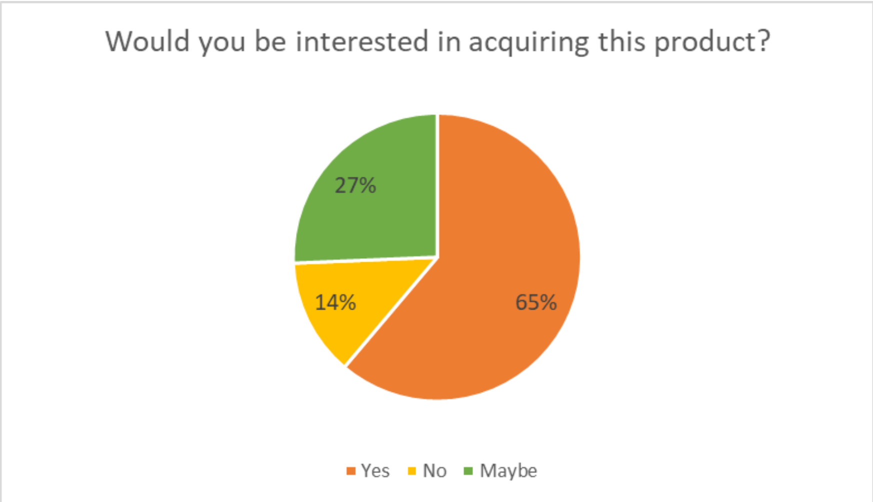

Figure 80 Product acquisition joint survey results

Product Cost:

The survey shows that even though there is a willingness to buy, there is no willingness to pay. Hence it is important to have a proper pricing strategy. The results can be seen in Figure 81:

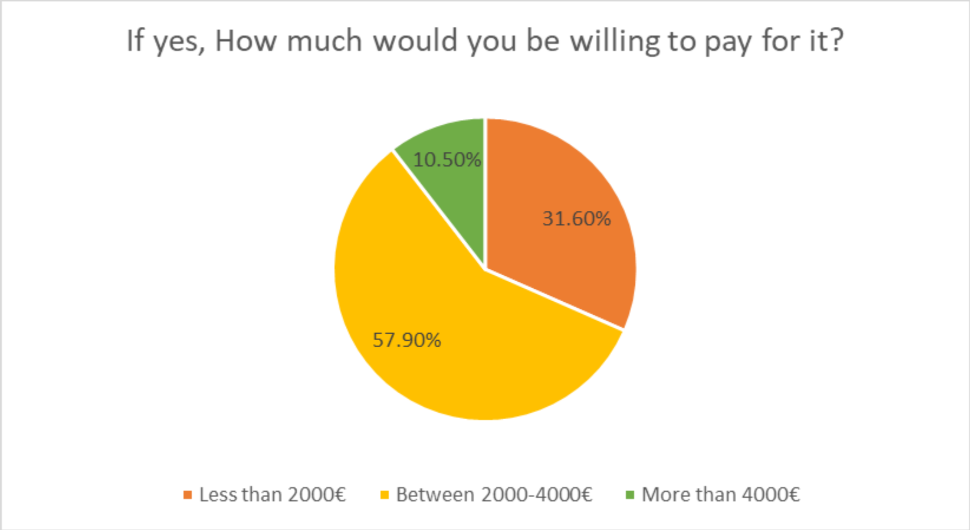

Figure 81 Product cost online survey results

The firefighters opted for a price range less than 2000€.

Product features(Figure 82*):*

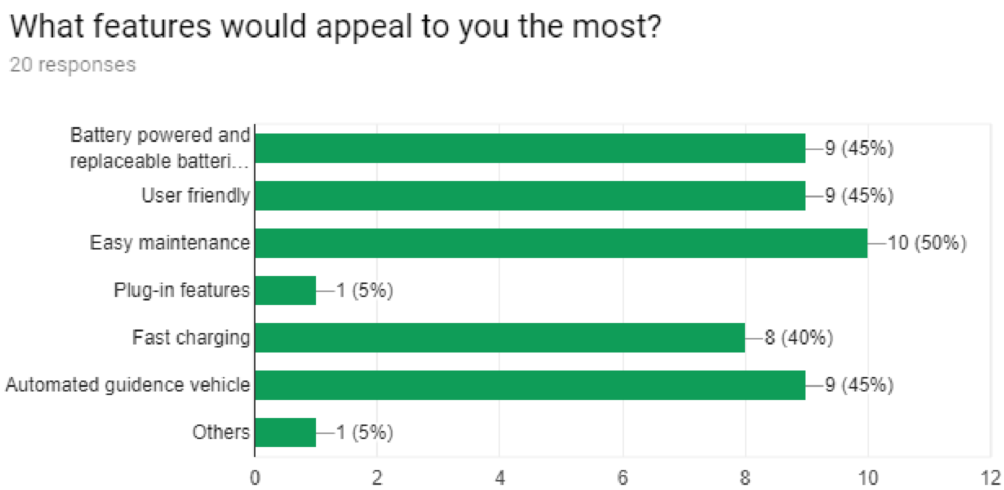

Figure 82 Product features online survey results

The firefighters opted for Easy Maintenance and Automated Guidance Vehicle features.

An added question in the survey was for other features needed. 3 responses were obtained. They were:

1. None.
2. RCP without DEA.
3. Bigger wheels would make even better.

Survey Summary:

The survey showed positive responses to the market need for such a product and most people were willing to buy a product of this kind. Even though there was a willingness to buy the device, the willingness to pay for it was not so high. This survey was only a preliminary survey and a more detailed analysis would be needed to know the pricing and the outreach of the device. Another survey will have to be done to understand the potential market for the stabilized stretcher.

4.7.3 Quantitative Market Analysis

INEM statistics:

Current scenario:

The AEM network has been maintained with 56 Ambulances (Figure 83) in operation [79].

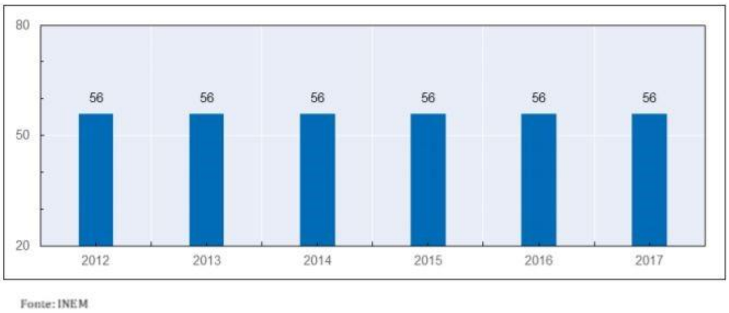

Figure 83 Number of Emergency Ambulances with INEM [79]

During the year 2017, the EMFs were activated 161,424 times, which stands for 442 drives per day. Considering the 56 EMS in operation, it means that each of the Ambulances was triggered on average 8 times a day.

Emergency ambulances based in Emergency Medical Posts - PEM

As of December 31, 2017, 305 PEM were in operation (Figure 84). It was in this context that protocols were set up for the constitution of 21 new EMPs in municipalities where there was still no PEM, and the Plan of the Institute was all the 278 municipalities of mainland Portugal with an ambulance of INEM. These EMPs are expected to start operating by 2018 and, until that date, will operate with own ambulances [79].

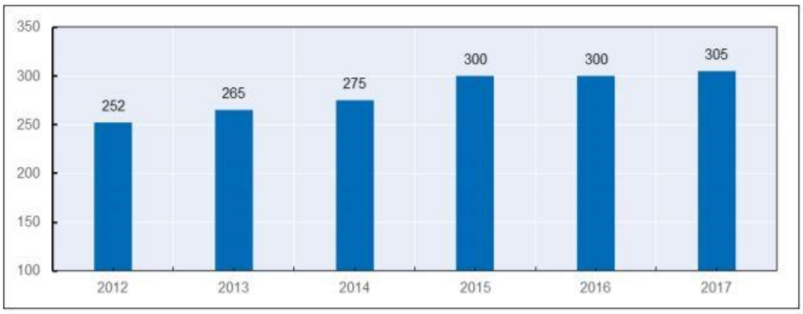

Figure 84 Evolution of the number of emergency medical stations [79]

INEM also intends to ensure the rapid renewal of the EMP fleet of ambulances and has already been signed in 2017, protocols for the renewal of 41 Ambulances, giving priority to the renewal of the circulating ambulance fleet_of 12 or more years, being a large investment dimension by INEM. This plan for the renewal of the EMP fleet replacement of 75 ambulances in each year, between 2018 and 2021, at which point the fleet of ambulances will be totally renewed.

Firefighters department statistics:

According to Pordata statistics, in the year 2016, there were 468 firefighters' departments also known as Corpos de Bombeiros [80]. A graph of the number of departments from 1993-2016 is shown below in Figure 85:

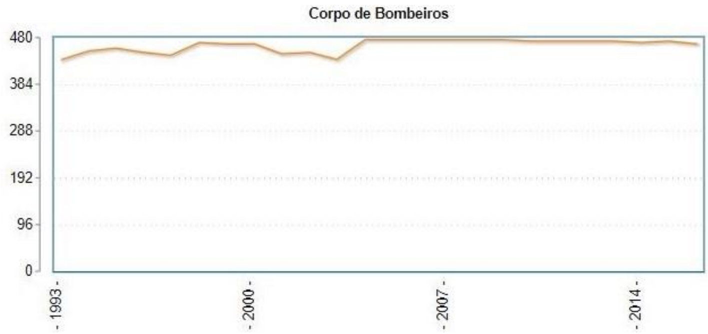

Figure 85 Number of Firefighters Department

Ambulance Transformation Companies:

Portugal has many ambulance transformation companies. These companies obtain type A, type B, and type C vans and then transform them into mobile health units/ ambulances. There are many companies in Portugal that transform vans. Some of these companies obtain their stretchers from companies such as Stryker (Teclife [81]) while some companies manufacture their own stretchers as well (Auto Ribiero [17]).

Some of the companies that do these transformations are:

1. Auto Ribiero
2. Emertech- Project
3. Teclife
4. Futurvida
5. Renault Portugal
6. Capsud
7. ACP- Automovel Club de Portugal

Online Suppliers:

Online suppliers are the companies that sell products through a website. These suppliers sell products locally and internationally. Online suppliers are essential to increase sales across borders. With the help of these suppliers, there is no need to register the product to be sold across borders. These suppliers sell ambulances and medical devices.

