Design of an ophthalmological and information point mobile unit

Alex Murillo Baixas

Relatório do Projecto Final do MIEM

Orientador na FEUP: Prof. Jorge Lino – MEC

Prof. Carlos Aguiar – FEUP/Design Studio

Faculdade de Engenharia da Universidade do Porto

Mestrado Integrado em Engenharia Mecânica

Julho 2009

I would like to dedicate this thesis to my friend at university Joan Llull, you will always be in our hearts.

SUMMARY

The objective of this project is to design a mobile unit for medical assistance around the country in the area of ophthalmology. The final goal is to open the way so that a mini-bus can be constructed.
This project is an application of a global project that is being done in the Design Studio at FEUP, with the goal to construct a new inter-universitary bus which would connect travellers coming from metro or bus to their universities.
The initial design work, including the design of the structural components, was made by Lúcia Fernandes and Carla Rocha from the Universidade de Aveiro.
The aim of this project is to apply the knowledge acquired during the engineering studies in a social way and the main objective of this project is to give more medical attention to the people who don't have access to. There are a number of possible scenarios:

- People who don't have a hospital close to their home, and thus may only go in case of emergency. These people would not normally go periodically for health check-ups.
- People who would only go to the witch doctor as they may be the only ones who go regularly to their district. This may sometimes cause more problems instead of solving them due to a lack of hygiene, proper medicines, etc.
- People who are unable to leave their home without help due to their health problems, such as disabled people or blind people.
- Those who live in little villages and have to wait for more than one month until one ophthalmologist visits the village.

It is also important to mention that alongside checking their eyes and detecting visual disorders the unit should also give information about prevention and hygiene. This mobile unit is designed to check the population's visual disorders, who may need surgery in hospitals. It could be also worthwhile having materials such as tents and disinfection equipment so that some field hospitals could be installed, if not in the same day, the coming days so that needy cases could be operated on, in these specified areas.
The interior design of the bus should be designed so that it provides the most important necessities determined and required, flexible and aesthetically pleasing for its potential users. With regards to the outside design, the environment and the climatology of the probable areas where it might have to pass have to be also taken into consideration.
Adding to this, a reciprocal dialogue has to be maintained with doctors, nurses, patients, designers and others in order to have a continual improvement of the final design/product. With that input, the colours, forms, furniture, necessary equipment and other aspects must be analyzed carefully in the design stage of the product.
The next stage in this process is for the prototype to be scrutinised with regard to the main difficulties that such a mobile unit may experience in terms of space, dimensions, vibrations, lightening and others such problems.

PREFACE

Due to the lack of a proper medical coverage, an inefficient public health system combined with the global growing population, it makes sense to support hospitals with mobile units that can help the hospitals in order not to collapse, and give attention to under-served patient populations

Every country has its own necessities but the type of assistance needed in occidental countries is different from the necessities of non-occidental countries.

While the assistance programs, mainly in rich countries, can be to just give more comfort to those patients that live far away from the hospital or to comfort those who do not have access to ophthalmologists in their hospital, in poorest countries the type of assistance can be more including of educational programs or even dealing with diseases that hardly have some case in occidental countries.

There's an increasing industry and business of mobile units trucks, bus etc. These are mainly used as a support unit in hospitals, as itinerant caravans through all over the country, having as stakeholders the state or even a private company.

The transportation of specific medical equipment needed to carry to places where often the roads are not paved and are full of dust, shocks, and mud might need careful study. Not only space but vibrations and electrical power sources are problems that need to be taken into consideration while the design of mobile units are in the process.

ABSTRACT

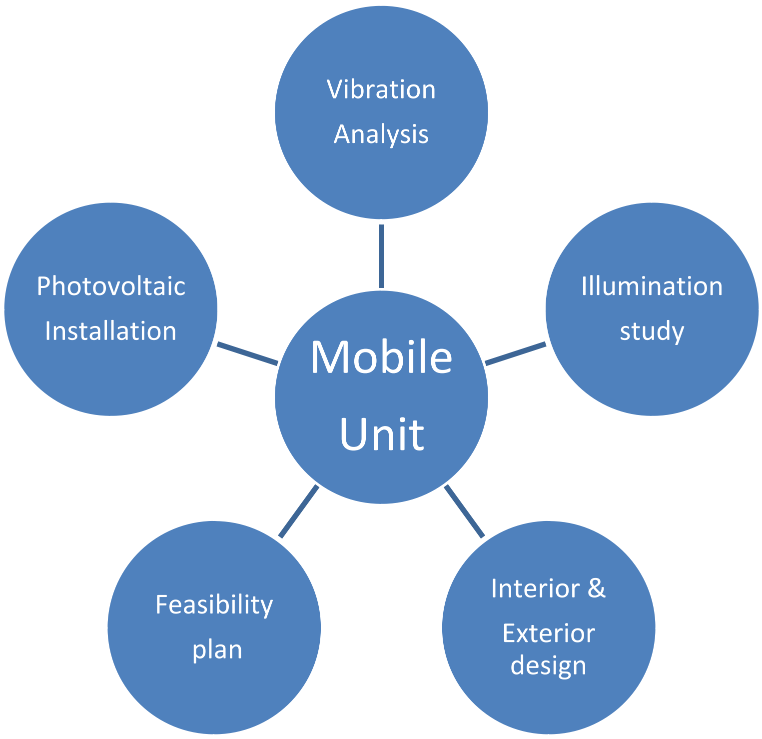
This project borne from a project that currently is performed for a company in the Design Studio of FEUP and that uses a standard metallic chassis. The goal is to use the same chassis/frame and conceive a mobile unit for the medical sector.

Considering that one of the advisors had already made contact with a doctor that expressed a real interest in the development of a small bus that is able to run around the country to give assistance to population that needs basic medical care in the field of ophthalmology, this project appears as a natural sequence of the current Design Studio work.

To design the global concept of this mobile unit it is fundamental to understand the limitations of the transportation of the medical basic equipment that is fundamental in ophthalmology, in order to conceive the necessary vibration dumping systems and others.

It is necessary to design the whole mobile unit and all it interior to accommodate and transport in safe conditions the adequate equipment, machines, objects and materials that are fundamental for this kind of assistance.

It is intended that the project of this mobile unit gives information and construction solutions that could be used in other mobile units for other types of applications. Concretely the main themes that are studied and analyzed are:



GRATITUDE

I would like to express my sincere thanks to my advisers at FEUP: Jorge Lino, Carlos Aguiar, and Xavier Carvalho. In addttion I would like to thanks César Vasques, to my family and to my friends Borja Santoro, Fernando Castán and Vitor Ribeiro from Auto-Ribeiro.

1 TABLE OF CONTENTS

2 LIST OF FIGURES

3 LIST OF TABLES

4 INTRODUCTION

With the purpose of giving the best description and approach at present situation of the visual impairment and blindness all over the world, some data and graphics have been reported so that people with no extended previous knowledge in medicine can have a clearly idea about the most common disease.

The description will explain: what exactly they are, how can be treated, wich are the regions or areas more affected all over the world and finally if they can be treated or prevented with the help of the mobile unit.

Please note that in chapters 1.1 and 1.2, all text and data, pictures and figures are taken from the World Health Organization (1) and (2).

4.1 FACTS ABOUT BLINDNESS AND VISUAL IMPAIRMENT

- Worldwide, more than 161 million people are visually impaired; among them, 124 million have low vision and 37 million are blind.
- Another 153 million people suffer from visual impairment due to uncorrected refractive errors (near-sightedness, far-sightedness or astigmatism). Virtually all these people could restore normal vision with eyeglasses or contact lenses.
- More than 90% of the world's visually impaired people live in low- and middle-income countries.
- Except in the most developed countries, cataract remains the leading cause of blindness.
- Cataract surgery is one of the most cost-effective treatments that can be offered in developing countries. It can allow people to increase their economic productivity by up to 1500% of the cost of the surgery during the first post-operative year.
- Age-related causes of visual impairment and blindness are increasing, as is blindness due to uncontrolled diabetes.
- The good news is that up to 75% of all blindness in adults is avoidable through prevention or treatment. Worldwide, corneal scarring is the single most important cause of avoidable blindness, followed by cataract and retinopathy of prematurity (ROP).

- Infectious causes of blindness are decreasing globally as a result of public health action. The number of people affected by blinding trachoma has decreased from 360 million people in 1985 to approximately 80 million people today.
- An estimated 1.4 million children under age 15 are blind. Yet approximately half of all childhood blindness can be avoided by early treatment of disease and correcting abnormalities at birth such as cataract and glaucoma.

4.2 MAIN CAUSES OF VISUAL IMPAIRMENT

Except for the most developed countries, cataract remains the leading cause of blindness in all regions of the world. Associated with ageing, it is even more significant as a cause of low vision.

Glaucoma is the second leading cause of blindness globally as well as in most regions, with age-related macular degeneration (AMD) ranking third on the global scale. However, in developed countries, AMD is the leading cause of blindness, due to the growing number of people over 70 years of age.

Other major causes are trachoma, other corneal opacities, diabetic retinopathy, and eye conditions in children (e.g. cataract, retinopathy of prematurity and vitamin A deficiency).

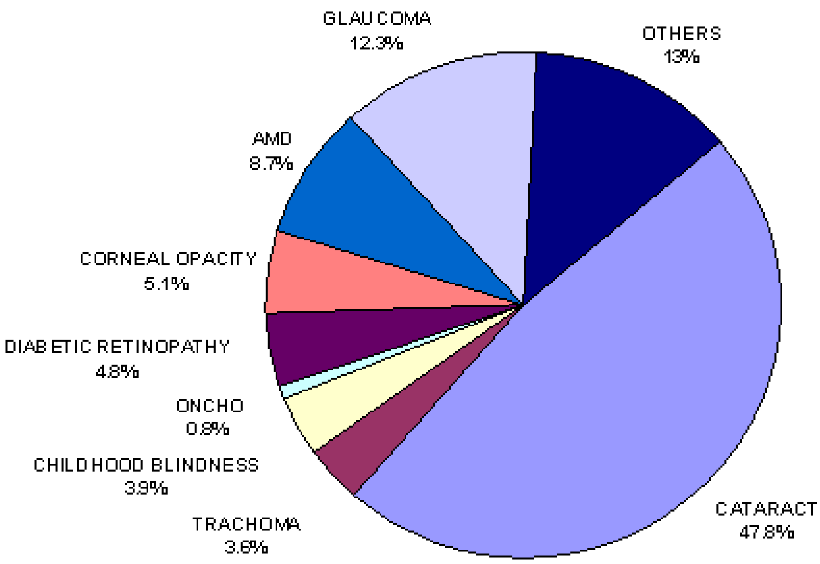
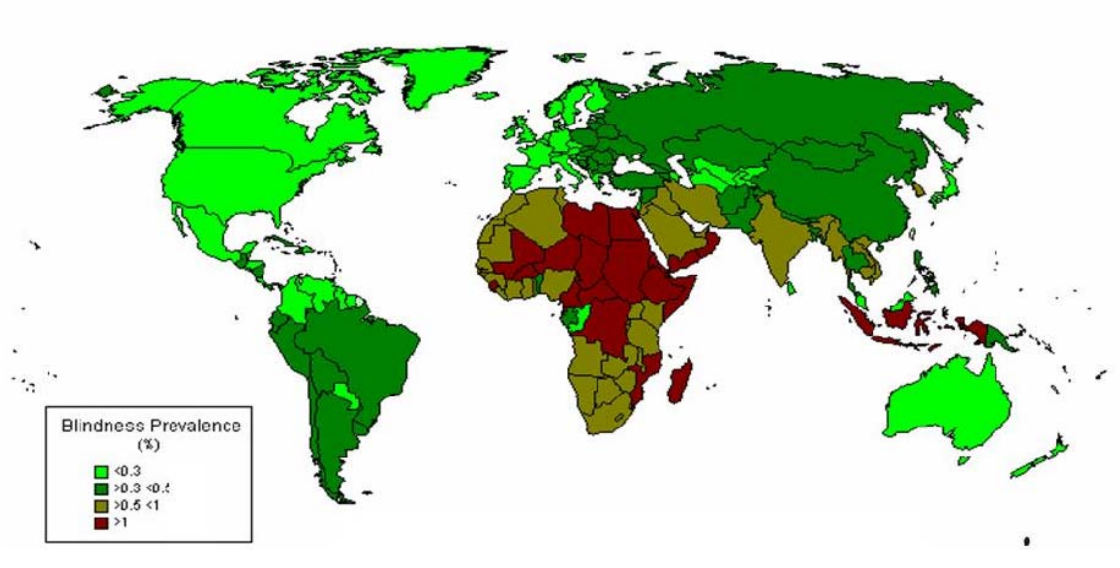


Figure 4-1: Global causes of blindness as a proportion of total blindness in 2002.