4.8 Business Strategy from Market Research

The products are new on the market. Hence the plan is to begin slow and steady and ease into the market rather than jumping into unknown territory. Being cautious can help us understand market response better and grow the business little by little. The business strategy is to target 10% of the existing markets. Based on that strategy, we get:

1. INEM has plans to renew 75 ambulances per year [79]. 10% of these can be targeted- 8 ambulances which can be rounded up to 10 ambulances in the first year.
2. Bombeiros- 468 centres with at least one ambulance. We target 10% opt for our device per year for one of their ambulances. Hence- 47 ambulances which can be rounded to 50 ambulances.
3. According to Jornaldenegocios, there are 600 ambulance B companies in Portugal [82]. 10% of 600 companies. - 60 companies with 1 ambulance.
4. We extrapolate the potential business with ambulance transformation companies. We target, 50 devices to ambulance transformation companies
5. The Military can be targeted once a market and credibility have been established.
6. Online sellers and International suppliers too are target markets once the product awareness has increased.

Based on the information the strategy is to begin selling the stabilization device in 2019. The sales target set is 150 stabilization devices. In the first 2 years, the customers do not need to pay for product maintenance. After the 2-year period, the customers can opt for a maintenance and repair contract.

The business strategy for the stabilized stretcher is to begin sales in the 3rd year (2021). The target is to begin slowly since it is a high-priced product. Hence, in the 3rd year, the sales target is 50 stretchers. The business target strategy is summarized in Table 9.

Table 9 Business target for 1st Year

Target Customer	Business Target (Stabilization Device) (units)
INEM	10
Firefighter's Department	50
Private Ambulance services	60
Ambulance Transformation Companies	30
Total	**150**

Manufacturing strategy:

The products offered are new to the market. To maintain high-quality standards, proper training, and knowledge management as required. The production plan is for 11 months per year. The strategy for the 1st year (Moderate Scenario) is shown in Table 10:

Table 10 Planned Production Quantity for the 1st Year

Month	Planned Production Quantity (units)

1-3	10
4-5	12
6-8	15
9-11	17
Total months=11	Total production= 150

Number of Employees:

At the beginning, to assemble one stabilization device, two employees will be needed, one electrical engineer for assembling the electronics and one production engineer to assemble the product. Apart from them, there will be an employee for quality management and another employee for maintenance management. With proper training, the production can be increased. Our business strategy is to create high value and high-quality products. Hence production time is not an issue initially. The stretcher assembly will need more employees. Depending on the sales forecast, the number of employees needed per year is shown in Annex B- Number of Employees Financial Analysis.

The financial analysis presented below is for the moderated sales scenario. A pessimistic and an optimistic scenario analysis is also done. The pessimistic scenario considers a 15% drop in sales while the optimistic scenario considers a 15% increase in sales as compared to the moderated scenario.

4.8.1 Input data

The input data below is for the moderate scenario while the results are shown for all 3 cases. The input data for the moderated, pessimistic and the optimistic scenario can be found in Annex C- Moderated Scenario, Annex D- Pessimistic Scenario and Annex E- Optimistic Scenario.

Sales + Service Provision:

The sales data can be seen in (Table 11):

Table 11 Sales Data/Year

Sales-National Market	2019	2020	2021	2022	2023	2024
Stabilization Device	**750,000**	**951,563**	**1,255,587**	**1,720,468**	**2,444,785**	**3,474,039**
Amounts Sold	150	188	244	329	461	645
The growth rate of units sold	0%	25.00%	30.00%	35.00%	40.00%	40.00%
Unit price (€)	5,000.00	5,075.00	5,151.13	5,228.39	5,306.82	5,386.42
Maintenance Contracts	**0**	**0**	**16,999**	**34,507**	**77,055**	**172,064**
Amounts Sold	0	0	110	220	484	1,065
The growth rate of units sold	0%	0%	0%	100.00%	120.00%	120.00%
Unit price (€)	150.00	152.25	154.53	156.85	159.20	161.59
Stretcher	**0**	**0**	**1,133,248**	**1,725,369**	**3,064,687**	**6,221,315**
Amounts Sold	0	0	50	75	131	263
The growth rate of units sold	0%	0.00%	0.00%	50.00%	75.00%	100.00%
Unit price (€)	22,000.00	22,330.00	22,664.95	23,004.92	23,350.00	23,700.25

TOTAL (€)	**750,000**	**951,563**	**2,405,833**	**3,480,344**	**5,586,527**	**9,867,418**

Material Costs:

The material costs incurred can be seen in

TOTAL CMVMC		562,500	713,672	1,740,913	2,510,187	4,005,839	7,020,672
VAT	23.00%	129,375	164,145	400,410	577,343	921,343	1,614,755
TOTAL CMVMC + VAT (€)		**691,875**	**877,816**	**2,141,323**	**3,087,530**	**4,927,182**	**8,635,427**

Table 12 Material Costs/Year

Supplies and External Services (FSE):

The supplies and service charges incurred can be seen in Table 13:

Table 13 Supplies and External Services (FSE)/Year

Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
FSE+VAT (€)	13,808.80	17,092.00	29,579.00	33,562.20	55,116.00	77,202.00

Cumulative Salaries:

The cumulative salaries can be seen in Table 14:

Table 14 Number of Employees/Year and Cumulative Salaries/Year

Year	2019	2020	2021	2022	2023	2024
TOTAL PERSONNEL EXPENSES (€)	152,467	181,546	230,232	267,380	321,326	423,138

Investments:

The investments made can be seen in Table 15. It can be seen that in the year 2021, an investment is made to expand operations into the stretcher industry.

Table 15 Total investments/Year

Investment/Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Buildings and other constructions			250,000			
Basic equipment			3,000	5,000	5,000	5,000
Office equipment		1,895	1,893	1,063	5,749	2,125
Total Investment (€)		**1,895**	**254,893**	**6,063**	**10,749**	**7,125**

Financing:

The financing sources can be seen in Table 16. We obtain financing through partner loans and bank financing.

Table 16 Financing acquired/Year

Financing Sources	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Financing Means	3,385	13,427	264,349	442,958	806,861	1,585,486
Capital	5,000					
Partner loans	50,000					
Bank financing and other Inst. Credit	25,000	22,500				
TOTAL (€)	**83,385**	**35,927**	**264,349**	**442,958**	**806,861**	**1,585,486**

4.8.2 Results for all Scenarios Analyzed

Upon the analysis of all three scenarios (Moderate, Pessimistic and Optimistic), the results can be seen in Table 17:

Table 17 Results for all 3 Scenarios Analyzed

Indicators	Moderated Scenario	Pessimistic Scenario	Optimistic Scenario
Internal Rate of Return (IRR)	109.32%	96.05%	137.05%
Pay Back Period	3 years	4 years	3 years
Net Present Value (NPV)	1,292,235€	2,148,912€	2,266,322€
Business Growth Rate (2024)	77%	77%	77%
Return on Investment (ROI) (2024)	34%	34%	34%
Annual Revenue generated (2024)	9,867,418€	8,387,305€	11,347,531€

4.8.3 Financial analysis summary

The financial analysis shows that there is a potential business case for the products with all 3 scenarios. The annual revenue generated at the end of the 6th year is 9.86 million€ (moderate scenario). The pessimistic generates 8.38 million€ which is a 17% drop in revenue compared to the moderate scenario. The optimistic scenario generates 11.34 million€. This is a 15% increase in revenue generated compared to the moderated scenario.

The business growth rate and the return on investments (ROI) are the same in the cases considered as seen in Table 17. The payback period is 3 years for the moderate and the optimistic scenario while for the pessimistic scenario, it takes 4 years to fulfill the payback.

The net present value (NPV) is the lowest for the moderate scenario because investments for expansion is done in the 3rd year. The optimistic scenario also considers expansion investments in the 3rd year but the revenue generated is already higher. The pessimistic scenario also shows a higher NPV due to the expansion's investments being pushed to the 4th year while the stretchers are being sold from the 3rd year. The sales of the stretchers generate higher revenue and hence the rise in NPV occurs.

The financial analysis highlights the potential the business plan has, and it also shows that a sustainable market can be established. The revenue generated gives us the opportunity to expand our products into further generations of products. It also gives the opportunity to explore new markets

CONCLUSIONS

5 Conclusions

5.1 Final comments

Research has shown that vibrations occur during ambulance transport. These vibrations affect both patients and paramedics alike. The vibrations have a more profound effect on the patients since they are already in a state of discomfort and trauma. Some of the effects of vibrations are:

1. Patient trauma or anxiety can increase.
2. Complications can arise.
3. The transport times can be longer.
4. Deaths of patients in the ambulances.
5. Not enough vibrational compensation happens.
6. Delay in the transport of the patient.
7. Risk of causing more injuries.
8. The decrease in patient comfort.
9. The decrease in the ability to supply better care for the patients.

Vibrations affect the paramedics in other ways. Depending on the level of vibrations, the vision of the paramedics can get distorted. The vibrations prevent the paramedics from performing simple functions such as administering injections. The level of noise also prevents the paramedics from effective communication. Even though the vibrations affect the patients and the paramedics, the focus in on the patients.

The Reasons for such occurrences are:

1. Stretchers are not equipped to reduce the vibrational effects.
2. Ambulances are not equipped with devices to reduce the vibrational effects.
3. The ergonomic focus has been on paramedic health due to paramedic sustainability issues.

One way to counter this problem is by developing a stabilized stretcher (Figure 77). The stabilized stretcher has a stabilization unit that actively compensates the vibration in real time. The stabilization unit (stabilization device) fits in between the legs of the stretcher and the mattress frame of the stretcher.

The product development approach was used to develop the product concept of the stretcher. The steps involved were:

1. The problem statement was defined- “Vibrations affect patients during ambulance transport.”
2. The second phase was the research phase. The first type of research was the On-Field research where interviews were conducted to understand:
    a. If there was a need for such a product,
    b. To understand the types of stretchers and ambulances used and
    c. To understand if vibrations was a problem during patient transport.
3. On-field research was done in 4 countries:
    a. Finland,
    b. India,
    c. Poland and
    d. Portugal.
4. The need finding research concluded that there was a need for such a product.
5. Based on the findings from the research, a technical research was done to understand what kind of solution could be developed and what components would be required to build the prototype for the solution.
6. The next phase was the prototyping and testing phase. The first prototype was built with Murata’s gyroscopic sensor to understand the capabilities of the sensor such as the response rate and the sensitivity. Another prototype was built to visually conceptualize how our product would look like. The final protype was the functional prototype. The final prototype had the following build strategy:
7. A custom designed data logger was built for a spring-linear motor-based system. The data logger is the brain of the system.
8. The data logger detects the vibrational information from the roads and processes the information to the drives of the linear motor.
9. The linear motors are controlled by the drive and the sensor guides the motors to compensate the vibrations occurring.
10. While the linear motor does the compensation, 3D printed chains hold the bed the position thereby improving the ride conditions of the patients.
11. From the prototyping, the Product concept was generated.