Cataract, glaucoma, corneal opacity, diabetic retinopathy, onchocerciasis, childhood blindness, trachoma, and some other causes of blindness can potentially all be prevented and/or treated. WHO estimates that, globally, up to 75% of all blindness is avoidable. However, the proportion of the specific causes of blindness varies considerably from region to region, depending on local circumstance. Only about half the cases of childhood blindness are avoidable.

Some of these diseases, such as trachoma and river blindness, are prevalent primarily in less developed areas of the world where there are also specific environmental hazards.

In many middle income and industrialized countries, three other eye conditions have emerged as potential threats to the status of sight of their populations. The increase of diabetes among many population groups has caused diabetic retinopathy to be added to the priority list, while glaucoma, an eye disease known for centuries, remains on the public health agenda due to difficulties in its early diagnosis and frequent necessity of lifelong treatment. Age-related macular degeneration (AMD) ranks third among the global causes of visual impairment with a blindness prevalence of 8,7%. It is the primary cause of visual deficiency in industrialized countries. An emerging important cause of visual impairment is uncorrected refractive errors.



Afr, WHO African Region; Amr, WHO Region of the Americas; Emr, WHO Eastern Mediterranean Region; Eur, WHO European Region; Sear, WHO South-Eas Region; Wpr, WHO Western Pacific Region.

	Afr	Amr	Emr	Eur	Sear	Wpr
Population	672.238	852.551	502.823	877.886	1590.832	1717.536
No. of blind People	6.782	2.419	4.026	2.732	11.587	9.312
No. with low vision	19.996	13.116	12.444	12.789	33.496	32.481
No. with visual impairment	**26.778**	**15.535**	**16.469**	**15.521**	**45.083**	**41.793**

Figure 4-2: Blindness prevalence 2002.

4.2.1 CATARACT

Definition:

Figure 4-3: The cataract cloude.

Cataract is clouding of the lens of the eye which impedes the passage of light. Although most cases of cataract are related to the ageing process, occasionally children can be born with the condition, or a cataract may develop after eye injuries, inflammation, and some other eye diseases.

Magnitude:

According to the latest assessment, age related cataract is responsible for 48% of world blindness, which represents about 18 million people.
Although cataracts can be surgically removed, in many countries surgical services are inadequate, and cataract remains the leading cause of blindness. As people in the world live longer, the number of people with cataract is growing. Cataract is also an important cause of low vision in both developed and developing countries. Even where surgical services are available, low vision associated with cataract may still be prevalent, as a result of the long period spent waiting for operations and barriers to surgical uptake, such as cost, lack of information, and transportation problems.

Prevention and treatment:

Comprehensive prevention of cataract development is not known yet. Reduction of cigarette smoking, ultraviolet light exposure, and alcohol consumption may prevent or rather delay the development of cataract. Diabetes mellitus, hypertension and high body mass index are identified as additional risk factors.
The treatment of cataract is an operation, which is very successful in restoring sight. The opaque lens is removed and replaced by an artificial intraocular lens. In many remote parts of the developing world, people remain blind from cataract, due to a lack of access to quality eye care at an affordable cost. Among the first 5 most cost-effective health intervention.

Why is cataract increasing so rapidly?

Approximately 85% of all cataract is age-related, the cause of which is unknown. The other 15% are the result of a variety of known causes. By definition, the prevalence of age-related cataract increases with age and, ultimately, everyone in their nineties will be affected. (Figure 9) Cataract also increases with age in developing countries - but often earlier in life and to a greater extent.

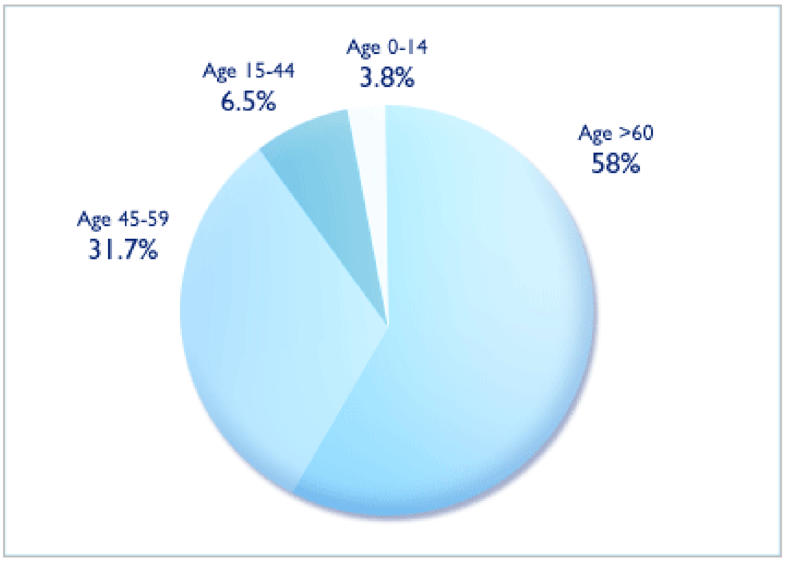


Figure 4-4: Distribution of global blindness by age group.

Between 2000 and 2020, the world's population is estimated to increase from 6.08 to 7.52 billion. This growth will occur mainly in developing countries.

During the same period, the number of people aged 65 years and older is estimated to increase from 425 million to 677 million globally. In the World Bank regions of China, India, Latin America and the Caribbean, the Middle Eastern Crescent and other Asia and islands, the population aged 65 years and older will double during this period. (Figure 10) While the number of cataract operations is increasing in most countries, this is not enough to compensate for the rise in incidence due to the 'ageing' of the population.

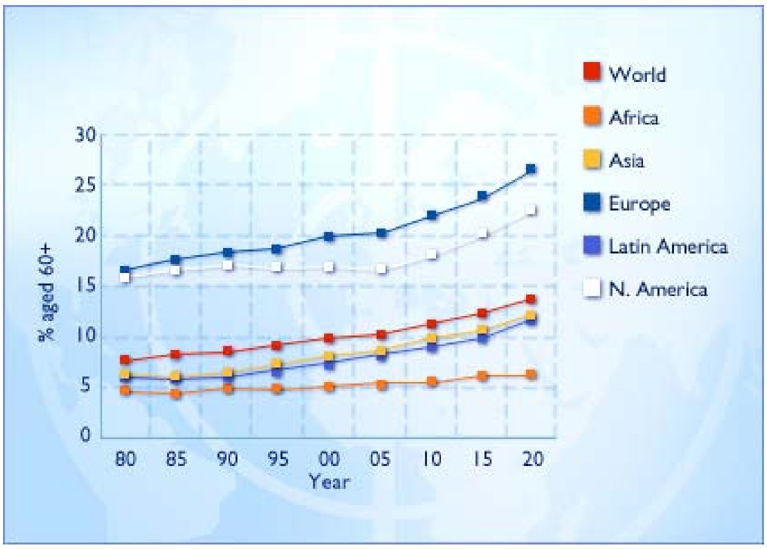


Figure 4-5: Ageing trend 1980-2002. Percentage of world population aged 60 years or older.

Due to modern surgical techniques with IOL implantation, cataract patients currently undergo operations at a much earlier stage than before. This has led to a threefold to fourfold increase in cataract surgery in a number of industrialized countries. As extra capsular cataract extraction with IOL implantation also becomes available in more developing countries, this will have huge implications for the number of needed operations.

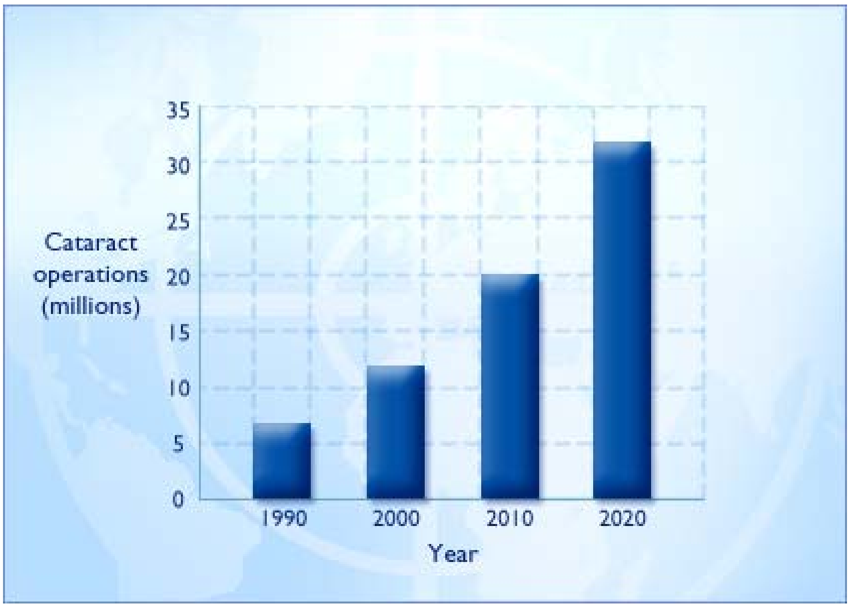


Figure 4-6: Forecast of the needed cataract surgeries.

4.2.2 REFRACTIVE ERRORS

Refractive errors can be divided into three major groups:

- People over 40 years of age with presbyopia (difficulty in near vision and reading)
- Myopia
- Uncorrected aphakia (eyes with lenses removed and not replaced by IOL or spectacles).

The global magnitude of refractive errors is not reliably known, as there is great variation in groupings according to age, definitions of blindness, and examination methods. Reports suggest that 5-25% of blindness in some countries is caused by refractive errors and as much as 4% of the population sees less than 6/18 (20/60, 0.33) because of this condition. Correction of significant refractive errors requires a well-trained refractionist and access to affordable and good-quality spectacles.

Presbyopia may be easiest to solve through bulk purchase of standard spherical reading spectacles. The costs of such spectacles are low and in most cases full refraction is not required.

Myopia usually develops at the age of 10-15 years. Intervention should focus on screening children in this age group using a simple test for refractive errors. Those who fail the test should be referred for refraction and provided with spectacles. Large-scale screening may increase awareness of refractive errors and motivate parents and grandparents to come forward for testing as well. Increasing demand for spectacles may also promote the development of more optical services.

Uncorrected aphakia is unfortunately still a frequent cause of blindness or low vision. Provision of aphakic glasses is an essential component of cataract intervention.

Training of refractionists and the development of affordable and good quality optical services should be an essential component in most VISION 2020 action plans.

4.2.3 CHILDHOOD BLINDNESS

Figure 4-7: 1.4 million of blind children in the world, three quarters of them situated in the poorest regions of Africa and Asia.

Definition:

Childhood blindness refers to a group of diseases and conditions occurring in childhood or early adolescence, which, if left untreated, result in blindness or severe visual impairment that are likely to be untreatable later in life. The major causes of blindness in children vary widely from region to region, being largely determined by socioeconomic development, and the availability of primary health care and eye care services. In high-income countries, lesions of the optic nerve and higher visual pathways predominate as the cause of blindness, while corneal scarring from measles, vitamin A deficiency, use of harmful traditional eye remedies, ophthalmic neonatorum, and rubella cataract are the major causes in low-income countries. Retinopathy of prematurity is an important cause in middle-income countries. Other significant causes in all countries are congenital abnormalities, such as cataract, glaucoma, and hereditary retinal dystrophies

Magnitude:

According to Gilbert and Foster, the prevalence of blindness in children varies according to socioeconomic development and under-5 mortality rates. In low-income countries with high under-5 mortality rates, the prevalence may be as high as 1.5 per 1000 children, while in high-income countries with low under-5 mortality rates, the prevalence is around 0.3 per 1000 children. Using this correlation to estimate the prevalence of blindness in children, the number of blind children in the world is approximately 1.4 million. Approximately three-quarters of the world's blind children live in the poorest regions of Africa and Asia.

Prevention and treatment:

Prevention and treatment of childhood blindness is disease specific. For Vitamin A deficiency, at a cost of only 5 US cents a dose, vitamin A supplements reduce child mortality by up to 34% in areas where Vitamin A deficiency is a public health problem. As vitamin A deficiency manifests often during an outbreak of measles, properly planned and implemented national vaccination programs against measles has reduced the prevalence of eye complications. In middle income countries, retinopathy of prematurity (ROP) is among the leading causes of blindness, the incidence of which can be reduced through availability and affordability of screening and curative services. Early treatment of cataract and glaucoma can be beneficial, while low vision devices are helpful in children with residual vision.

High-income countries (EME and FSE)[a, b]		Middle-income countries (LAC, MEC and China)[a, b]		Low-income countries (India, OAI and SSA)[a, b]	
ROP[c]	9000	Cataract	45 000	Corneal scar	200 000
Teratogens	5400	ROP	29 000	Cataract	133 000
Cataract	5400	Glaucoma	17 000	Glaucoma	60 000
Glaucoma	2000	Teratogens	12 000	Optic atrophy	60 000
Total	**21 800**	**Total**	**103 000**	**Total**	**453 000**

Table 4-1: Estimation of the number or prevalent cases of children with severe visual impairment and blindness due to avoidable causes, by level of socioeconomic development.