Figure 86 123

To progress from the product concept and prototyping stage to product development, a business plan is devised. The canvas business model by Alexander Osterwalder is used to make the business model. The strategy is to develop two products in the first 6 years to be sold in Portugal. The first product is a stabilization device which will fit in between the legs of the stretcher and the mattress frame of the stretcher. The stabilization device is custom designed as per our customer needs. Custom designed solutions enhance customer relationships. The customer can choose the features they want in the device. Some of the features are:

1. Battery powered and Replaceable batteries.
2. Portable (Stabilization device feature only).
3. User-friendly.
4. Easy maintenance.
5. Robust.
6. Superior vibration absorption.
7. Increased comfort.
8. Fast charging and
9. Automated guidance vehicle (Stretcher feature only).

The second product is an actively stabilized stretcher. This product is an upgrade to the stabilization device. This product will help improve ride conditions of the patients even more. The product has an ergonomic design to help the paramedics as well (Example: Improved handle design). The stretcher will have an automated guidance vehicle feature in addition to the features in the stabilization device.

The products offer:

1. Increase in comfort by a reduction in vibrations felt by the users.
2. Better stabilization of the patients.
3. Reduced trauma.
4. Better transport conditions.
5. The possibility of faster transport.
6. Possibility to perform more operations on the patient during emergency transport.

After the 6 years, plans can be made to expand into other stabilization sectors and also to provide a further range of products in this sector.

To support the business model strategy, a market need survey, a market analysis and a financial analysis was done. The market need survey is done online. Firefighters, Paramedics, Doctors and Nurses filled the survey. It is a simple survey with questions regarding the market need, willingness to buy, willingness to pay and features required.

The market analysis provides insight into the stretcher industry in Portugal. The information is collected from:

1. The annual report of INEM (Instituto Nacional de Emergência Médica) which is the National Institute of Medical Emergency of Portugal.
2. Statistic databases (Example: Pordata) and
3. Websites (Company websites and yellow pages).

Based on the information the strategy is to begin selling the stabilization device in 2019. The sales target set is 150 stabilization devices. In the first 2 years, the customers do not need to pay for product maintenance. After the 2-year period, the customers can opt for a maintenance and repair contract. The sales for the stabilized stretcher will begin only in the third year (2021).

The financial analysis is done based on the business strategy and the market analysis. The key indicators are:

1. The Sales Revenue,
2. The material costs incurred,
3. The Supplies and External Services costs incurred,
4. The Cumulative Salaries,
5. The Investments and
6. The Financing.

Three scenarios are considered. The business strategy is the moderate sales scenario. The other two scenarios consider a 15% drop in sales (Pessimistic scenario) and a 15% increase in sales (Optimistic scenario) respectively. The financial analysis shows the following results:

Indicators	Moderated Scenario	Pessimistic Scenario	Optimistic Scenario
Internal Rate of Return (IRR)	107.32%	96.05%	137.05%
Pay Back Period	3 years	4 years	3 years
Net Present Value (NPV)	1,292,235€	2,148,912€	2,266,322€
Business Growth Rate (2024)	77%	77%	77%
Return on Investment (ROI) (2024)	34%	34%	34%
Annual Revenue generated (2024)	9,867,418€	8,387,305€	11,347,531€

The financial analysis concludes the business plan. The business plan presents an opportunity to launch new products in the Portugal market. Even with a pessimistic scenario, a sustainable business opportunity is presented, and new products and segments can be explored.

5.2 Future works

The literature review presents information about the effects of vibrations on the human body. The literature also presents information about the road induced vibrations and the suspension systems used in ambulances. Even though there is research work available, it only gives some input regarding the issues. More intensive research is required to truly understand the effects of these vibrations.

Even though the prototype is a functional prototype, more research and development are required. Some of the focus points are:

1. R&D is required to test the prototype, to understand power requirements, or the extent to which the motor can be scaled down.
2. The possibility of using asynchronous servo drives with smaller inertial mass
3. For the actual product, a more sophisticated control scheme is required.
4. Additional data that could be used for improving the control include ambulance steering, tire acceleration, and road surface radar information. These could be used to predict the ambulance movement in advance.
5. Other possibilities include creating a time series model of the accelerations of the bed, also allowing for prediction of movement to some degree.
6. In order to enable tilting across two axes, the future models should either have four motors in the corners, or “delta” system with two motors on one end and one stronger motor in another.

In-depth market survey and market analysis is required validate the business model and financial analysis. The current market survey and analysis can be used to establish the need for existing potential of the market. More subjects need to be interviewed and more data bases need to be analyzed for better results.

REFERENCES AND OTHER SOURCES OF INFORMATION

References, Books and Websites

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References, Books and Websites

[1] S. Al-Shaqsi, “Models of International Emergency Medical Service (EMS) Systems.,” *Oman Med. J.*, vol. 25, no. 4, pp. 320–3, Oct. 2010.

[2] J. L. Arnold, “International Emergency Medicine and the Recent Development of Emergency Medicine Worldwide,” *Ann. Emerg. Med.*, vol. 33, no. 1, pp. 97–103, Jan. 1999.

[3] “INEM Category - INEM.” [Online]. Available: https://www.inem.pt/category/inem/o-inem/. [Accessed: 19-Sep-2018].

[4] “INEM publishes annual report on emergency activity - INEM.” [Online]. Available: https://www.inem.pt/2018/04/17/inem-publica-relatorio-anual-sobre-atividade-dos-meios-de-emergencia/. [Accessed: 19-Sep-2018].

[5] “Emergency Medical Ambulance - INEM.” [Online]. Available: https://www.inem.pt/2017/05/29/ambulancia-de-emergencia-medica/. [Accessed: 19-Sep-2018].

[6] “Motorcycle Emergency Medical - INEM.” [Online]. Available: https://www.inem.pt/2017/05/29/motociclo-de-emergencia-medica/. [Accessed: 19-Sep-2018].

[7] M. Soares-Oliveira, P. Egipto, I. Costa, and L. M. Cunha-Ribeiro, “Emergency motorcycle: has it a place in a medical emergency system?,” *Am. J. Emerg. Med.*, vol. 25, no. 6, pp. 620–622, Jul. 2007.

[8] “Ambulância de Socorro - INEM.” [Online]. Available: https://www.inem.pt/2017/05/29/ambulancia-de-socorro/. [Accessed: 19-Sep-2018].

[9] “Mobile Emergency Psychological Intervention Unit - INEM.” [Online]. Available: https://www.inem.pt/2017/05/29/unidade-movel-de-intervencao-psicologica-de-emergencia/. [Accessed: 20-Sep-2018].

[10] “Emergency Medical Helicopter - INEM.” [Online]. Available: https://www.inem.pt/2017/05/29/helicoptero-de-emergencia-medica/. [Accessed: 20-Sep-2018].

[11] “Existing means.” [Online]. Available: https://www.bombeiros.pt/meios-existentes/. [Accessed: 20-Sep-2018].

[12] “stretcher Meaning in the Cambridge English Dictionary.” [Online]. Available: https://dictionary.cambridge.org/dictionary/english/stretcher. [Accessed: 20-Sep-2018].

[13] WHO international, “Stretcher, Mobile Hospital,” 2012. [Online]. Available: http://www.who.int/medical_devices/innovation/hospt_equip_34.pdf. [Accessed: 20-Sep-2018].

[14] "Stretchers | Stryker." [Online]. Available: https://www.stryker.com/us/en/portfolios/medical-surgical-equipment/stretchers.html. [Accessed: 20-Sep-2018].

[15] "Ambulance Cots." [Online]. Available: http://www.fernoems.com/products/ambulance-cots/cots. [Accessed: 20-Sep-2018].

[16] "Self loading stretcher with adjustable heights Cross | Spencer." [Online]. Available: https://www.spencer.it/en/products/transport-systems/ambulance-stretchers/cross. [Accessed: 20-Sep-2018].

[17] "Auto Ribeiro –." [Online]. Available: http://www.autoribeiro.com/b.php. [Accessed: 20-Sep-2018].

[18] "Ems - Ambulance Stretcher - Transfers Main Stretcher." [Online]. Available: http://www.ems.tc/en/products/stretchers/ems-transfer-main-stretcher. [Accessed: 20-Sep-2018].

[19] "Stretcher with adjustable heights Roller | Spencer." [Online]. Available: https://www.spencer.it/en/products/transport-systems/ambulance-stretchers/roller. [Accessed: 20-Sep-2018].

[20] American Academy of Orthopaedic Surgeons, *Emergency Care and Transportation of the Sick and Injured - American Academy of Orthopaedic Surgeons - Google Books*. 2011.

[21] "Model 71 Basket Stretcher, 71 Stretcher Basket." [Online]. Available: http://www.fernoems.com/en/products/basket-stretchers/basket-stretchers/Model-71-Basket-Stretcher.aspx?ec_trk=followlist&ec_trk_data=basket-stretchers. [Accessed: 20-Sep-2018].

[22] "Ferno 65 EXL Scoop Stretcher | Scoop Stretchers." [Online]. Available: https://www.dsmedical.co.uk/treatment-c14/immobilisation-c32/ferno-65-exl-scoop-stretcher-pinned-p317. [Accessed: 20-Sep-2018].

[23] "Double Fold Stretcher : Medical Equipment Supplier : Malaysia Rescue Kit Supplier : Paramedic Stretcher Supplier." [Online]. Available: http://www.promed.com.my/products/stretcher/paramedic-stretcher/double-fold-stretcher-w2-strap-nylon-mesh-carrying-bag/. [Accessed: 20-Sep-2018].

[24] "GLOBEX Evacuation Chair 6 - Products | GLOBEX Evacuation." [Online]. Available: https://globexevacuation.com/evacuation-chairs/gec6-evacuation-chair. [Accessed: 20-Sep-2018].

[25] R. Brandel, "EMS Safety, Stretchers, and Stretcher Handling," 2016.

[26] J. Graziosi, L. Barber, M. Wojcik, and M. S. Fofana, "Ambulance Services, Reliability Problems and Potential Technologies An Interactive Qualifying Project," 2010.

[27] "EMTs and Paramedics : Occupational Outlook Handbook: : U.S. Bureau of Labor Statistics." [Online]. Available: https://www.bls.gov/ooh/healthcare/emts-and-paramedics.htm#tab-3. [Accessed: 20-Sep-2018].

[28] A. M. Abd-El-Tawwab, "Ambulance Stretcher with Active Control Isolator System," *J. Low Freq. Noise, Vib. Act. Control*, vol. 20, no. 4, pp. 217–227, Dec. 2001.

[29] N. . J. Granlund and F. Lindström, "Reducing Whole-Body Vibration by Geometric Repair of Pavements," *J. Low Freq. Noise, Vib. Act. Control*, vol. 23,

no. 2, pp. 103–114, Jun. 2004.

[30] M. Fereydooni, A. Nejat Lorestani, H. Rabbani, and P. Javadikia, “Measurement and Analysis of Vibration of Operator in Universal 650, Massey Ferguson 285 & MF 299 Tractors,” *Int. J. Mech. Appl.*, vol. 2, no. 5, pp. 88–92, Dec. 2012.

[31] G. Z. Heinrich Dupuis, *The Effects of Whole-Body Vibration*. Springer, 2012.

[32] N. H. Prasad, L. H. Brown, S. C. Ausband, O. Cooper-Spruill, R. G. Carroll, and T. W. Whitley, “Prehospital blood pressures: Inaccuracies caused by ambulance noise?,” *Am. J. Emerg. Med.*, vol. 12, no. 6, pp. 617–620, Nov. 1994.

[33] N. JMansfield, *HUMAN RESPONSE TO VIBRATION*. 2004.

[34] U. Weber *et al.*, “Emergency ambulance transport induces stress in patients with acute coronary syndrome.,” *Emerg. Med. J.*, vol. 26, no. 7, pp. 524–8, Jul. 2009.

[35] B. Basri and M. J. Griffin, “The vibration of inclined backrests: perception and discomfort of vibration applied normal to the back in the x-axis of the body,” *J. Sound Vib.*, vol. 330, no. 18–19, pp. 4646–4659, Aug. 2011.

[36] C. V Bellieni, I. Pinto, N. Stacchini, D. M. Cordelli, and F. Bagnoli, “[Vibration risk during neonatal transport].,” *Minerva Pediatr.*, vol. 56, no. 2, pp. 207–12, Apr. 2004.

[37] H. B. Sherwood, A. Donze, and J. Giebe, “Mechanical Vibration in Ambulance Transport,” *J. Obstet. Gynecol. Neonatal Nurs.*, vol. 23, no. 6, pp. 457–463, Jul. 1994.

[38] B.-M. Karlsson *et al.*, “Sound and vibration: effects on infants’ heart rate and heart rate variability during neonatal transport,” *Acta Paediatr.*, vol. 101, no. 2, pp. 148–154, Feb. 2012.

[39] M. J. Sherwood, N., & Griffin, “Effects of whole-body vibration on short-term memory.,” *Aviat. Space. Environ. Med.*, vol. 61, no. 12, pp. 1092–1097, 1990.

[40] “Vibration Damping - www.sorbothane.com.” [Online]. Available: https://www.sorbothane.com/vibration-damping.aspx. [Accessed: 20-Sep-2018].

[41] D. I. G. Jones, *Handbook of viscoelastic vibration damping*. J. Wiley, 2001.

[42] “ERAS GmbH | vibration measurement | vibration analysis | vibration control | vibration isolation | vibration reduction | anti vibration.” [Online]. Available: https://www.eras.de/EN/EN_SOL_bnaw.html. [Accessed: 20-Sep-2018].

[43] “Shock absorbing stretcher support.” [Online]. Available: http://www.stem.it/en-en/stretcher-supports-ambulances/shock-absorbing-stretcher-support-eden.html. [Accessed: 20-Sep-2018].

[44] “Mine shock and vibration damped stretcher rack.” [Online]. Available: http://www.medevac.no/index.php/en/land-systems-2/11-mine-shock-and-vibration-damped-stretcher-rack. [Accessed: 20-Sep-2018].

[45] “ProMIL 360 Hydraulic Lift Treatment Base.” [Online]. Available: https://www.frestems.fi/products/military-stretcher-fastening-systems/promil-360-hydraulic-lift-treatment-base/. [Accessed: 20-Sep-2018].

[46] L. Bruzzone *et al.*, “PARALLEL ROBOT FOR AMBULANCE STRETCHER ACTIVE SUSPENSION,” 2002.

[47] T. Ono and H. Inooka, “Actively-controlled beds for ambulances,” *Int. J. Autom. Comput.*, vol. 6, no. 1, pp. 1–6, Feb. 2009.

[48] H. D. Chae and S.-B. Choi, "A new vibration isolation bed stage with magnetorheological dampers for ambulance vehicles," *Smart Mater. Struct.*, vol. 24, no. 1, p. 017001, Jan. 2015.

[49] R. Votrubec, "Control System of One-Axis Vibration-Insulation Platform with Gyroscopic-Stabilizer," in *Mechatronics 2013*, Cham: Springer International Publishing, 2014, pp. 733–739.

[50] "Construction of stabilised platform," Sep. 1972.

[51] "Shock absorbing transport frame," Feb. 2002.

[52] "Vibration damping supports," Aug. 1983.

[53] "Actuator arrangement for active vibration isolation using a payload as an inertial reference mass," Jan. 2005.

[54] "Vibration isolator having magnetic springs," Oct. 1999.

[55] "Patient transport method and apparatus," Mar. 2005.

[56] "Vibration isolation arrangement," Nov. 1987.

[57] "Upper frame position holding structure and ambulance vibration-proof rack having upper frame position holding structure," Nov. 2012.

[58] A. Osterwalder, Y. Pigneur, T. Clark, and A. Smith, *Business model generation : a handbook for visionaries, game changers, and challengers*. .

[59] "Porto Design Factory — P.PORTO | Ensino Superior Público." [Online]. Available: https://www.ipp.pt/innovation/porto-design-factory. [Accessed: 21-Sep-2018].

[60] "Ficha de projeto — Porto Design Factory." [Online]. Available: https://www.pdf.ipp.pt/apresentacao/ficha_de_projeto. [Accessed: 21-Sep-2018].

[61] "Product Development Project - Porto Design Factory." [Online]. Available: https://www.pdf.ipp.pt/educacao/product_development_project. [Accessed: 21-Sep-2018].

[62] "Course Overview » PdP – Aalto University." [Online]. Available: http://pdp.fi/course-overview/. [Accessed: 21-Sep-2018].

[63] "About Murata | Murata Manufacturing Co., Ltd." [Online]. Available: https://www.murata.com/en-us/about?intcid5=com_xxx_xxx_cmn_nv_xxx. [Accessed: 21-Sep-2018].

[64] "SCC2000 Series Combined Gyro Sensor and Accelerometer | Gyro Sensors | Sensors | Murata Manufacturing Co., Ltd." [Online]. Available: https://www.murata.com/products/sensor/gyro/scc2000. [Accessed: 21-Sep-2018].

[65] "APOLLO HOSPITALS DONATES STATE OF ART AMBULANCE TO TTD – TTD News." [Online]. Available: http://news.tirumala.org/apollo-hospitals-donates-state-of-art-ambulance-to-ttd/. [Accessed: 21-Sep-2018].

[66] "POWERFlexx+? Powered Cot, Ferno Powered Cot." [Online]. Available: http://www.fernoems.com/en/powerflexx/powerflexx-powered-cot.aspx?ec_trk=followlist&ec_trk_data=powerflexx. [Accessed: 22-Sep-2018].

[67] "EMGFA." [Online]. Available: https://www.emgfa.pt/pt/organizacao/dirsam/hfarhospital. [Accessed: 20-Sep-2018].

[68] "Ambulância e transporte de doentes." [Online]. Available: https://www.acp.pt/saude-e-seguros/para-a-sua-saude/servicos-incluidos-para-socios/transporte-de-doentes/entity/ambulancia-e-transporte-de-doentes. [Accessed: 20-Sep-2018].

[69] "Tagus Ambulâcias." [Online]. Available: http://www.ambulanciastagus.pt/. [Accessed: 20-Sep-2018].

[70] "Range of processed cars | Renault Portugal." [Online]. Available: https://www.renault.pt/gama/transformados/veiculos-transformados/ambulancias.jsp. [Accessed: 20-Sep-2018].

[71] "Ambulâncias usados para venda - Mascus Portugal." [Online]. Available: https://www.mascus.pt/transporte/ambulancias-usadas. [Accessed: 20-Sep-2018].

[72] "MedicalExpo - The online medical exhibition: medical material, medical imagery, hospital furniture, laboratory equipment, etc." [Online]. Available: http://www.medicalexpo.com/. [Accessed: 20-Sep-2018].

[73] J. A. Rodgers, D. C. Yen, and D. C. Chou, "Developing e-business; a strategic approach," *Inf. Manag. Comput. Secur.*, vol. 10, no. 4, pp. 184–192, Oct. 2002.

[74] "Advantages and disadvantages of online retailing | nibusinessinfo.co.uk." [Online]. Available: https://www.nibusinessinfo.co.uk/content/advantages-and-disadvantages-online-retailing. [Accessed: 20-Sep-2018].

[75] "Placing Medical Devices in Portugal -- MEDICA - World Forum for Medicine." [Online]. Available: https://www.medica-tradefair.com/cgi-bin/md_medica/lib/pub/tt.cgi/Placing_Medical_Devices_in_Portugal.html?oid=29030&lang=2&ticket=g_u_e_s_t. [Accessed: 20-Sep-2018].

[76] E. D. Parrish, N. L. Cassill, and W. Oxenham, "Niche market strategy for a mature marketplace," *Mark. Intell. Plan.*, vol. 24, no. 7, pp. 694–707, Dec. 2006.

[77] "Hospital Stretchers Market is Expected to Reach USD 1.7 Billion Globally By 2019: Transparency Market Research." [Online]. Available: https://globenewswire.com/news-release/2014/10/28/677217/10104818/en/Hospital-Stretchers-Market-is-Expected-to-Reach-USD-1-7-Billion-Globally-By-2019-Transparency-Market-Research.html. [Accessed: 22-Sep-2018].

[78] "Global Emergency Stretcher Market Report 2017 – Market Reports World." [Online]. Available: https://www.marketreportsworld.com/global-emergency-stretcher-market-report-2017-10574929. [Accessed: 22-Sep-2018].

[79] "RELATÓRIO ANUAL Meios de Emergência Médica."

[80] "PORDATA - Corpos de Bombeiros." [Online]. Available: https://www.pordata.pt/Portugal/Corpos+de+Bombeiros-1107. [Accessed: 23-Sep-2018].

[81] "Beginning | SafeMobility." [Online]. Available: http://www.teclife.pt/pt. [Accessed: 23-Sep-2018].

[82] "B AMBULANCES in Portugal. List of AMBULANCE B companies in Portugal." [Online]. Available: https://empresite.jornaldenegocios.pt/Actividade/AMBULANCIAS-B/. [Accessed: 23-Sep-2018].

Annexes

Annex A- Market analysis

Annex C- Number of Employees

Annex D- Moderated Scenario

Annex E- Pessimistic Scenario

Annex F- Optimistic Scenario

Annex

Annex A- Market analysis

Actively Stabilized EMS Stretcher

The idea is to develop a stabilized stretcher. The proposed stretcher will receive the vibration information from the road during the transport of the patient and will actively compensate the effects of vibrations on the stretcher. With the effects of vibrations being reduced, the ride conditions improve resulting in safer transport.

Email address *

Do you think there is a need for this type of product? *

- (•) Yes
- ( ) No
- ( ) Maybe

Figure 87 Interview 1 Side 1

Would you be interested in acquiring this product? *

- ( ) Yes
- ( ) No
- (•) Maybe

If yes, how much would you be willing to pay for it?