4.2.4 LOW VISION

Definition:

Refractive errors include myopia (short-sightedness) and hyperopia (long-sightedness) with or without astigmatism (when the eye can sharply image a straight line lying only in one meridian).

Figure 4-8:About 124 million people suffer low vision.

For low vision, the following two definitions are in use:
• (WHO) Low vision is visual acuity less than 6/18 and equal to or better than 3/60 in the better eye with best correction.
• (Low Vision Services or Care) a person with low vision is one who has impairment of visual functioning even after treatment and/or standard refractive correction, and has a visual acuity of less than 6/18 to light perception, or a visual field less than 10 degrees from the point of

fixation, but who uses, or is potentially able to use, vision for the planning and/or execution of a task for which vision is essential.

Magnitude:

Recent studies have confirmed the existence of a large burden of uncorrected refractive errors, although the interventions required are significantly cost effective, and have an important impact on economic development and quality of life. Severe refractive errors have been estimated to account for about 5 million blind people. According to the most recent data available to WHO, there are an estimated 124 million people in the world with low vision. About a fourth of these would benefit from low vision services.

Prevention and treatment:

Refractive errors can be rectified with appropriate optical correction while people with low vision may be helped with low vision devices.

4.2.5 TRACHOMA

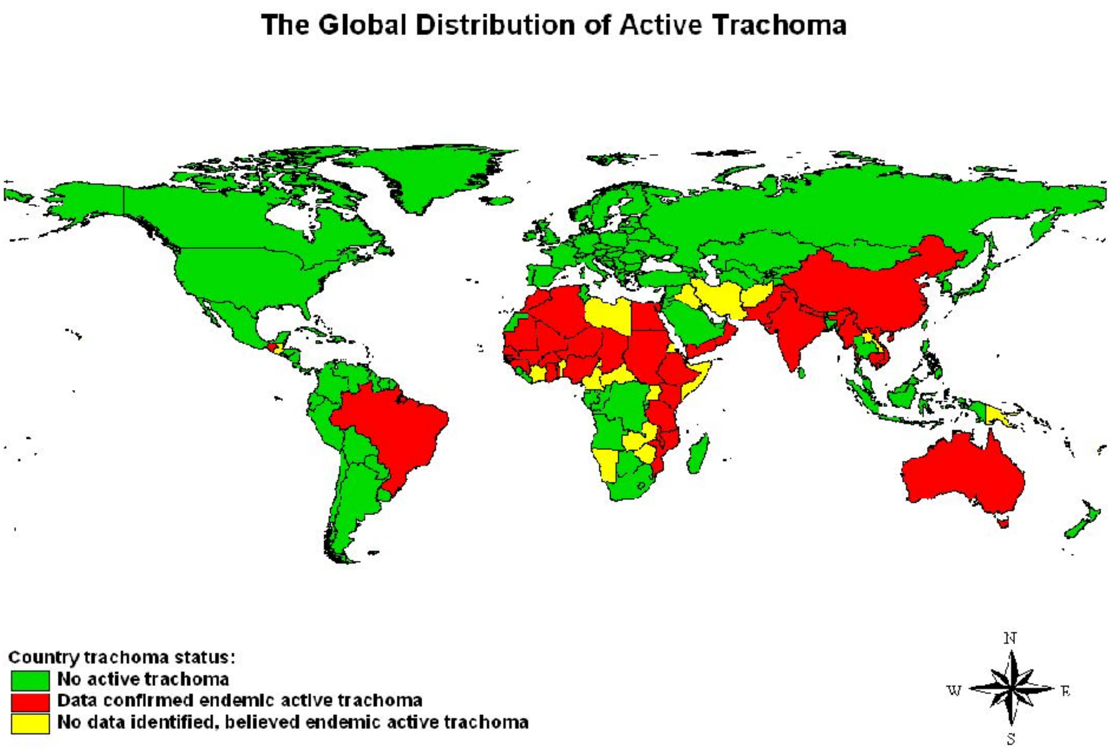


Figure 4-9: Global distribution of active trachoma. Year 2002.

The disease and how it affects people:

Trachoma is an infection of the eyes that may result in blindness after repeated re-infections. It is the world's leading cause of preventable blindness and occurs where people live in overcrowded conditions with limited access to water and health care. Trachoma spreads easily from person to person and is frequently passed from child to child and from child to mother within the family. Infection usually first occurs in childhood but people do not became blind until adulthood. The disease progresses over years as repeated infections cause scarring on the inside of the eyelid, earning it the name of the "quiet disease" The eyelashes eventually turn in. This causes rubbing on the cornea at the front of the eye. The cornea becomes scarred leading to severe vision loss and eventually blindness.

The cause:

Trachoma is caused by an organism called Chlamydia trachomatis. Through the discharge from an infected child's eyes, trachoma is passed on by hands, on clothing, or by flies that land on the face of the infected child.

Distribution

Trachoma occurs worldwide and most often in poor rural communities in developing countries. Blinding trachoma is widespread in the Middle East, North and Sub-Sahara Africa, parts of the Indian subcontinent, Southern Asia and China. Pockets of blinding trachoma occur in Latin America, Australia (among native Australians) and the Pacific Islands.

Scope of the Problem:

The World Health Organization (WHO) estimates that six million worldwide are blind due to trachoma and more than 150 million people are in need of treatment.

Interventions:

Primary interventions advocated for preventing trachoma infection include improved sanitation, reduction of fly breeding sites and increased facial cleanliness (with clean water) among children at risk of disease. The scaring and visual change for trachoma can be reversed by a simple surgical procedure performed at village level which reverses the inturned eyelashes.

Good personal and environmental hygiene has been proven to be successful in combating trachoma. Encouraging the washing of children's faces, improved access to water, and proper disposal of human and animal waste has been shown to decrease the number of trachoma infections in communities.

4.2.6 ONCHOCERCIASIS

Onchocerciasis, or river blindness, is endemic in 30 countries in Africa and also occurs in small foci in six Latin American countries and in Yemen. Currently, there are an estimated 18 million people who are infected with onchocerciasis. Among these, approximately 0.3 million people are already blind from this disease. The disease is expected to be brought under control by the year 2010 if present efforts in endemic countries are successfully completed.

An approach has recently been developed and introduced, whereby community-directed treatment with annual doses of ivermectin would make it possible to eliminate this blinding disease burden from the affected countries in Africa and Latin America. However, the increased numbers of patients needing treatment (many of whom are living in areas of conflict), and the duration of treatment (at least 20 years), are raising concern about whether the problem will be brought under control by 2010.

Over the last 25 years, considerable progress has been made by the Onchocerciasis Control Program (OCP) in 11 countries in West Africa through both vector control and ivermectin distribution. This success, when expressed in health, economic and developmental terms, was the reason behind the launch in December 1995 of a new program, the African Program for Onchocerciasis (APOC) in 19 other African countries.

In Latin America, the Onchocerciasis Elimination Program in the Americas (OEPA) is successfully using ivermectin distribution in six countries in Central and South America. A coordination group of NGOs is working closely with all three onchocerciasis control programs and with national counterparts in virtually all endemic countries.

4.2.7 GLAUCOMA

Definition:

Glaucoma can be regarded as a group of diseases that have as a common end point a characteristic optic neuropathy which is determined by both structural change and functional deficit. The medical understanding of the nature of glaucoma has changed profoundly in the past few years and a precise comprehensive definition and diagnostic criteria are yet to be finalized. There are several types of glaucoma, however, the two most common are primary open angle glaucoma (POAG), having a slow and insidious onset, and angle closure glaucoma (ACG), which is less common and tends to be more acute.

Magnitude:

The number of persons estimated to be blind as a result of primary glaucoma is 4.5 million, accounting for slightly more than twelve per cent of all global blindness. Risk factors are those limited to the onset of disease and those associated with progressive worsening in already established disease. The primary risk factors that are linked to the individual and the onset of the disease are age and genetic predisposition. The incidence of POAG rises with age and its progression is more frequent in people of African origin. ACG is the common form of glaucoma in people of Asian origin.

Prevention and treatment:

There is little known about primary prevention of glaucoma; however, there are effective methods of medical and surgical treatment if the disease is diagnosed in its early stage. Through appropriate treatment, sight may be maintained; otherwise the progression of the condition leads eventually to severe restriction of the visual field and irreversible blindness.

4.2.8 DIABETIC RETINOPATHY

Definition

Diabetic retinopathy is composed of a characteristic group of lesions found in the retina of individuals having had diabetes mellitus for several years. The abnormalities that characterize diabetic retinopathy occur in predictable progression with minor variations in the order of their appearance. Diabetic retinopathy is considered to be the result of vascular changes in the retinal circulation. In the early stages vascular occlusion and dilations occur. It progresses into a proliferative retinopathy with the growth of new blood vessels. Macular edema (the thickening of the central part of the retina) can significantly decrease visual acuity.

Magnitude:

There are important differences over the past few decades in diagnosis, medical care, socioeconomic factors and other risk factors that influence the prevalence and geographic distribution of diabetes and retinopathy as well. It is estimated that in 2002 diabetic retinopathy accounted for about 5% of world blindness, representing almost 5 million blind. As the incidence of diabetes gradually increases, there is the possibility that more individuals will suffer from eye complications which, if not properly managed, may lead to permanent eye damage.

Prevention and treatment:

Risk factors for diabetic retinopathy include duration of diabetes, level of glycemia, presence of high blood pressure, dependence on insulin, pregnancy, levels of selected serum lipids, nutritional and genetic factors. Medical interventions can decrease some of the risk to vision caused by diabetic retinopathy. The control of glycemia decreases the risk of the incidence and the progression of the retinopathy. If sight threatening retinopathy is present, timely laser photocoagulation of the retina decreases the risk of a subsequent severe visual lesion.

4.2.9 AGE RELATED MACULAR DEGENERATION

Definition:

Age-related macular degeneration (AMD) is a condition affecting people over the age of 50 and involves the loss of the person's central field of vision. It occurs when the macular (or central) retina develops degenerative lesions. It is thought that circulatory insufficiency, with reduction in the blood flow to the macular area, also plays a part. Several forms of AMD exist.

Magnitude:

Globally, AMD ranks third as a cause of visual impairment with a blindness prevalence of 8.7%. It is the primary cause of visual impairment in industrialized countries. The main risk factor is ageing. Other risk factors may include the use of tobacco, genetic tendencies, the degree of pigmentation (with light colored eyes being at higher risk), arterial hypertension, the ultraviolet rays, and consumption of a non-balanced diet.

Prevention and treatment

At present, there is neither prevention nor a cure. Palliative treatments which seem to be able to retard the progress somewhat include the use of lasers, dynamic phototherapy and sometimes surgery. Rehabilitative training of those with impaired vision includes the availability of bright lighting in the living and work spaces and the use of special aids for viewing and computer use.

4.2.10 CORNEAL OPACITIES

Definition

Corneal visual impairment encompasses a wide variety of infectious and inflammatory eye diseases that cause scarring of the cornea, the clear membrane that covers the outside of the eye. Significant scarring ultimately leads to functional vision loss.

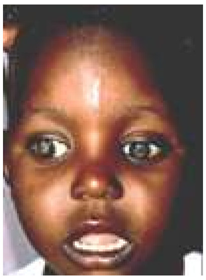


Figure 4-10: Lack of donors make access to the corneal surgery difficult to reach.

Magnitude

The 4th cause of blindness globally (5.1%), corneal blindness is one of the major causes of visual deficiency after cataract, glaucoma and age related macular degeneration (AMD). Trachoma is responsible for nearly 4.9 million blind, mainly as a result of corneal scarring and vascularization. Ocular trauma and corneal ulcerations are significant causes of corneal blindness. They are often underreported but they are estimated at 1.5 to 2.0 million new cases of unilateral blindness every year. Among the causes of childhood blindness (approximately 1.5 million cases in the world and 5 million children with visual impairment) appear xerophthalmia (350,000 cases per year), new-born conjunctivitis, and rarer ocular infections like herpes and keratoconjunctivitis.

Even though the control of onchocerciasis and leprosy are public health success stories, these diseases are still significant causes of blindness, affecting approximately 250,000 individuals each. Traditional eye medicines have also been implicated as a major risk factor in the current epidemic of corneal ulceration in developing countries.

Corneal visual impairment is encompasses a wide variety of infectious and inflammatory eye diseases that cause corneal scarring, which ultimately leads to functional vision loss.

Prevention and treatment

Public health prevention programs are the most cost-effective means of decreasing the global burden of corneal blindness Indeed, the only currently available curative treatment is the surgery, by graft of cornea. But the access to this surgery is very difficult, even in the developed countries, for lack of donors.