- ( ) Less than 2000€
- ( ) Between 2000-4000€
- (•) More than 4000€

What features would appeal to you the most? *

- [x] Battery powered and replaceable batteries
- [x] User friendly
- [x] Easy maintenance
- [x] Plug-in features
- [x] Fast charging
- [x] Automated guidence vehicle
- [ ] Others

What other features would you like the product to have?

Figure 88 Interview 1 Side 2

Actively Stabilized EMS Stretcher

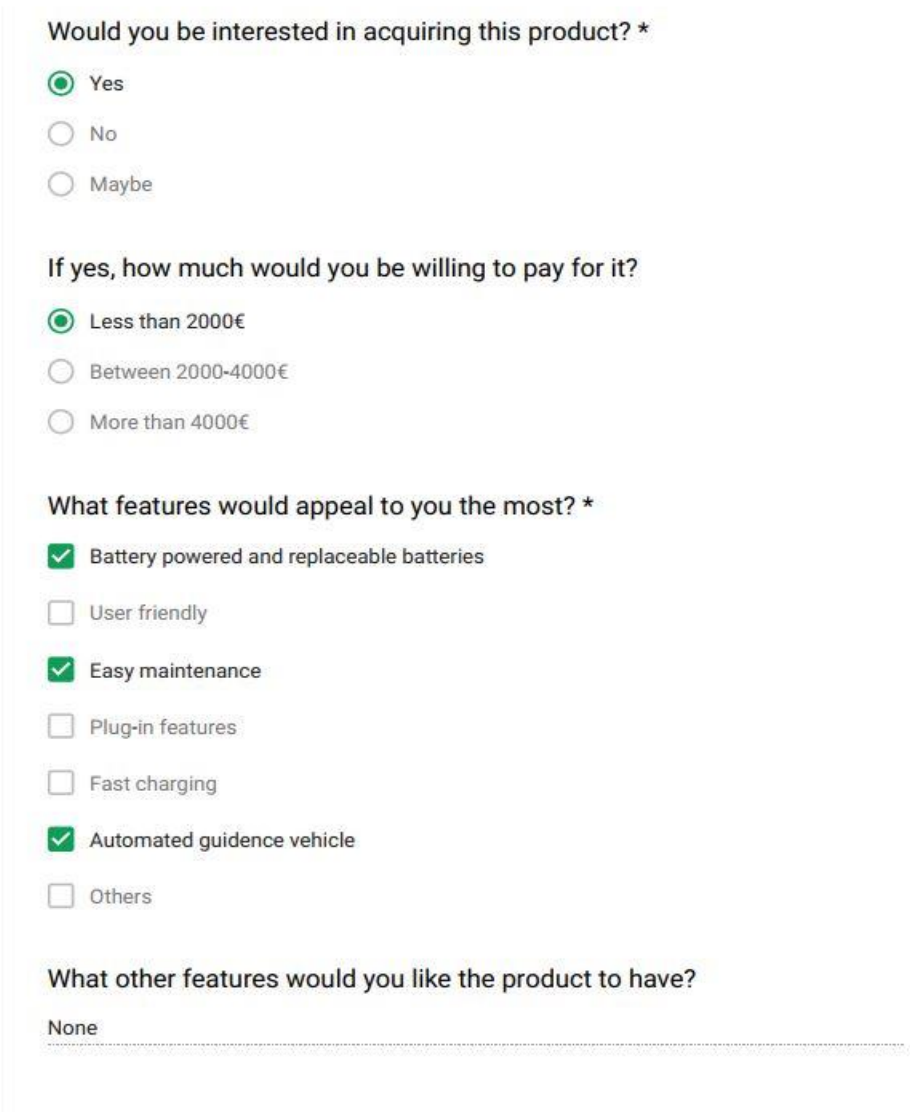
The idea is to develop a stabilized stretcher. The proposed stretcher will receive the vibration information from the road during the transport of the patient and will actively compensate the effects of vibrations on the stretcher. With the effects of vibrations being reduced, the ride conditions improve resulting in safer transport.

Email address *

Do you think there is a need for this type of product? *

- (●) Yes
- ( ) No
- ( ) Maybe

Figure 89 Interview 2 Side 1



Would you be interested in acquiring this product? *

- (●) Yes
- ( ) No
- ( ) Maybe

If yes, how much would you be willing to pay for it?

- (●) Less than 2000€
- ( ) Between 2000-4000€
- ( ) More than 4000€

What features would appeal to you the most? *

- [x] Battery powered and replaceable batteries
- [ ] User friendly
- [x] Easy maintenance
- [ ] Plug-in features
- [ ] Fast charging
- [x] Automated guidence vehicle
- [ ] Others

What other features would you like the product to have?

None

Figure 90 Interview 2 Side 2

Annex B- Number of Employees

Table 18 Number of Employees per year in a Moderated sales scenario

Year	Production Employees
2019	2
2020	2
2021	4
2022	5
2023	7
2024	12

Table 19 Number of Employees per product

Year	P1 (units)	P2 (units)	P1(avg. u/m)	P2(avg u/m)	PT1(avg. d/u)	PT2(avg. d/u)	EP1	EP2
2019	150	-	14	-	1.5	-	2	-
2020	188	-	17.	-	1.2	-	2	-
2021	244	50	22.	4.5	0.9	5	2	2
2022	329	75	30	7	0.67	3	3	2
2023	461	131	42	12	0.5	1.6	4	3
2024	645	263	59	24	0.34	0.8	6	6

Table 20 Number of Employees per product table Legend

Abbreviation	Definition
P1	Product 1- Stabilization device
P2	Product 2- Stabilized stretcher
PT1	Product 1 Production Time
PT2	Product 2 Production Time
EP1	Employees for Product 1
EP2	Employees for Product 2
Avg. u/m	Average Units/Month
Avg. d/u	Average Days/Unit

Annex C- Moderated Scenario

	2019	2020	2021	2022	2023	2024
Taxa de variação dos preços		1.50%	1.50%	1.50%	1.50%	1.50%

VENDAS - MERCADO NACIONAL	2019	2020	2021	2022	2023	2024
Stabilization Device	**750,000**	**951,563**	**1,255,587**	**1,720,468**	**2,444,785**	**3,474,039**
Quantidades vendidas	150	188	244	329	461	645
Taxa de crescimento das unidades vendidas	0%	25.00%	30.00%	35.00%	40.00%	40.00%
Preço Unitário	5,000.00	5,075.00	5,151.13	5,228.39	5,306.82	5,386.42
Maintenance Contracts	**0**	**0**	**16,999**	**34,507**	**77,055**	**172,064**
Quantidades vendidas	0	0	110	220	484	1,065
Taxa de crescimento das unidades vendidas	0%	0%	0%	100.00%	120.00%	120.00%
Preço Unitário	150.00	152.25	154.53	156.85	159.20	161.59
Stretcher	**0**	**0**	**1,133,248**	**1,725,369**	**3,064,687**	**6,221,315**
Quantidades vendidas	0	0	50	75	131	263
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	50.00%	75.00%	100.00%
Preço Unitário	22,000.00	22,330.00	22,664.95	23,004.92	23,350.00	23,700.25
	0	**0**	**0**	**0**	**0**	**0**
Quantidades vendidas	0	0	0	0	0	0
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	0.00%	0.00%	0.00%
Preço Unitário	500.00	507.50	515.11	522.84	530.68	538.64
TOTAL	**750,000**	**951,563**	**2,405,833**	**3,480,344**	**5,586,527**	**9,867,418**

Figure 91 Yearly Sales data in Moderate scenario

VENDAS - EXPORTAÇÃO	2019	2020	2021	2022	2023	2024
Produto A *	0	0	0	0	0	0
Quantidades vendidas		0	0	0	0	0
Taxa de crescimento das unidades vendidas						
Preço Unitário		0.00	0.00	0.00	0.00	0.00
Produto B *	0	0	0	0	0	0
Quantidades vendidas		0	0	0	0	0
Taxa de crescimento das unidades vendidas						
Preço Unitário		0.00	0.00	0.00	0.00	0.00
TOTAL	0	0	0	0	0	0

* Produtos / Famílias de Produtos / Mercadorias

NOTA: Caso não tenha conhecimento das quantidades, colocar o valor das vendas na linha das "Quantidades Vendidas" e o valor 1 na linha do "Preço Unitário".

PRESTAÇÕES DE SERVIÇOS - MERCADO NACIONAL	2019	2020	2021	2022	2023	2024
Serviço A	0	0	0	0	0	0
Taxa de crescimento						
Serviço B		0	0	0	0	0
Taxa de crescimento						
Serviço C		0	0	0	0	0
Taxa de crescimento						
Serviço D		0	0	0	0	0
Taxa de crescimento						
TOTAL	0	0	0	0	0	0

Figure 92 Export Sales information for moderated scenario

TOTAL VENDAS - MERCADO NACIONAL		750,000	951,563	2,405,833	3,480,344	5,586,527	9,867,418
TOTAL VENDAS - EXPORTAÇÕES		0	0	0	0	0	0
TOTAL VENDAS		750,000	951,563	2,405,833	3,480,344	5,586,527	9,867,418
IVA VENDAS	23.00%	172,500	218,859	553,342	800,479	1,284,901	2,269,506
TOTAL PRESTAÇÕES DE SERVIÇOS - MERCADO NACIONAL		0	0	0	0	0	0
TOTAL PRESTAÇÕES DE SERVIÇOS - EXPORTAÇÕES		0	0	0	0	0	0
TOTAL PRESTAÇÕES SERVIÇOS		0	0	0	0	0	0
IVA PRESTAÇÕES DE SERVIÇOS	23.00%	0	0	0	0	0	0
TOTAL VOLUME DE NEGÓCIOS		750,000	951,563	2,405,833	3,480,344	5,586,527	9,867,418
IVA		172,500	218,859	553,342	800,479	1,284,901	2,269,506
TOTAL VOLUME DE NEGÓCIOS + IVA		922,500	1,170,422	2,959,175	4,280,824	6,871,428	12,136,924
Perdas por imparidade %	2.00%	18,450	23,408	59,183	85,616	137,429	242,738

Figure 93 Moderated scenario yearly sales revenue

CMVMC - Custo das Mercadorias Vendidas e Matérias Consumidas

CMVMC	Margem Bruta	2019	2020	2021	2022	2023	2024
MERCADO NACIONAL		562,500	713,672	1,740,913	2,510,187	4,005,839	7,020,672
Stabilization Device	25.00%	562,500	713,672	941,690	1,290,351	1,833,588	2,605,529
Maintenance Contracts	65.00%			5,950	12,078	26,969	60,222
Stretcher	30.00%			793,273	1,207,759	2,145,281	4,354,921
MERCADO EXTERNO							
Produto A *							
Produto B *							
TOTAL CMVMC		562,500	713,672	1,740,913	2,510,187	4,005,839	7,020,672
IVA	23.00%	129,375	164,145	400,410	577,343	921,343	1,614,755
TOTAL CMVMC + IVA		691,875	877,816	2,141,323	3,087,530	4,927,182	8,635,427