4.2.11 GENETIC EYE DISEASES

Definition

Genetic eye diseases include a large number of ocular pathologies which have in common the transmission from parents to children by their genetic inheritance. All do not cause visual impairment.

Magnitude

Knowledge about genetic eye diseases has increased dramatically during the last twenty years. Although there are no global statistics which let us know the extent of the burden of visual impairment from genetic causes, it does seem that genetic eye pathology represents a significant percentage of the causes of blindness in industrialized countries.

Prevention and treatment

The only current means of prevention of genetic eye pathology is genetic counseling. Treatment of genetic eye disorders is largely experimental, with the exception of surgeries on the cornea, lens and vitreous, which are well-documented in certain cases. The best hopes for treatment, however, lie in the use of gene therapy, growth promotion therapies for degenerative diseases, and possibly the grafting of retinal cells.

Treatment at minibus:

From all of these 11 most common diseases, there are some that can be analyzed and treated with no surgery so it can be solved in the mini-bus. There are others that might need surgery, so they should be practiced in a Hospital or even in disinfected camp tends. And finally there's a third type of disease that in some cases it might need surgery and some can be solved without surgery just with some medication.

Diseases that should be treated in a Hospital or disinfected camp tends:

- Genetic eye diseases.
- Corneal opacities.
- Age related macular degeneration (AMD) and Cataract

Diseases that can be treated in the minibus

- Diabetic retinopathy: Some extra laser equipment would be needed.
- Onchocerciasis: The treatment is for almost 20 years, but it can be solved with pills.
- Trachoma: Some antibiotic are needed.
- Low Vision

Refractive errors Diseases that in some cases can be treated and others not:

- Glaucoma: Some cases can be treated with eye drops.
- Childhood Blindness: Vaccination programs against measles and vitamin A supplements.

4.3 SUMMARY OF THE VISIT AT S. JOÃO HOSPITAL, OPHTHALMOLOGIC DEPARTMENT:

Attended by:

Luis Torrão: Chief Doctor

Sofia Fonseca: Doctor

Rodolfo: Optic technician.

In the visit to the hospital one can see how they organize their work and which equipment they use in a normal visit. They only treat adult patients, as with children they need to do the "lang" and also the binocular sight test". The role of the optic technician is basic so he helps to reduce the time that one normal consultancy lasts. He does an initial reading with the autorefractometer this machine gives a first approximation to the eye graduation. Later, this is further analysed with the projector and the lenses box.

He also uses the tonometer to check if the pressure of the eye is in its normal range.
Other diseases could be treated in the consultancy, including:
Trachoma: The Bill Gates foundation is already working in an antibiotic to finish this disease.
Onchocerciasis: Could be treated with pills.
Diabetic retinopathy: This one can be treated with laser equipment.
Glaucoma: Some kind of this can be treated with eye drops.
Low vision: Refractive errors can be rectified with appropriate optical correction while people with poor vision may be helped with low vision devices

Time:
A normal visit takes about 15 minutes, in one afternoon of 5 hours of work they can visit between 15 and 20 patients.
The Dra. Sofia usually classified the visits in two phases. People without any visual impairment just need the first one and then they can go at home. The second phase is only necessary for patients that have some visual impairment or risk like diabetics.
The first phase is about the revision of the retina: They use the projector, the retinoscopy, and the lamp, they also use the phoropter, and some disposable material as silicone gloves, and napkins.
Before the second phase begins, patients need to have some eyedrops, and let them wait 30 minutes. After this time, they are ready to have a more exhaustive treatment.

5 LITERATURE REVIEW:

5.1 STATE OF THE ART:

5.1.1 MMIC MOBILE MEDICAL:

Figure 5-1: MMIC commercial logotype.

It's the most experienced company in medical mobile units with more than 10 years. They also built ophthalmological units where doctors can also operate because their units are trailers (16 meters long).

Main Characteristics:

- Set-up can be done in 1 hour by 1 person.
- When configured as hydraulically expandable trailer provides almost three times of space than other mobile units. It can also be non-expandable trailer.

- They provide to each unit lighting, integrated power, heating, air conditioning equipped with HVAC/HEPA filtration, plumbing, communications, fire suppression and alarm.
- In order to assure sealing from weather and thermal protection it's furnished with two part floor.
- They offer multiple transportation options such as train, air, or ship.

Figure 5-2: MMIC 16 meter trailer.

Optional Equipment:

- Power, communications, water and vacuum have redundant systems in case one fails.
- Monitoring systems, nurse call can be integrated.
- Tanks for storage of fresh, black and grey water.
- Diesel generator
- Differenced and separated pre and post-operative rooms.
- Wheel chair lift accompanied of a spacious entrance and transition areas.
-

Telemedicine

Telemedicine employs monitors and fiber optic or copper cable in order to provide streaming connection to anywhere in the world or also to local networks.

As it is designed to be easy to use, and it provides exceptional mobility, it is changing the future of healthcare. Surgeries, doubts, data transfer and much more can be seen and control all over the world.

Mobile Surgery Unit

- The operation room was designed to convene or surpass the U.S healthcare standards.
- Depending on configuration, pre or post operation rooms have the capacity of two or three patients.
- Clean area has been designed separate from the mucky room.
- Sterilization if instruments are assured in the clean utility room.
- Integrated medical gases zoned for activation with required shut-off valves.

Figure 5-3: Interior and exterior of an expandable MMIC mobile surgery unit

Mobile Diagnostic Unit

This unit is equipped with a multi-function lab premeditated for microbiological, biochemical, immune and blood lab work.

Mobile Breast Care Center:

It includes ultrasound equipment, digital mammography, digital imaging and stereotactic breast biopsy table.

Mobile Laboratory/Pharmacy Unit

Different rooms and zones for phlebotomy, pharmacy, lab, microbiology, blood testing & storage, patient waiting and processing, are installed in this unit model.

Figure 5-4: 3-D designed MMIC mobile Laboratory/Pharmacy unit

Mobile CT Scan-Ophthalmology-Dental Unit

It it’s designed with CT scan room and two general exam stations which can be configured for specific applications.

Figure 5-5: MMIC Mobile unit equipped with scan.

Mobile Intensive Care Unit

- Equipped with 6 beds but it can be designed to achieve customer desires.
- It can be used in large dimension disasters as surgery room.
- Multiple uses of two rooms can be easily adapted.

Mobile Ophthalmology Unit

- It’s a non-expandable unit, divided in exam and laser room, and ultrasound room. Different areas are divided by curtains.
- Each exam room if full equipped with the necessary equipment.

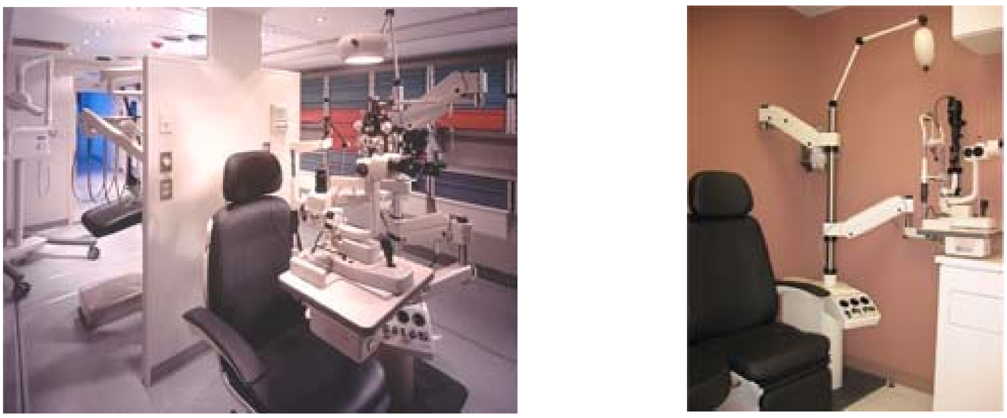


Figure 5-6: MMIC Ophthalmology Unit.

Mobile Dialysis Unit

It can be equipped with six dialysis stations and also can have one in reserve.

Licensing & State Regulations:
MMIC received CMS authorization in October 1997. In March 1998, California officially certified the first Mobile Surgery Unit™ as a self-supporting ambulatory surgery center (ASC); the first time in the history of U.S. healthcare that a Mobile Surgery Unit™ was licensed as a self-supporting surgery center.

Since then, Florida has passed legislation allowing Mobile Surgery Units™ to be licensed for use in their Department of Corrections and Virginia now has two operational units. Other states have either reviewed or are in the process of reviewing applications for their specific requirements.

Figure 5-7: Another perspective of the MMIC CT Scan mobile unit.

5.1.2 LA BOIT INC.

Figure 5-8: La Boit is a US company that transforms buses into medical mobile units.

La Boit's are made in all-aluminum cage in order to give the user all the strengh need to anchor equipment and cabinetry .

Main Characteristics:

- Two meter high interiors
- Proven standard designs
-Custom made cabinetry with slam-shut latches
- All non-pourous materials for easy cleaning

Optional Equipment:

- Dental Chairs
- Chair Lighting

- Compressor
- Dry Vacuum
- Delivery Systems
- X-ray Capabilities
- Auto Clave
- Ultrasonic Cleaner
- Handicap Accessible
- Flat Screen TVs (for patient education)

Figure 5-9 La boit Mobile AIDS Information and laboratory point.

Figure 5-10: Laboit Children's information point.

5.2 EXAMPLE CASE:

5.2.1 THE ARMENIAN EYE CARE PROJECT:

The 16 meter tractor-trailer equipped with entire sterile and operating rooms, examination rooms was established at Malayan, Arshtarak (Armenia). This mobile eye hospital is owned by the AECP (Armenian Eye Care Protect). It operates during three weeks, seven days a week. American ophthalmologists and its Armenian colleagues made 200 surgeries and almost 90% made by local doctors. (and laser treatments), observed 5000 patients and referred 500 to the hospital.

The cost of this vehicle, with the equipment included is about $1 million, and is supposed to be the first of its kind in the world.

The initial purpose of the AECP was to come to Armenia and assist in operations that local doctors were not as experienced as American one's. They trained Armenian doctors and some of them travelled to U.S to take supplementary training.

The project chose Ashtarak to initiate its program, since the town is close to Yerevan and doctors could go back and forth from the Malayan Center. In the end, however, the mobile unit will be spending numerous weeks a year in each of the 11 regions of Armenia, plus Karabakh.

Figure 5-11: The AECP trailer parked in Armenia.

The initial phase of treatment is a series of screenings, in which doctors gather information and determine what treatment patients will require when the truck arrives in a certain place. Another task of the screening is to find out if the patient social status corresponds with the "socially vulnerable" criteria established by the Armenian government. If they fit it, they are given free treatment, including operation.

The Mobile Eye Hospital first found that the majority of the patients are elderly; some of them have never had any treatment for its diseases either because they could not pay it or they don't trust in the Armenian health care system. This skepticism come from soviet times and also some of them are afraid of what doctors may say about the health.

Some examples of patients are:

75 years-old woman who never went before to check her eyes, and being examined by the AECP staff they discover that she has a cataract. Although she would have free treatment, because her family was deported to Siberia under Stalin's regime, she state that her destiny is in God's hands only. Even thought this case is not only one, is rare.

Another example would be the case of a 72 year old woman, who appointed for a surgery because she knew that she was suffering from cataracts for more than four years. She never went to a doctor because the total cost of the examination and surgery was between $120 from $200 and her pension was of $10 a month.

Figure 5-12: The ophalmologist examinates one patient with the slit lamp.

It's also a great experience for residency students to work side by side with experienced physicians who might not have this chance in a simple hospital.

The mobile unit will also provide data taken from all over the places through the questionnaires that the AECP made; this data will be used by the government of Armenia who said that they don't have the means to do a nationwide canvassing.

5.2.2 AQUILA (ITALY) EARTHQUAKE:

During the spring of year 2009, there was an earthquake where hundreds of people died and much more were injured, and buildings and roads were also severely damaged.

Figure 5-13: The unit arrived in the firsts days.

After the earthquake lots of dust, small particles of many materials, some pollutant gases were spread in the air as a result of buildings falling down and storehouses being damaged. This can cause eye irritations, not just to the population but also to the emergency units that are working in the area like fire-fighters, nurses, doctors, police and others. There was an ophthalmological mobile unit situated in the city of Aquila that deals with these problems, which acted as a support to the hospitals, which were almost collapsed.

Figure 5-14: Different views of the mobile unit.

5.3 EQUIPMENT AND DISPOSABLE MATERIAL:

The equipment needed in an ophthalmological office that would provide general consultancy is listed below. Furthermore, any medical office needs additional stuff, the disposable material; wich is also taken into consideration for the design of the furniture and for the financial analysis.

5.3.1 AUTOREFRACTOMETER:

Figure 5-15: One of the new autorefractometers models.

The reason for it's growing popularity, it's mainly because this instrument offers velocity and a reasonable exactitude. On the other hand, retinoscope provides information that autorefractometer don't provide. There are some situations of some patients. where a retinoscope will be also necessary.

The autorefractometers basically compress a source of a infrared light, one target of fixation and one optometer of Badal. The most deepest part of the eye, the coroides and the sclera reflect the infrared light (between 800- 900 nm) in these range of wavelength.

5.3.2 TONOMETER:

The tonometry it's a test that measures the intraocular pressure (inside the eye). The ocular globe requires a great precision in its structures to get the formation of clear images, some alteration in these structures can cause the deformation of the image.

There are two categories of tonometers, the contact a non-contact. The contact tonometers are cheaper but indeed of this, the patient must receive anesthetic eyedrops wich implies less comfort and some possible allergic reactions.

Figure 5-16: Non-contact tonometer.

5.3.3 SLIT LAMP

Basically this apparatus is the microscope that is used to look the eyes. The patient has a place where to put his head in a stable position. The doctor can see the eye augmented through some lenses.

There is one source of light that illuminates the eye; this light is situated in a mobile vertical tower. The slit lamp allows the doctor to see the different layers of the eye as are the cornea and the crystalline.

Figure 5-17: The slit lamp is one of the most important required equipment.

5.3.4 PHOROPTER:

This is an instrument used during an eye examination to measure refractive error and determine eyeglass prescriptions. Typically, the patient sits behind the phoropter, and looks through it at an eye chart. The optometrist then changes lenses and other settings, while asking the patient for feedback on which settings give the best vision of the images shown.

Figure 5-18: New generation phoropter.

5.3.5 OPTOTYPE PROJECTOR:

This device is used to project different visual test so that the patient can be examined and then determine its visual acuity, optotypes of different sizes are presented to a person and the smallest size is determined at which the person can reliably identify the optotypes.

Figure 5-19: The optptype projector is used in combination with the phoropter.

5.3.6 REFRACTION LENS ANALYZER

This equipment is used to analyze the lenses of the patients so the optometrist can have a first approach to the patient's visual acuity.

Figure 5-20: A simply lens analyzer.

5.3.7 RETINOSCOPE:

This system of illumination introduces light in the patient eye, watching the highlights that appear in the eye, one can determine the refractive estate of the patient.

Figure 5-21: Portable Retinoscope.

5.3.8 OPHTHALMOSCOPE:

The ophthalmoscope (or funduscope) is an instrument used to examine the eye. Its use is crucial in determining the health of the retina and the vitreous humor.

The ophthalmoscopy it’s practice as part of a routine examination and allows the doctor to detect detachment of the retina, glaucoma, diabetes, arterial hypertension and others.

There are two types available:

- Direct ophthalmoscope

It is an instrument about the size of a small flashlight (torch) with several lenses that can magnify up to about 15 times. This type of ophthalmoscope is most commonly used during a routine physical examination.

Figure 5-22: Direct ophtalmoscope.

- Indirect ophthalmoscope:

  An indirect ophthalmoscope constitutes a light attached to a headband, in addition to a small handheld lens. It provides a wider view of the inside of the eye. Furthermore, it allows a better view of the fundus of the eye, even if the lens is clouded by cataracts. An indirect ophthalmoscope can be either monocular or binocular.

5.3.9 THREE MIRROR LENS OR SUPERFIELD.

It is made by three mirrors and when the observer watches the eye trough them obtain a vision of the fundus peripheral and the vitreous. This is the unique lens that permits the whole exploration of the vitreous cavity.

Figure 5-23: Three mirror lens.

5.3.10 DISPOSABLE MATERIAL:

- Alcohol
- Gloves
- Syringe
- Ointment.
- Eye drops.
- Napkins
- Antiseptic soap for hands.

5.4 VEHICLE VIBRATIONS

In this thesis the vibrations that are transmitted from the road to the vehicle body are relevant because the mobile unit carries ophthalmological equipment. This equipments are sensitive to the vibrations, and can be easily disarranged and give wrong readings and results.

In order to isolate the equipment as maximum as possible, one can work in two directions. The first one is to isolate the apparatus from the table where they are on. This could be done with some rubbers; these can be chosen and designed in order to absorb some range of frequencies. The second one is to identify the road inputs to the system and choose the best damping system in order to transmit to the body the less vibration.

5.4.1 INTRODUCTION:

When vehicle travels at high speeds it experiences a wide spectrum of vibrations. This spectrum of vibrations can be mainly classified in two, ride and noise, according to frequency:

- Ride: 0-25 Hz.
- Noise: 25-20000 Hz.

Ride vibrations are normally referred to tactile and visual vibrations and noise are identified as aural vibrations. The lower frequency threshold of hearing is approximately 25 Hz and it's also the upper frequency limit of simpler vibrations that frequent in all motor vehicles. Different types of vibrations are commonly interrelated and it may be complicated to consider ach

The 25 Hz is approximately the lower frequency threshold of hearing, as well as the upper frequency limit of the simpler vibrations common to all rubber-tired motor vehicles. The different types of vibrations are usually so interrelated that it may be difficult to consider each independently.

Analyzing low frequency vibrations is important when one is studying the vehicle dynamics. The vehicle is a dynamic system that only presents vibrations when as response to excitation inputs. To have a better idea of how the ride behaviour of the whole dynamic system works it's helpful to think the system as shown in Figure 4-24.

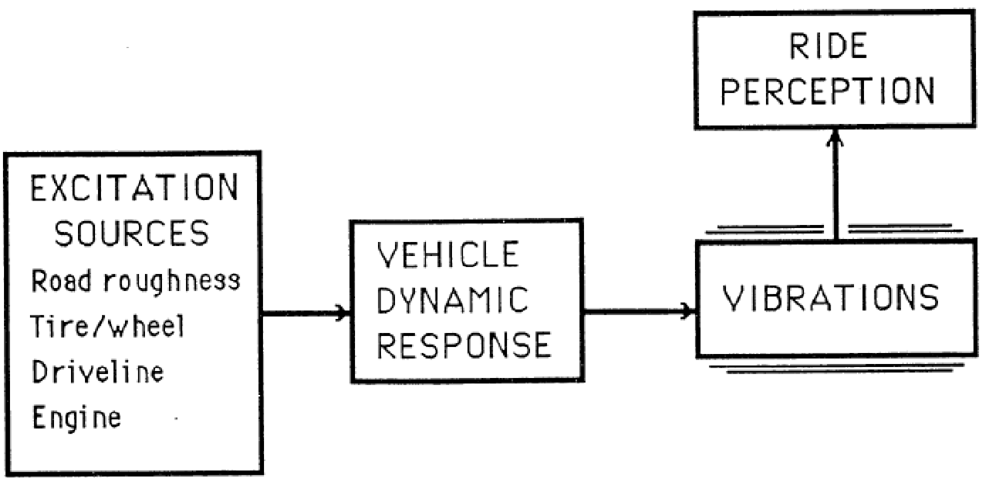


Figure 5-24: The ride dynamic system (3)

5.4.2 EXCITATION SOURCES:

There are many possible sources from wich the vehicle might be excited. Although mainly are classified in two groups; Road roughness and on-board sources. The onboard sources arise from rotating components such as the engine, the driveline, and tire/wheel assemblies. Note that on-board sources will not be studied in this thesis.

5.4.2.1 GENERALIZED MODEL OF A DETERIORATED ROAD:

In this study dirt tracks have a relevant importance in the study, the minibus would probably have to go into them and carry the ophthalmological equipment wich is fragile, sensitive, and expensive.

For the explanation of random road unevenness $H_0(l)$ has been chosen the model that establishes the international standard ISO8608 for the measurement and processing of measured longitudinal road profiles:

$$G_{H_0}(\Omega) = C \cdot \Omega^{-w}$$

Where:

Ω = Circular (angular) spatial frequency [rad/m].

C =The unevenness index $\left[rad^{w-1} m^{3-w}\right]$

w = The waviness. It was demonstrated that when evaluating some hundred of in-service roads in Germany, United States and Sweden, the waviness values appear to cover a broad interval from 1.5 to 3.5.

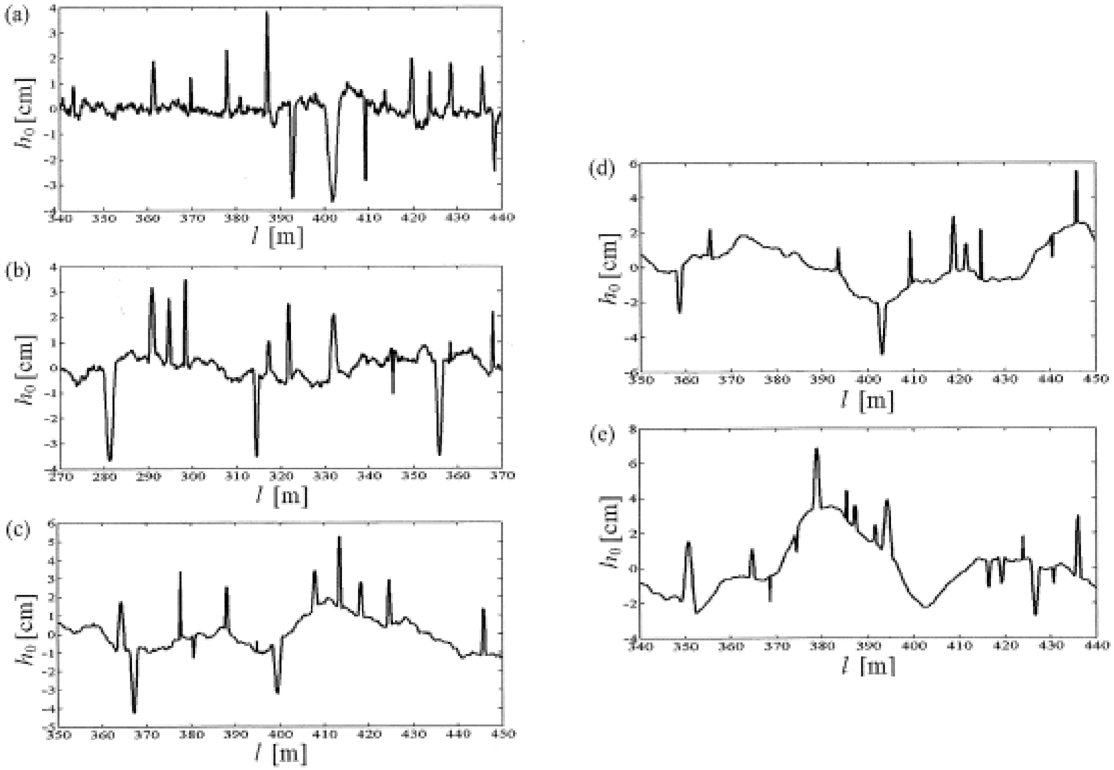


Figure 5-25: Examples of simulated road profiles with superimposed w values: (a) w=1.5 ; (b) w=2 ; (c) w=2.5; (d) w=3; (e) w=3.5. (4)

5.4.3 ROAD ROUGHNESS:

Road roughness includes everything from potholes resulting from little pavement failures, or dirt tracks to the random deviations that are unavoidable, due to constructive limits.

Roughness is characterized by the elevation profile along the wheel tracks over wich the vehicle passes.

Road profiles are categorized as “broad-band random signals” and can be described by the profile itself or its statistical properties. One of the most useful representations is the Power Spectral Density (PSD) function.