Figure 94 Material costs incurred in moderate sales scenario

Investimento por ano	2019	2020	2021	2022	2023	2024
Propriedades de investimento						
Terrenos e recursos naturais						
Edificios e Outras construções			250,000			
Outras propriedades de investimento						
Total propriedades de investimento			**250,000**			
Activos fixos tangíveis						
Terrenos e Recursos Naturais						
Edificios e Outras Construções						
Equipamento Básico			3,000	5,000	5,000	5,000
Equipamento de Transporte						
Equipamento Administrativo		1,895	1,893	1,063	5,749	2,125
Equipamentos biológicos						
Outros activos fixos tangiveis						
Total Activos Fixos Tangíveis		**1,895**	**4,893**	**6,063**	**10,749**	**7,125**
Activos Intangíveis						
Goodwill						
Projectos de desenvolvimento						
Programas de computador						
Propriedade industrial						
Outros activos intangíveis						
Total Activos Intangíveis						
Total Investimento		**1,895**	**254,893**	**6,063**	**10,749**	**7,125**
IVA 23%		**436**	**1,125**	**1,394**	**2,472**	**1,639**

Figure 95 Investment for moderated sales scenario

Valores Acumulados	2019	2020	2021	2022	2023	2024
Propriedades de investimento						
Terrenos e recursos naturais						
Edificios e Outras construções			250,000	250,000	250,000	250,000
Outras propriedades de investimento						
Total propriedades de investimento			**250,000**	**250,000**	**250,000**	**250,000**
Activos fixos tangíveis						
Terrenos e Recursos Naturais						
Edificios e Outras Construções						
Equipamento Básico			3,000	8,000	13,000	18,000
Equipamento de Transporte						
Equipamento Administrativo		1,895	3,788	4,850	10,599	12,724
Equipamentos biológicos						
Outros activos fixos tangiveis						
Total Activos Fixos Tangíveis		**1,895**	**6,788**	**12,850**	**23,599**	**30,724**
Activos Intangíveis						
Goodwill						
Projectos de desenvolvimento						
Programas de computador						
Propriedade industrial						
Outros activos intangíveis						
Total Activos Intangíveis						
Total		**1,895**	**256,788**	**262,850**	**273,599**	**280,724**

Figure 96 Total investments for moderated sales scenario

Quadro de Pessoal (n.º pessoas)	2019	2020	2021	2022	2023	2024
Administração / Direcção	1	1	1	1	1	1
Administrativa Financeira	1	1	1	1	1	1
Comercial / Marketing	1	1	1	2	2	2
Produção / Operacional	2	2	4	5	7	12
Qualidade	1	1	2	2	2	2
Manutenção	1	1	3	3	4	5
Aprovisionamento						
Investigação & Desenvolvimento	3	3	3	3	3	3
Outros						
TOTAL	**10**	**10**	**15**	**17**	**20**	**26**

Figure 97 Number of Employees

	2019	2020	2021	2022	2023	2024
Nº Meses	12	12	12	12	12	12
Taxa de crescimento						

	Tx IVA	CF	CV	Valor Mensal	2019	2020	2021	2022	2023	2024
Subcontratos	23.0%	100.0%								
Serviços especializados										
Trabalhos especializados	23.0%	100.0%			2,400.00	2,400.00	2,400.00	2,400.00	4,800.00	4,800.00
Publicidade e propaganda	23.0%	100.0%		250.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00	3,000.00
Vigilância e segurança	23.0%	100.0%								
Honorários	23.0%	100.0%								
Comissões	23.0%	100.0%								
Conservação e reparação	23.0%	100.0%								
Materiais										
Ferramentas e utensílios de desgaste rápido	23.0%	100.0%		20.00	720.00	720.00	1,200.00	1,440.00	1,920.00	3,120.00
Livros e documentação técnica	23.0%	100.0%								
Material de escritório	23.0%	100.0%		20.00	1,080.00	1,080.00	1,560.00	1,800.00	2,280.00	3,480.00
Artigos para oferta	23.0%	100.0%								
Energia e fluidos										
Electricidade	23.0%	100.0%					600.00	600.00	1,800.00	1,800.00
Combustíveis	23.0%	100.0%		25.00			2,750.00	5,500.00	12,100.00	26,620.00
Água	6.0%	100.0%								
Deslocações, estadas e transportes										
Deslocações e Estadas	23.0%	100.0%		50.00	1,050.00	1,800.00	2,400.00	2,400.00	3,000.00	3,600.00
Transportes de pessoal	23.0%	100.0%								
Transportes de mercadorias	23.0%	100.0%								
Serviços diversos										
Rendas e alugueres	23.0%	100.0%			360.00	360.00	2,400.00	2,400.00	7,800.00	7,800.00
Comunicação	23.0%	100.0%			360.00	1,200.00	2,760.00	3,120.00	3,840.00	5,640.00
Seguros		100.0%		50.00			600.00	600.00	600.00	600.00
Royalties	23.0%	100.0%								
Contencioso e notariado	23.0%	100.0%			1,000.00	1,000.00	1,500.00	1,700.00	2,000.00	2,600.00
Despesas de representação	23.0%	100.0%		100.00	2,100.00	3,600.00	4,800.00	4,800.00	6,000.00	7,200.00
Limpeza, higiene e conforto	23.0%	100.0%					780.00	780.00	1,560.00	1,560.00
Outros serviços	23.0%	100.0%								
TOTAL FSE					**12,070.00**	**15,160.00**	**26,750.00**	**30,540.00**	**50,700.00**	**71,820.00**
FSE - Custos Fixos					**12,070.00**	**15,160.00**	**26,750.00**	**30,540.00**	**50,700.00**	**71,820.00**
FSE - Custos Variáveis										
TOTAL FSE					**12,070.00**	**15,160.00**	**26,750.00**	**30,540.00**	**50,700.00**	**71,820.00**
IVA					1,738.80	1,932.00	2,829.00	3,022.20	4,416.00	5,382.00
FSE + IVA					**13,808.80**	**17,092.00**	**29,579.00**	**33,562.20**	**55,116.00**	**77,202.00**

Figure 98 Supplies and Service cost incurred in Moderate sales scenario

	2019	2020	2021	2022	2023	2024
Investimento	95,197	14,408	357,766	81,594	158,704	313,127
Margem de segurança	50.00%	40.00%	30.00%	20.00%	10.00%	10.00%
Necessidades de financiamento	**142,800**	**20,200**	**465,100**	**97,900**	**174,600**	**344,400**

Fontes de Financiamento	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Meios Libertos	3,385	13,427	264,349	442,958	806,861	1,585,486
Capital	5,000					
Outros instrumentos de capital						
Empréstimos de Sócios	50,000					
Financiamento bancário e outras Inst. Crédito	25,000		35,000			
Subsidios						
TOTAL	**83,385**	**13,427**	**299,349**	**442,958**	**806,861**	**1,585,486**

N.º de anos reembolso	4.00
Taxa de juro associada	3.50%
N.º anos de carência	0.50

Figure 99 Moderate Sales Scenario Investments

	2019	2020	2021	2022	2023	2024
Vendas e serviços prestados	750,000.00	951,562.50	2,405,832.93	3,480,344.41	5,586,526.85	9,867,417.85
Variação nos inventários da produção						
CMVMC	562,500.00	713,671.88	1,740,912.84	2,510,186.88	4,005,838.78	7,020,672.11
FSE Variáveis						
Margem Bruta de Contribuição	**187,500.00**	**237,890.63**	**664,920.09**	**970,157.52**	**1,580,688.07**	**2,846,745.74**
Ponto Crítico	**658,146.00**	**788,338.90**	**970,100.67**	**1,111,701.32**	**1,363,406.69**	**1,766,908.59**

Figure 100 Critical points for moderate sales scenario

	2019	2020	2021	2022	2023	2024
ACTIVO						
Activo Não Corrente		**1,516**	**245,276**	**239,369**	**236,373**	**228,703**
Activos fixos tangíveis		1,516	5,276	9,369	16,373	18,703
Propriedades de investimento			240,000	230,000	220,000	210,000
Activos Intangíveis						
Investimentos financeiros						
Activo corrente	**215,688**	**256,323**	**560,460**	**1,143,127**	**2,241,241**	**4,471,898**
Inventários	23,438	29,736	72,538	104,591	166,910	292,528
Clientes	135,300	153,212	392,154	526,812	821,151	1,455,995
Estado e Outros Entes Públicos						
Accionistas/sócios						
Outras contas a receber						
Diferimentos						
Caixa e depósitos bancários	56,950	73,375	95,768	511,724	1,253,180	2,723,375
TOTAL ACTIVO	**215,688**	**257,839**	**805,736**	**1,382,496**	**2,477,614**	**4,700,601**

Figure 101 Active Balance for Moderated Sales Scenario

INDICADORES ECONÓMICOS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Taxa de Crescimento do Negócio		27%	153%	45%	61%	77%
Rentabilidade Líquida sobre as vendas	0%	1%	10%	12%	14%	16%
INDICADORES ECONÓMICOS - FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Return On Investment (ROI)	1%	5%	31%	31%	32%	34%
Rendibilidade do Activo	2%	7%	42%	42%	43%	45%
Rotação do Activo	348%	369%	299%	252%	225%	210%
Rendibilidade dos Capitais Próprios (ROE)	36%	70%	115%	77%	66%	64%
INDICADORES FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Autonomia Financeira	4%	7%	27%	41%	49%	53%
Solvabilidade Total	104%	107%	137%	169%	195%	211%
Cobertura dos encargos financeiros	514%	1980%	13975%	26165%	53500%	148994%
INDICADORES DE LIQUIDEZ	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Liquidez Corrente	1.18	1.16	1.04	1.47	1.80	2.03
Liquidez Reduzida	1.05	1.02	0.91	1.34	1.67	1.90
INDICADORES DE RISCO NEGÓCIO	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Margem Bruta	175,430	222,731	638,170	939,618	1,529,988	2,774,926
Grau de Alavanca Operacional	3887%	1280%	189%	164%	145%	133%
Grau de Alavanca Financeira	122%	104%	101%	100%	99%	99%

Figure 102 Moderate Sales Scenario Principle Indicators

Annex D- Pessimistic Scenario

VENDAS - MERCADO NACIONAL	2019	2020	2021	2022	2023	2024
Stabilization Device	**637,500**	**808,828**	**1,067,249**	**1,462,398**	**2,078,067**	**2,952,933**
Quantidades vendidas	128	159	207	280	392	548
Taxa de crescimento das unidades vendidas	0%	25.00%	30.00%	35.00%	40.00%	40.00%
Preço Unitário	5,000.00	5,075.00	5,151.13	5,228.39	5,306.82	5,386.42
Maintenance Contracts	**0**	**0**	**14,449**	**29,331**	**65,497**	**146,254**
Quantidades vendidas	0	0	94	187	411	905
Taxa de crescimento das unidades vendidas	0%	0%	0%	100.00%	120.00%	120.00%
Preço Unitário	150.00	152.25	154.53	156.85	159.20	161.59
Stretcher	**0**	**0**	**963,260**	**1,466,564**	**2,604,984**	**5,288,118**
Quantidades vendidas	0	0	43	64	112	223
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	50.00%	75.00%	100.00%
Preço Unitário	22,000.00	22,330.00	22,664.95	23,004.92	23,350.00	23,700.25
	0	**0**	**0**	**0**	**0**	**0**
Quantidades vendidas	0	0	0	0	0	0
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	0.00%	0.00%	0.00%
Preço Unitário	500.00	507.50	515.11	522.84	530.68	538.64
TOTAL	**637,500**	**808,828**	**2,044,958**	**2,958,293**	**4,748,548**	**8,387,305**

Figure 103 Yearly Sales data in Pessimistic scenario

TOTAL VENDAS - MERCADO NACIONAL		**750,000**	**951,563**	**2,405,833**	**3,480,344**	**5,586,527**	**9,867,418**
TOTAL VENDAS - EXPORTAÇÕES		**0**	**0**	**0**	**0**	**0**	**0**
TOTAL VENDAS		**750,000**	**951,563**	**2,405,833**	**3,480,344**	**5,586,527**	**9,867,418**
IVA VENDAS	23.00%	**172,500**	**218,859**	**553,342**	**800,479**	**1,284,901**	**2,269,506**
TOTAL PRESTAÇÕES DE SERVIÇOS - MERCADO NACIONAL		**0**	**0**	**0**	**0**	**0**	**0**
TOTAL PRESTAÇÕES DE SERVIÇOS - EXPORTAÇÕES		**0**	**0**	**0**	**0**	**0**	**0**
TOTAL PRESTAÇÕES SERVIÇOS		**0**	**0**	**0**	**0**	**0**	**0**
IVA PRESTAÇÕES DE SERVIÇOS	23.00%	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL VOLUME DE NEGÓCIOS		**750,000**	**951,563**	**2,405,833**	**3,480,344**	**5,586,527**	**9,867,418**
IVA		**172,500**	**218,859**	**553,342**	**800,479**	**1,284,901**	**2,269,506**
TOTAL VOLUME DE NEGÓCIOS + IVA		**922,500**	**1,170,422**	**2,959,175**	**4,280,824**	**6,871,428**	**12,136,924**
Perdas por imparidade %	2.00%	**18,450**	**23,408**	**59,183**	**85,616**	**137,429**	**242,738**

Figure 104 Pessimistic scenario yearly sales revenue

CMVMC	Margem Bruta	2019	2020	2021	2022	2023	2024
MERCADO NACIONAL		**478,125**	**606,621**	**1,479,776**	**2,133,659**	**3,404,963**	**5,967,571**
Stabilization Device	25.00%	478,125	606,621	800,437	1,096,798	1,558,550	2,214,700
Maintenance Contracts	65.00%			5,057	10,266	22,924	51,189
Stretcher	30.00%			674,282	1,026,595	1,823,489	3,701,682
MERCADO EXTERNO							
Produto A *							
Produto B *							
TOTAL CMVMC		**478,125**	**606,621**	**1,479,776**	**2,133,659**	**3,404,963**	**5,967,571**
IVA	23.00%	109,969	139,523	340,348	490,742	783,141	1,372,541
TOTAL CMVMC + IVA		**588,094**	**746,144**	**1,820,124**	**2,624,400**	**4,188,104**	**7,340,113**

Figure 105 Material costs incurred in pessimistic sales scenario

TOTAL FSE	12,070.00	15,160.00	26,337.50	29,715.00	47,085.00	64,147.00
FSE - Custos Fixos	12,070.00	15,160.00	26,337.50	29,715.00	47,085.00	64,147.00
FSE - Custos Variáveis						
TOTAL FSE	12,070.00	15,160.00	26,337.50	29,715.00	47,085.00	64,147.00
IVA	1,738.80	1,932.00	2,829.00	3,022.20	4,416.00	4,995.60
FSE + IVA	13,808.80	17,092.00	29,166.50	32,737.20	51,501.00	69,142.60

Figure 106 Supplies and Service cost incurred in Pessimistic sales scenario

Quadro de Pessoal (n.º pessoas)	2019	2020	2021	2022	2023	2024
Administração / Direcção	1	1	1	1	1	1
Administrativa Financeira	1	1	1	1	1	1
Comercial / Marketing	1	1	1	2	2	2
Produção / Operacional	2	2	4	5	7	10
Qualidade	1	1	2	2	2	2
Manutenção	1	1	3	3	4	5
Aprovisionamento						
Investigação & Desenvolvimento	3	3	3	3	3	3
Outros						
TOTAL	10	10	15	17	20	24

Figure 107 Number of Employees for Pessimistic scenario

Valores Acumulados	2019	2020	2021	2022	2023	2024
Propriedades de investimento						
Terrenos e recursos naturais						
Edifícios e Outras construções				250,000	250,000	250,000
Outras propriedades de investimento						
Total propriedades de investimento				**250,000**	**250,000**	**250,000**
Activos fixos tangíveis						
Terrenos e Recursos Naturais						
Edifícios e Outras Construções						
Equipamento Básico			3,000	8,000	13,000	18,000
Equipamento de Transporte						
Equipamento Administrativo		1,895	3,788	4,850	10,599	12,724
Equipamentos biológicos						
Outros activos fixos tangíveis						
Total Activos Fixos Tangíveis		**1,895**	**6,788**	**12,850**	**23,599**	**30,724**
Activos Intangíveis						
Goodwill						
Projectos de desenvolvimento						
Programas de computador						
Propriedade industrial						
Outros activos intangíveis						
Total Activos Intangíveis						
Total		**1,895**	**6,788**	**262,850**	**273,599**	**280,724**

Figure 108 Investment for Pessimistic Scenario

	2019	2020	2021	2022	2023	2024
Investimento	87,533	12,348	91,967	320,102	136,313	267,678
Margem de segurança	50.00%	40.00%	30.00%	20.00%	10.00%	10.00%
Necessidades de financiamento	**131,300**	**17,300**	**119,600**	**384,100**	**149,900**	**294,400**

Fontes de Financiamento	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Meios Libertos			194,013	344,066	647,206	1,320,001
Capital	5,000					
Outros instrumentos de capital						
Empréstimos de Sócios	75,000					
Financiamento bancário e outras Inst. Crédito	30,000	25,000				
Subsidios						
TOTAL	**110,000**	**25,000**	**194,013**	**344,066**	**647,206**	**1,320,001**

N.º de anos reembolso	4.00
Taxa de juro associada	3.50%
N.º anos de carência	0.50

Figure 109 Pessimistic Scenario Financing

	2019	2020	2021	2022	2023	2024
Vendas e serviços prestados	637,500.00	808,828.13	2,044,957.99	2,958,292.75	4,748,547.82	8,387,305.17
Variação nos inventários da produção						
CMVMC	478,125.00	606,621.09	1,479,775.91	2,133,658.85	3,404,962.96	5,967,571.29
FSE Variáveis						
Margem Bruta de Contribuição	**159,375.00**	**202,207.03**	**565,182.08**	**824,633.89**	**1,343,584.86**	**2,419,733.88**
Ponto Crítico	**658,146.00**	**788,338.90**	**932,425.86**	**1,108,741.72**	**1,350,630.42**	**1,639,971.46**

Figure 110 Pessimistic Scenario Critical Points

	2019	2020	2021	2022	2023	2024
ACTIVO						
Activo Não Corrente		**1,516**	**5,276**	**249,369**	**246,373**	**238,703**
Activos fixos tangiveis		1,516	5,276	9,369	16,373	18,703
Propriedades de investimento				240,000	230,000	220,000
Activos Intangiveis						
Investimentos financeiros						
Activo corrente	**201,326**	**229,713**	**630,587**	**845,643**	**1,741,888**	**3,617,450**
Inventários	19,922	25,276	61,657	88,902	141,873	248,649
Clientes	115,005	130,230	333,331	447,790	697,978	1,237,596
Estado e Outros Entes Públicos						
Accionistas/sócios						
Outras contas a receber						
Diferimentos						
Caixa e depósitos bancários	66,399	74,207	235,599	308,951	902,036	2,131,205
TOTAL ACTIVO	**201,326**	**231,229**	**635,863**	**1,095,012**	**1,988,261**	**3,856,153**

Figure 111 Pessimistic Scenario Active Balance

INDICADORES ECONÓMICOS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Taxa de Crescimento do Negócio		27%	153%	45%	61%	77%
Rentabilidade Líquida sobre as vendas	-3%	-2%	10%	11%	13%	16%
INDICADORES ECONÓMICOS - FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Return On Investment (ROI)	-11%	-8%	32%	30%	32%	34%
Rendibilidade do Activo	-10%	-6%	40%	40%	42%	45%
Rotação do Activo	317%	350%	322%	270%	239%	218%
Rendibilidade dos Capitais Próprios (ROE)	130%	51%	159%	85%	71%	67%
INDICADORES FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Autonomia Financeira	-8%	-15%	20%	36%	45%	51%
Solvabilidade Total	92%	87%	125%	156%	183%	203%
Cobertura dos encargos financeiros	-1977%	-482%	9189%	21779%	66634%	346668%
INDICADORES DE LIQUIDEZ	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Liquidez Corrente	1.07	1.05	1.33	1.24	1.62	1.91
Liquidez Reduzida	0.96	0.94	1.20	1.11	1.48	1.78
INDICADORES DE RISCO NEGÓCIO	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Margem Bruta	147,305	187,047	538,845	794,919	1,296,500	2,355,587
Grau de Alavanca Operacional	-707%	-1266%	210%	180%	154%	135%
Grau de Alavanca Financeira	96%	84%	100%	100%	99%	99%

Figure 112 Pessimistic Scenario Principal Indicators

Na perspectiva do Projecto Pós-Financiamento	2019	2020	2021	2022	2023	2024	2025
Free Cash Flow to Firm	-103,166	-23,051	102,046	23,964	510,892	1,052,323	810,112
WACC	8.65%	14.68%	-0.52%	-1.24%	-1.42%	-1.45%	-1.45%
Factor de actualização	1	1.147	1.141	1.127	1.111	1.095	-
Fluxos actualizados	-103,166	-20,100	89,451	21,270	459,985	961,375	740,098
Fuxos atualizados acumulados	-103,166	-123,266	-33,815	-12,545	447,440	1,408,815	2,148,912
Valor Actual Líquido (VAL)	2,148,912						
Taxa Interna de Rentibilidade	96.05%						