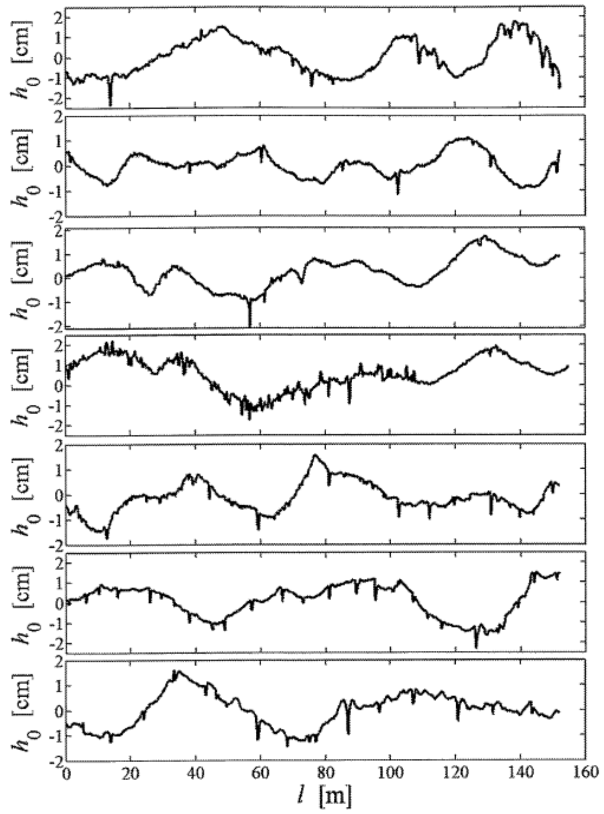


Figure 5-26: Examples of longitudinal profiles of in-situ roads. (2)

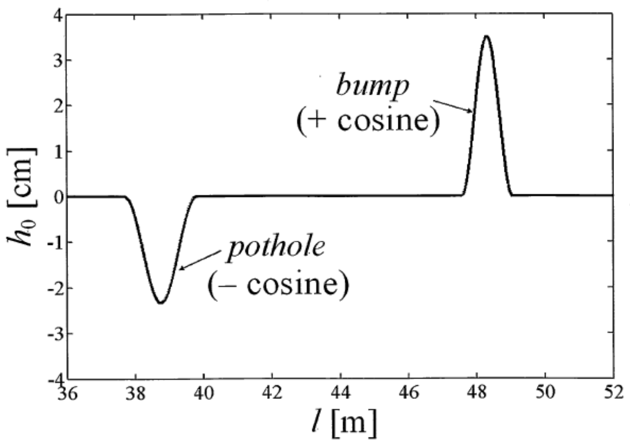


Figure 5-27: Obstacles are considered in the cosine form with their random alternation and position on the track. (2)

As any random signal, the elevation profile measured over a length of road can be decomposed by the Fourier Transform process into a series of sine waves changing in their amplitude and phase relationships. The plot of the amplitude versus spatial frequency is the

PSD. Spatial frequency is expressed in cycles/meter (the wavenumber) and is the inverse of the wavelength of the sine wave on wich is based.

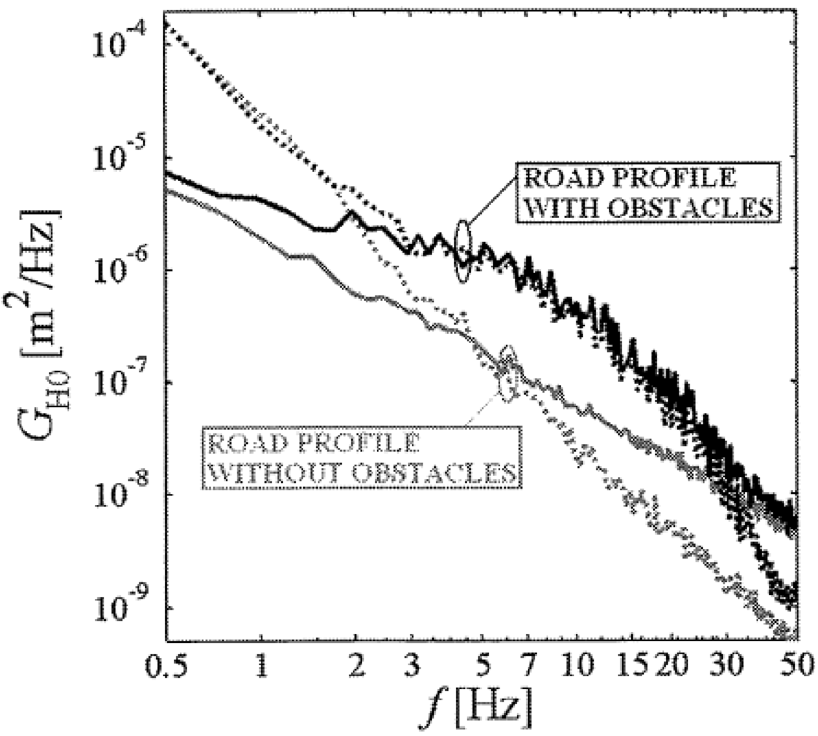


Figure 5-28: Comparison of PSDs profile with obstacles (black one) vs. profile without obstacles (grey) for v=90Km/h. (2)

Plots like the figure above are typically obtained. However, the PSD of every road is unique, but all roads show the characteristic drop in amplitude with wavenumber or frequency. The reason for this is that deviations in the road surface measured in the order of hundreds of meters in length may have amplitudes of centimetres while those only a few meters in length are normally fractions of centimetres especially when the measured road has no remarkable obstacles. As plot in Figure 5-28, the level of amplitude is indicative of the roughness level, higher amplitudes indicates rougher roads.

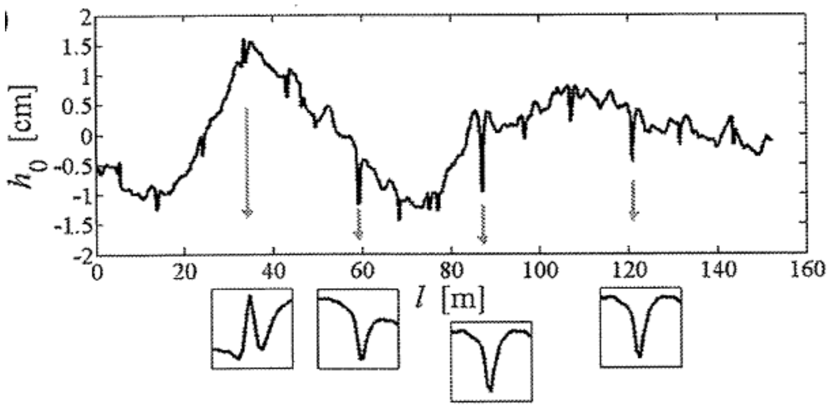


Figure 5-29: Example of measured random profile with exaggerated obstacle shapes. (2)

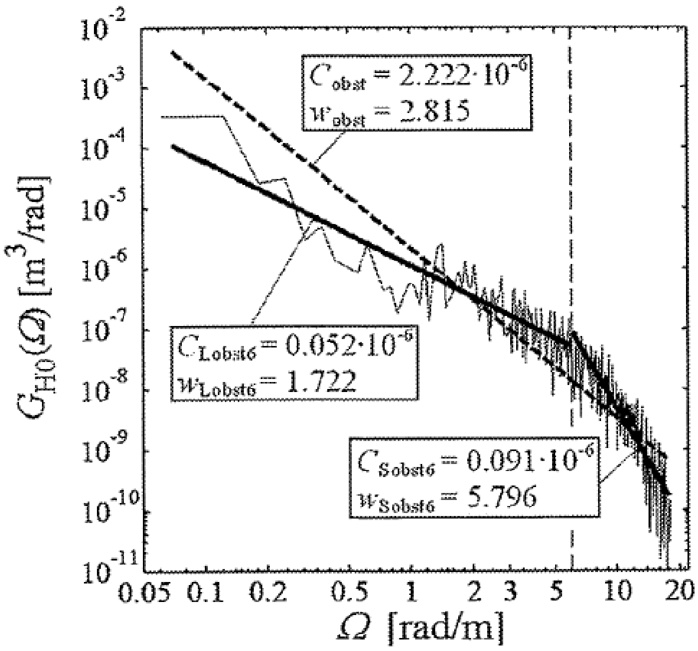


Figure 5-30:PSD of the measured random profile shown in Figure 4-29, with two single and two straight-line approximations. (2)

Although many ride problems are peculiar to a specific road, or road type, the notion of "average" road properties can often be helpful in understanding the response of a vehicle to road roughness. The general similitude in the spectral content of the roads seen in Figure 5-28,(that elevation amplitude diminishes systematically with increasing frequency) has long been recognized as true of most roads. Other important for our final purpose, are stony roads, these will have a slightly differing spectral qualities. The general level of elevation of the curve may be raised or lowered to represent different roughness levels, but the characteristic slopes and inflections points are constant.

The roughness acts as vertical displacement input to the wheels, exciting ride vibrations. The most common and significant measure of ride vibration is the acceleration produced. The roughness should be treated as an acceleration input at the wheels for an easy understanding of the dynamics of ride. To get to this point, the first step would be to determine the speed of travel so that the elevation profile is transformed to displacement as a function time. The second step would be to differentiate once to obtain the velocity of the input at the wheels, and finally it may be differentiated a second time to obtain the acceleration.

5.4.4 VEHICLE RESPONSE PROPERTIES:

When low frequencies are studied, the body moves as a one unit on the suspensions, this body is considered to be the sprung mass portion of the vehicle. This is called rigid-body motion. There are more variables of design and operating condition that are known to affect the vibration response of the vehicle. Additionally, one must look to structural modes of vibration and resonances of sub-systems on the vehicle.

As state above, the dynamic behaviour of the vehicle can be characterized by considering input-output relationships. The input might be an excitation while the output will be the vibrations on the body. The ratio of output and input amplitudes represent the gain for the dynamic system. It's often called "transmissibility", and it's a no dimensional ratio of response amplitude to excitation amplitude for a system in steady-state forced vibration. This ratio may be one of forces, displacements, velocities or accelerations.

5.4.5 THE QUARTER-CAR MODEL:

At the most fundamental level, all common vehicles can be represented with a sprung mass supported by primary suspensions systems at each wheel. This is called the quarter-car model. The dynamic behaviour of this system is the first level of isolation from roughness of the road and it will give a first approximation of the vehicle dynamics.

This model consists of a sprung mass supported on primary suspension wich one after another is connected to the unsprung mass of the axle. The tire is represented as a simple spring and the suspension as a spring and a shock absorber...

The sprung mass is capable of motion in the vertical direction. The effective stiffness of the suspension and tire springs in series is called the "ride rate" determined as follows.

$$RR = \frac{K_s * K_t}{K_s + K_t} \qquad \text{(Eq. 4.1)}$$

Where,

RR=Ride rate

K_s =Suspension stiffness

K_t =Tire stiffness

In there's no damping, the undamped natural frequency at each corner of the vehicle can be determined from:

$$\omega_n = \sqrt{\frac{RR}{M}} \text{ (rad/sec)} \qquad \text{or} \qquad f_n = 0{,}159\sqrt{\frac{RR}{W/g}} \text{ (cycles/sec)} \qquad \text{(Eq. 4.2)}$$

Where:

M= Sprung mass

W=Mg=Weight of the sprung mass.

G= acceleration of gravity

When damping is present, as it is in the suspension, the resonance occurs at the "damped natural frequency" ω_d:

$$\omega_d = \omega_n \sqrt{1-\zeta^2} \qquad \text{(Eq. 4.3)}$$

where:

$$\zeta = \text{Damping ratio} = \frac{Cs}{\sqrt{4KsM}} \qquad \text{(Eq. 4,4)}$$

Cs= Suspension damping coefficient

With the purpose of providing a good ride, the suspension damping ratio on modern passenger cars usually takes a value between 0,2 and 0,4. If one study wich are the damping natural frequencies for 0,2 and for 0,4 and then compare the results with the values obtained for the undamped natural frequency will get to these results:

$\omega_d = 0{,}98 * \omega_n$ (for $\zeta = 0{,}2$)

$\omega_d = 0{,}92 * \omega_n$ (for $\zeta = 0{,}4$)

So as there is so little difference the undamped natural frequency, ω_n ,is normally used to characterize the vehicle.

The static deflection of the suspension due to the weight of the vehicle is represented as follows:

Static Deflection= $\dfrac{W}{K_s}$

It is a simple parameter indicative of the lower bound on the isolation of a system and predominates in determining the natural frequency

A static deflection of 254 mm is necessary to achieve a 1 Hz natural frequency, considered to be a design optimum for highway vehicles. While is not necessary for the suspension to provide a full 254 mm (10 inches) of travel to achieve 1Hz frequency, in general, provisions for larger deflections are necessary with lower frequencies. For example, with a spring rate low enough to yield a 1 Hz frequency, at least 127 mm of stroke must be available in order to absorb a bump acceleration of one-half "g" without hitting the suspensions stops. Large cars have a usable suspension stroke in the range of 177,8 to 203,2 mm , whereas small and compact the stroke may be reduced to 127 mm or 152,4 mm.

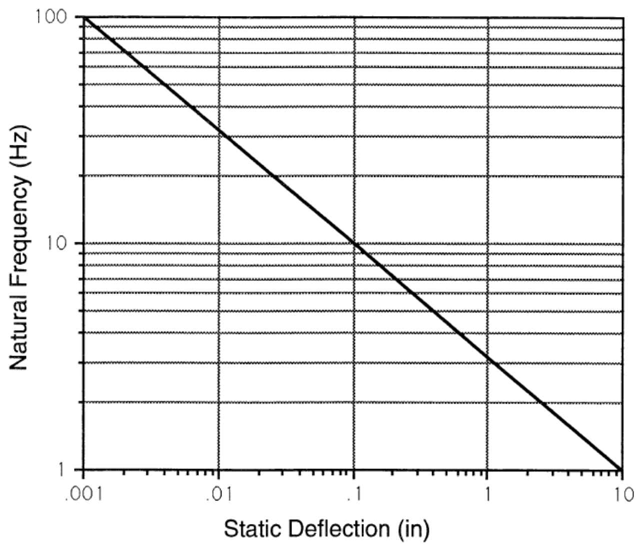


Figure 5-31: Undamped natural frequency versus static deflection of a suspension. (1)

If one writes the Newton's second law for the sprung and sprung mass of the quarter-car model in steady case may obtain the dynamic behavior. If a free body diagram is considered for each, the following equations are obtained.