Figure 113 Pessimistic Scenario Post Project financing perspective

Annex E- Optimistic Scenario

	2019	2020	2021	2022	2023	2024
Taxa de variação dos preços		1.50%	1.50%	1.50%	1.50%	1.50%
VENDAS - MERCADO NACIONAL	2019	2020	2021	2022	2023	2024
Stabilization Device	862,500	1,094,297	1,443,925	1,978,538	2,811,502	3,995,145
Quantidades vendidas	173	216	280	378	530	742
Taxa de crescimento das unidades vendidas	0%	25.00%	30.00%	35.00%	40.00%	40.00%
Preço Unitário	5,000.00	5,075.00	5,151.13	5,228.39	5,306.82	5,386.42
Maintenance Contracts	0	0	19,549	39,683	88,613	197,873
Quantidades vendidas	0	0	127	253	557	1,225
Taxa de crescimento das unidades vendidas	0%	0%	0%	100.00%	120.00%	120.00%
Preço Unitário	150.00	152.25	154.53	156.85	159.20	161.59
Stretcher	0	0	1,303,235	1,984,175	3,524,390	7,154,512
Quantidades vendidas	0	0	58	86	151	302
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	50.00%	75.00%	100.00%
Preço Unitário	22,000.00	22,330.00	22,664.95	23,004.92	23,350.00	23,700.25
	0	0	0	0	0	0
Quantidades vendidas	0	0	0	0	0	0
Taxa de crescimento das unidades vendidas	0%	0.00%	0.00%	0.00%	0.00%	0.00%
Preço Unitário	500.00	507.50	515.11	522.84	530.68	538.64
TOTAL	862,500	1,094,297	2,766,708	4,002,396	6,424,506	11,347,531

Figure 114 Optimistic Scenario Sales data

TOTAL VENDAS - MERCADO NACIONAL		862,500	1,094,297	2,766,708	4,002,396	6,424,506	11,347,531
TOTAL VENDAS - EXPORTAÇÕES		0	0	0	0	0	0
TOTAL VENDAS		862,500	1,094,297	2,766,708	4,002,396	6,424,506	11,347,531
IVA VENDAS	23.00%	198,375	251,688	636,343	920,551	1,477,636	2,609,932
TOTAL PRESTAÇÕES DE SERVIÇOS - MERCADO NACIONAL		0	0	0	0	0	0
TOTAL PRESTAÇÕES DE SERVIÇOS - EXPORTAÇÕES		0	0	0	0	0	0
TOTAL PRESTAÇÕES SERVIÇOS		0	0	0	0	0	0
IVA PRESTAÇÕES DE SERVIÇOS	23.00%	0	0	0	0	0	0
TOTAL VOLUME DE NEGÓCIOS		862,500	1,094,297	2,766,708	4,002,396	6,424,506	11,347,531
IVA		198,375	251,688	636,343	920,551	1,477,636	2,609,932
TOTAL VOLUME DE NEGÓCIOS + IVA		1,060,875	1,345,985	3,403,051	4,922,947	7,902,142	13,957,463
Perdas por imparidade %	2.00%	21,218	26,920	68,061	98,459	158,043	279,149

Figure 115 Optimistic Scenario total sales revenue

CMVMC	Margem Bruta	2019	2020	2021	2022	2023	2024
MERCADO NACIONAL		646,875	820,723	2,002,050	2,886,715	4,606,715	8,073,773
Stabilization Device	25.00%	646,875	820,723	1,082,944	1,483,903	2,108,627	2,996,359
Maintenance Contracts	65.00%			6,842	13,889	31,015	69,256
Stretcher	30.00%			912,264	1,388,922	2,467,073	5,008,159
MERCADO EXTERNO							
Produto A *							
Produto B *							
TOTAL CMVMC		646,875	820,723	2,002,050	2,886,715	4,606,715	8,073,773
IVA	23.00%	148,781	188,766	460,471	663,944	1,059,544	1,856,968
TOTAL CMVMC + IVA		795,656	1,009,489	2,462,521	3,550,659	5,666,259	9,930,741

Figure 116 Optimistic Scenario Material Costs Incurred

FSE - Custos Fixos	12,070.00	16,960.00	28,102.50	32,305.00	53,455.00	77,693.00
FSE - Custos Variáveis						
TOTAL FSE	12,070.00	16,960.00	28,102.50	32,305.00	53,455.00	77,693.00
IVA	1,738.80	1,932.00	3,022.20	3,215.40	4,609.20	5,768.40
FSE + IVA	13,808.80	18,892.00	31,124.70	35,520.40	58,064.20	83,461.40

Figure 117 Sales and Services Optimistic Scenario

Quadro de Pessoal (n.º pessoas)	2019	2020	2021	2022	2023	2024
Administração / Direcção	1	1	1	1	1	1
Administrativa Financeira	1	1	1	1	1	1
Comercial / Marketing	1	1	1	2	2	2
Produção / Operacional	2	2	5	6	8	14
Qualidade	1	1	2	2	2	2
Manutenção	1	1	3	3	4	5
Aprovisionamento						
Investigação & Desenvolvimento	3	3	3	3	3	3
Outros						
TOTAL	10	10	16	18	21	28

Figure 118 Number of Employees for Optimistic Scenario

Investimento por ano	2019	2020	2021	2022	2023	2024
Propriedades de investimento						
Terrenos e recursos naturais						
Edifícios e Outras construções			250,000			
Outras propriedades de investimento						
Total propriedades de investimento			250,000			
Activos fixos tangiveis						
Terrenos e Recursos Naturais						
Edifícios e Outras Construções						
Equipamento Básico			3,000	5,000	5,000	5,000
Equipamento de Transporte						
Equipamento Administrativo		1,895	1,893	1,063	5,749	2,125
Equipamentos biológicos						
Outros activos fixos tangiveis						
Total Activos Fixos Tangiveis		1,895	4,893	6,063	10,749	7,125
Activos Intangiveis						
Goodwill						
Projectos de desenvolvimento						
Programas de computador						
Propriedade industrial						
Outros activos intangíveis						
Total Activos Intangiveis						
Total Investimento		1,895	254,893	6,063	10,749	7,125

Figure 119 Optimistic Scenario Investment

	2019	2020	2021	2022	2023	2024
Investimento	102,861	16,168	373,396	93,070	181,378	359,078
Margem de segurança	50.00%	40.00%	30.00%	20.00%	10.00%	10.00%
Necessidades de financiamento	**154,300**	**22,600**	**485,400**	**111,700**	**199,500**	**395,000**

Fontes de Financiamento	2019	2020	2021	2022	2023	2024
Meios Libertos	22,403	36,206	321,990	531,222	956,784	1,852,321
Capital	5,000					
Outros instrumentos de capital						
Empréstimos de Sócios	50,000					
Financiamento bancário e outras Inst. Crédito	25,000		35,000			
Subsidios						
TOTAL	**102,403**	**36,206**	**356,990**	**531,222**	**956,784**	**1,852,321**

N.º de anos reembolso	4.00
Taxa de juro associada	3.50%
N.º anos de carência	0.50

Figure 120 Optimistic Scenario Financing

	2019	2020	2021	2022	2023	2024
Vendas e serviços prestados	862,500.00	1,094,296.88	2,766,707.87	4,002,396.07	6,424,505.88	11,347,530.52
Variação nos inventários da produção						
CMVMC	646,875.00	820,722.66	2,002,049.76	2,886,714.92	4,606,714.59	8,073,772.92
FSE Variáveis						
Margem Bruta de Contribuição	**215,625.00**	**273,574.22**	**764,658.11**	**1,115,681.15**	**1,817,791.28**	**3,273,757.60**
Ponto Crítico	**658,146.00**	**795,538.90**	**1,020,776.12**	**1,165,497.11**	**1,422,047.78**	**1,887,606.56**

Figure 121 Optimistic Scenario Critical Points

	2019	2020	2021	2022	2023	2024
ACTIVO						
Activo Não Corrente		**1,516**	**245,276**	**239,369**	**236,373**	**228,703**
Activos fixos tangíveis		1,516	5,276	9,369	16,373	18,703
Propriedades de investimento			240,000	230,000	220,000	210,000
Activos Intangíveis						
Investimentos financeiros						
Activo corrente	**255,725**	**321,473**	**719,450**	**1,410,429**	**2,702,479**	**5,293,680**
Inventários	26,953	34,197	83,419	120,280	191,946	336,407
Clientes	155,595	176,194	450,977	605,834	944,324	1,674,395
Estado e Outros Entes Públicos						
Accionistas/sócios						
Outras contas a receber						
Diferimentos						
Caixa e depósitos bancários	73,177	111,083	185,055	684,315	1,566,209	3,282,878
TOTAL ACTIVO	**255,725**	**322,989**	**964,726**	**1,649,798**	**2,938,852**	**5,522,383**

Figure 122 Optimistic Scenario Active Balance

INDICADORES ECONÓMICOS	2019	2020	2021	2022	2023	2024
Taxa de Crescimento do Negócio		27%	153%	45%	61%	77%
Rentabilidade Líquida sobre as vendas	3%	3%	11%	13%	15%	16%
INDICADORES ECONÓMICOS - FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Return On Investment (ROI)	9%	11%	32%	32%	32%	34%
Rendibilidade do Activo	12%	15%	43%	42%	43%	44%
Rotação do Activo	337%	339%	287%	243%	219%	205%
Rendibilidade dos Capitais Próprios (ROE)	81%	64%	102%	72%	64%	63%
INDICADORES FINANCEIROS	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Autonomia Financeira	11%	17%	31%	44%	50%	54%
Solvabilidade Total	110%	119%	145%	177%	201%	216%
Cobertura dos encargos financeiros	3400%	5438%	17156%	31524%	63613%	174305%
INDICADORES DE LIQUIDEZ	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Liquidez Corrente	1.23	1.27	1.16	1.58	1.89	2.09
Liquidez Reduzida	1.10	1.13	1.03	1.45	1.75	1.95
INDICADORES DE RISCO NEGÓCIO	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Margem Bruta	203,555	256,614	736,556	1,083,376	1,764,336	3,196,065
Grau de Alavanca Operacional	681%	537%	178%	156%	140%	130%
Grau de Alavanca Financeira	102%	101%	100%	99%	99%	99%

Figure 123 Optimistic Scenario Principal Indicators

Na perspectiva do Projecto Pós-Financiamento	2019	2020	2021	2022	2023	2024	2025
Free Cash Flow to Firm	-80,458	20,038	-51,406	438,152	775,406	1,493,243	665,886
WACC	5.97%	7.29%	7.97%	8.44%	8.64%	8.71%	8.71%
Factor de actualização	1	1.073	1.158	1.256	1.365	1.484	-
Fluxos actualizados	-80,458	18,677	-44,380	348,837	568,229	1,006,559	448,857
Fuxos atualizados acumulados	-80,458	-61,781	-106,160	242,677	810,906	1,817,464	2,266,322
Valor Actual Líquido (VAL)	2,266,322						
Taxa Interna de Rentibilidade	137.05%						

Figure 124 Optimistic Scenario Post Project financing perspective