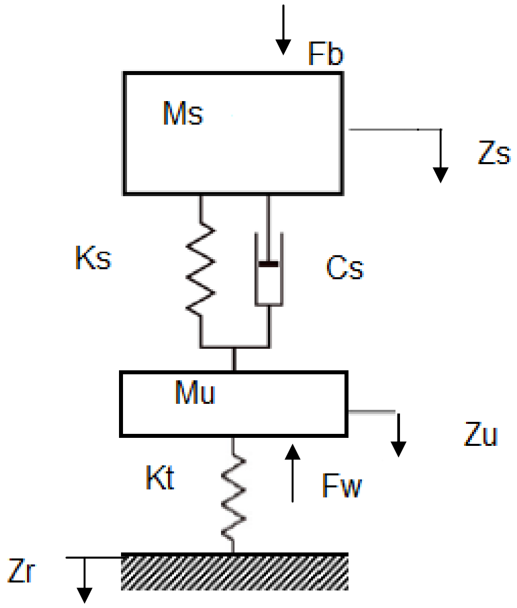


Figure 5-32: The quarter-car model.

$$M_s\ddot{Z}_s + C_s\dot{Z}_s + K_sZ_s = C_s\dot{Z}_u + K_sZ_u + F_b$$
$$M_u\ddot{Z}_u + C_s\dot{Z}_u + (K_s + K_t)Z_u = C_s\dot{Z}_s + K_sZ_s + K_tZ_r + F_w \qquad \text{(Eq. 4.5)}$$

Where:

Z_s = Sprung mass displacement

Z_u = Unsprung mass displacement

Z_r = Road displacement

F_b = Force on the sprung mass

F_w = Force on the unsprung mass

The solutions can be obtained for the steady-state harmonic motion by methods found in classical texts.

The most interesting solutions are those for the sprung mass motion in response to road displacement inputs, forces at the axle, and forces applied directly to the sprung mass. The amplitude ratios for these cases are:

$$\frac{\ddot{Z}_s}{\ddot{Z}_r} = \frac{K_1 * K_2 + j(K_1 * C * \omega)}{\left[\chi\omega^4 - (K_1 + K_2\chi + K_2)\omega^2 + K_1 * K_2\right] + j\left[K_1 * C * \omega - (1+\chi)C\omega^3\right]} \qquad \text{(Eq. 4.6)}$$

$$\frac{\ddot{Z}_s}{F_b / M_s} = \frac{K_2\omega^2 + j\left[C\omega^3\right]}{\left[\chi\omega^4 - (K_1 + K_2\chi + K_2)\omega^2 + K_1 * K_2\right] + j\left[K_1 * C * \omega - (1+\chi)C\omega^3\right]}$$

Where:

χ = m/M= Ratio of unsprung to sprung mass.

$C = C_s / M_s$

$K_1 = K_t / M_s$

$K_2 = K_s / M_s$

J = Complex operator

To find the amplitude of the equations above, the imaginary and real parts of the numerators and denominators must be evaluated at the frequency of interest.

For calculating the magnitude is necessary to determine by taking the square root of the sum of the squares of the real and imaginary parts. Once the magnitude the numerator or denominator is calculated one can consequently calculate the ratio.

Using the equations above, one can study the vibrations produced on the sprung mass as a result of inputs from road roughness or vertical forces applied directly to the sprung mass from onboard sources. In this work, only road roughness inputs would be treated.

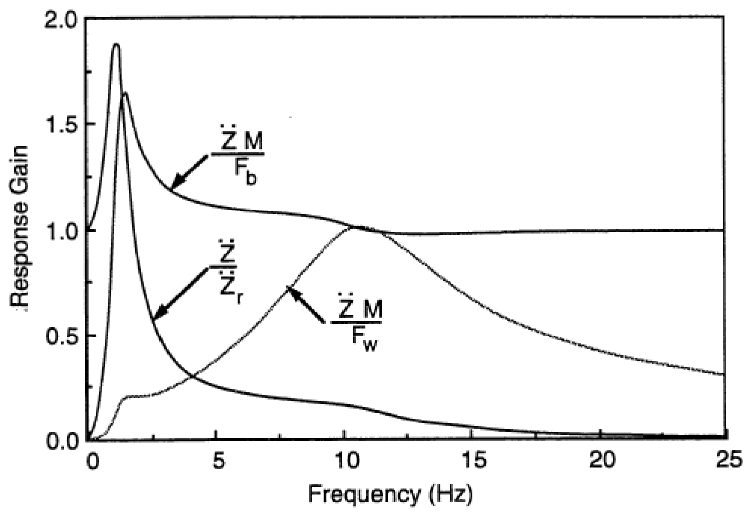


Figure 5-33: Quarter-car response to road, tire/wheel, and body inputs. (1)

As seen in the figure above, at very low frequency the sprung mass moves in exact duplication of the road input so the gain is unity. The sprung mass is designed in passenger motor vehicles design to have its natural frequency at or just above 1 Hz. Consequently, at frequencies near 1Hz the sprung mass is resonating and road inputs are amplified. The amplitude ratio at this peak on typical passenger cars will be in the range of 1.5 to 3, and in heavy trucks the amplitude ratio is dependent on the road and operating conditions, but in the worst cases may be between 5 to 6 (1). At higher frequencies than the resonance, the road inputs are gradually more attenuated. Although, in the range of 10 to 12 Hz the unsprung mass of the tire/wheel assembly has a vertical resonance mode, that the reason of the small bump seen in that region.

5.4.6 SUSPENSION STIFFNESS:

The suspension spring is in series with the hypothetic spring that represents the stiffness of the tire, as it is only an approximation, the suspension spring predominates in the computation of the ride rate (RR) thus to determine the natural frequency of the system in the vertical bounce mode. The best isolation is achieved by keeping the natural frequency as low because the road accelerations inputs increase in amplitude at higher frequencies.

The effects of the accelerations transmitted to the sprung mass can be estimated by approximating the road acceleration input as a function that increases with the square of frequency. Then the mean square acceleration can be calculated as follows:

$$G_{zs}(f) = |H_v(f)|^2 G_{zr} \qquad \text{(Eq. 4.7)}$$

Where:

$G_{zs}(f)$ =Acceleration PSD on the sprung mass.

$H_v(f)$ = Response gain for road input.

G_{zr} =Acceleration PSD of the road input.

As seen in the figure below, if on combine the basic isolation properties of the quarter car model with a typical spectra of road roughness, a first idea of the ride acceleration spectrum that should be expected on a motor vehicle because road inputs is obtained.

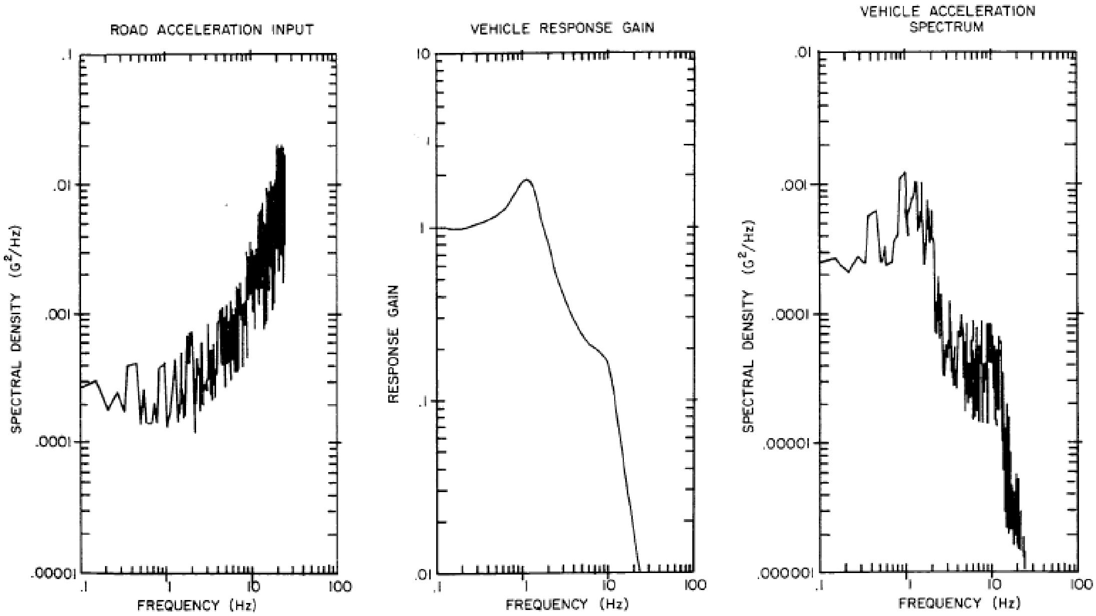


Figure 5-34: Isolation of raod acceleration by the quarter-car model. (1)

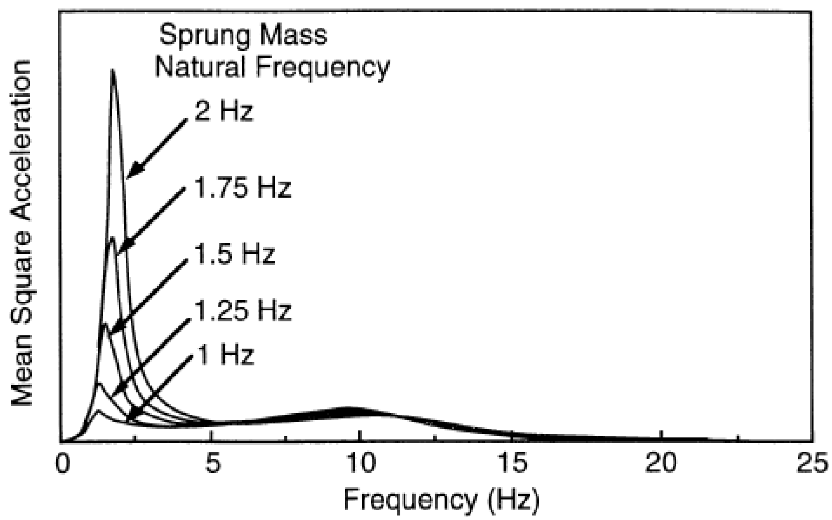


Figure 5-35: On-road acceleration spectra with different spung mass natural frequencies. (1)

I n the figure above the suspension spring rate has been varied to achieve natural frequencies between 1Hz and 2Hz. The plot shows the Mean Square Acceleration versus Frequency, the area under the curve indicates the relative level of mean-square acceleration.

At higher values of natural frequency, wich means stiffer suspension springs, the acceleration peak increases, wich mean that there would be a greater transmission or road acceleration inputs to the vehicle body. Note that the lowest acceleration occurs at 1 Hz. Moreover, stiffer springs elevate the natural frequency of the wheel hop (near 10Hz), permitting more acceleration transmission in the high frequency range.

5.4.7 SUSPENSION DAMPING

Damping in suspensions comes principally from the action of hydraulic shock absorbers. Contrary to what one must think, they do not absorb the shock from road obstacles, what they really do is to dissipate the energy put into the system by the bump.

The nominal effect of damping for the quarter-car model by the response gains is shown in Figure 5-36. The percent damping is calculated from the damping ration given in equation (Eq. 4,4).

Looking at the figure one can determine that at damping beyond the critical (100%) the damper become so stiff that the suspension no longer acts and the vehicle just bounce on its tires, resonating at the 3 to 4Hz range. At 100%, the 1Hz bounce motions are controlled but on the contrary, there's not good isolation at higher frequencies. At 40% the damping ratio curve is realistically representative of most common cars, note that the peak at the resonant frequency is in the range of 1,5 to 2 Hz.

And finally, at 10% damping, wich is known as "light damping" or "float", this response cause the sprung mass to amplify long undulations in the roadway, and it is dominated by a very high response at 1Hz. It's the typical behavior of heavy trucks. Whereas this could be undesirable, there's an important benefit obtained at frequencies beyond the resonant point, wich is the high attenuation achieved.

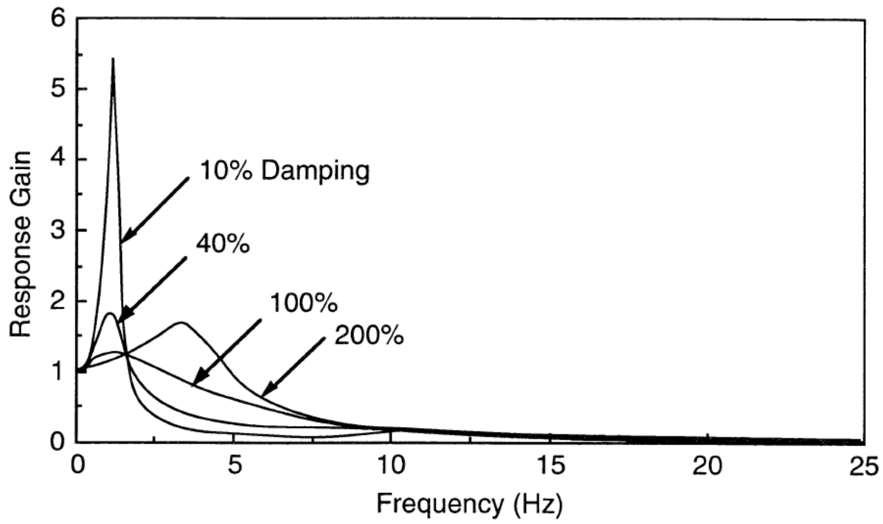


Figure 5-36: The effect of damping on suspension isolation behaviour. (1)

Note that this is just an analytical treatment that provides a simplified approximation to the ride effect of damping in the suspension. Shock absorbers must assure a good tire-to-road contact essential for handling a safety and not only tailored to achieve the desired ride characteristics. With the aim to achieve this objective, a valving must be chosen and then it no longer can be treated as a simple linear element. The assumption made until now, force is proportional to velocity will not be valid then.

5.4.8 PITCH AND BOUNCE MOTIONS

The simple estimation of the quarter-car model do not totally represent the rigid-body motions that may occur on a motor vehicle. Any vehicle is a multi-input system because of the longitudinal distance between the axles, that responds with pitch motions and vertical bounce. Pitch and bounce motions are important to understand because the combination of them determines vertical and longitudinal vibrations at any point of the vehicle.

Rear wheels see almost the same input from the road but only delayed in time. The time delay is equal to the wheelbase distance divided by the speed of travel. The time delay acts to filter bounce and pitch excitation amplitude, it is called "wheelbase filtering" (3). Because of the stiffer suspensions and wheelbase distances (3,7-4,6 meters) the bounce and pitch vibration behavior of trucks, and consequently the mini-bus presents different representation than cars. The bounce response will have a null at the resonant frequency and the pitch response will be at full amplitude.

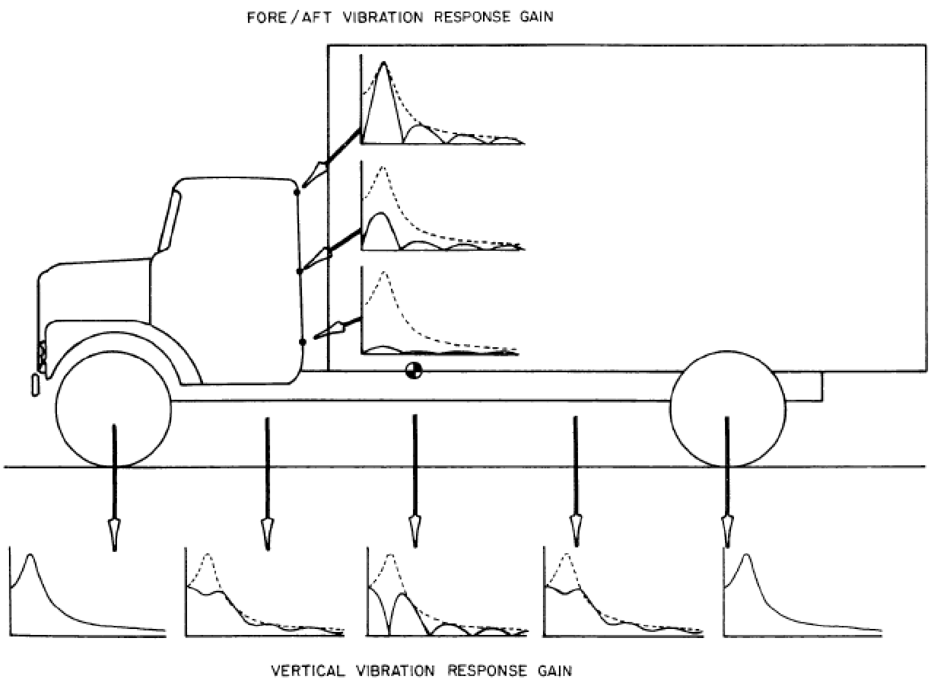


Figure 5-37: Effect of wheelbase filtering on vertical and longitudinal response gain of a truck.

The vertical vibration response will be different with the location along the length of the vehicle, depending on the relative actions of the bounce and pitch motions. Next to the midpoint of the vehicle the vertical vibrations are affected only by bounce, therefore, at this point one can see the wheelbase filtering phenomenon. The vertical acceleration at this point decreases at the bounce null frequencies. At the points located closer to the extremes of the vehicle, both bounce and pitch contribute to the vertical acceleration, and the effect of wheelbase filtering is less palpable. Over the axles the wheelbase filtering will not have any effect and the vertical response will be equivalent to that seen in the quarter-car model.

Pitch action is the mainly source for fore/aft vibrations seen in locations above the center of gravity. The amplitude of these vibrations will depend on the elevation of the position one wants to study.

5.5 ILLUMINATION

5.5.1 INTRODUCTION

To allow people make visual work efficiently it’s necessary to have an appropriate illumination, this can be provided by natural light, artificial or a mix of both types. The visibility and comfort required in work places depends on the type and duration of the activity.

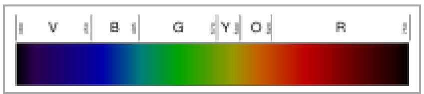
The illumination requirements are determined by the satisfaction of the three basic human necessities:

- Visual comfort, in wich the workers have a good sensation of welfare, it also contributes indirectly to the productivity.
- Visual advantages, in wich the workers are capable of doing its visual work inclusively in hard circumstances and during longer periods.
- Security.

5.5.2 DEFINITIONS

5.5.2.1 THE LIGHT

Is the radiant energy that produces a visual sensation. Visible light is situated in the luminous spectra, between the ultraviolet and infrared radiations, it’s between the wavelength limits of 380nm and 760 nm.



Color	Wavelength	Frequency
violet	380–450 nm	668–789 THz
blue	450–495 nm	606–668 THz
green	495–570 nm	526–606 THz
yellow	570–590 nm	508–526 THz
orange	590–620 nm	484–508 THz
red	620–750 nm	400–484 THz

Figure 5-38: Spectral colors.

5.5.2.2 LUMINOUS FLUX

It's defined as the quantity of luminous energy emitted by a light source for time unit, in all the directions. Its representation is the letter ϕ and its units are the lumen (lm). Its expression is:

$$\phi_L = \frac{dQ_L}{dt}(lm) \qquad \text{(Eq. 4.8)}$$

$$\sin\alpha \pm \sin\beta = 2\sin\tfrac{1}{2}(\alpha \pm \beta)\cos\tfrac{1}{2}(\alpha \mp \beta) \qquad \text{(Eq. 4.9)}$$

Where:

ϕ_L = Luminous Flux (lm).

$\frac{dQ_L}{dt}$ = Quantity of luminous energy radiated for time unit.

5.5.2.3 LUMINOUS EFFICIENCY

Indicates the luminous flux that is emitted by a source for each unity of electrical power consumed for its obtaining. It's represented with the Greek letter ε and its units are lumen/watt (lm/W).

$$\varepsilon = \frac{\phi_L}{P}(lm/W) \qquad \text{(Eq. 4.10)}$$

Where:

ε = Luminous efficiency

P= Active power (W)

5.5.2.4 LUMINOUS INTENSITY

It's the relation between the luminous flux emitted by a source of light in one direction for each solid angle unit in the same direction; it's measured in stereoradians (sr). Being that the angle formed between the center of one sphere of unitary radius and one piece of the surface of one squared unit of that sphere.

$$I = \frac{\phi_L}{\omega}(cd) \qquad \omega = \frac{S}{r^2} \qquad \text{(Eq. 4.11)}$$

I = Luminous intensity (cd)

ϕ_L = Luminous flux (lm)

ω = Solid angle (sr)

r = Projection radius (m)

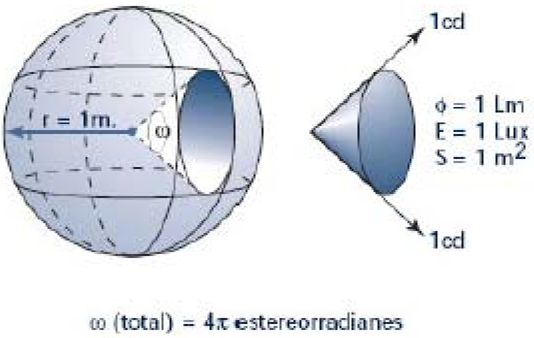


Figure 5-39: Luminous intensity concept.

5.5.2.5 ILLUMINATION LEVEL (ILLUMINANCE)

The illumination levels are defined as the relation between the luminous flux and the area of the surface in wich the flux enter into. Its symbol is the letter E and its unities are the lux.

$$E = \frac{\phi_L}{S}$$ (Eq.4.12)

Where:

E = Illuminance (lux)

ϕ_L = Luminous flux (lm)

S = Surface (m^2)

5.5.2.6 MEAN ILLUMINANCE

It's an important measurement that has to be considered in every illumination project. It's defined as the relation between the sums of the illuminances calculated in each point divided by the number of these points.

$$E_{mean} = \frac{\sum_{i=1}^{np} Ep_i}{np} (lux)$$

(Eq.4.13)

E_{mean} = Mean Illuminance.

Ep_i = Illuminance in the i point.

np =Number of considered points.

5.5.2.7 LUMINANCE

Is the relation between the luminous intensity and the vertically projected surface to the direction of the irradiation. This surface is equal to the product of the real illuminated surface by the cosines of the angle (β) that is between the direction of the luminous intensity and its perpendicular.

$$L = \frac{I}{S * \cos(\beta)} (cd / m^2)$$

(Eq.4.14)

L = Luminance (cd/m^2)

I = Luminous intensity (cd)

S = Surface (m^2)

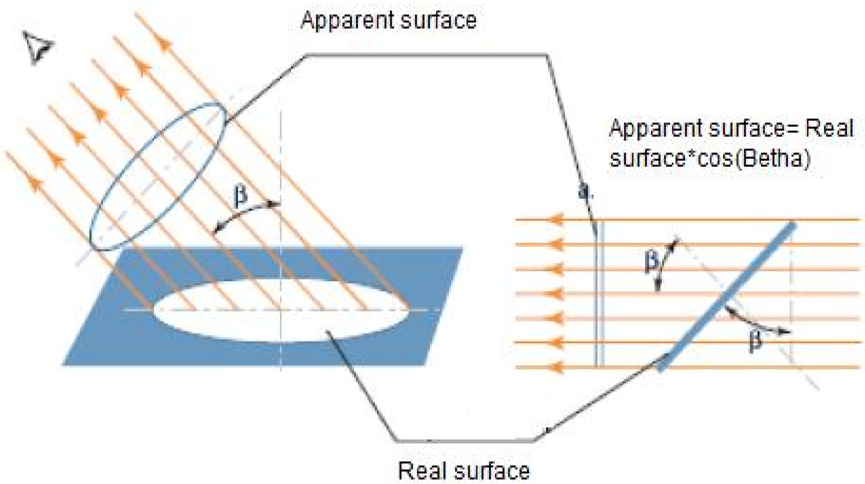


Figure 5-40: The differences between the real and the apparent surface.

5.5.2.8 UNIFORMITY

The illuminance proportioned in one determined surface it will never be totally uniform. This is due to the fact that it will be always different values of illuminance in the visual scenario. In order to define the uniformity of the illumination levels in one area, it's necessary to define the factors that determine the variations of the illuminance.

General Illuminance uniformity factor:

Is the relation between the minimum illuminance and the mean illuminance in one surface of the case study.

$$U_m = \frac{E_{\min}}{E_{mean}} \quad \text{Or} \quad U_m = \frac{E_{mean}}{E_{\min}}$$ (Eq.4.15

Extreme uniformity factor:

Is the relation between the minimum illuminance and the maximum illuminance on the surface of the installation one is studying.

$$U_e = \frac{E_{\min}}{E_{\max}} \quad \text{Or} \quad U_e = \frac{E_{\max}}{E_{\min}}$$ (Eq.4.16)

5.5.2.9 BOTHERING DAZZLING

The index of the bothering dazzling originated from the lamps of one indoor installation must be determined by using the method of United Glare Rating (UGR) from the CIE, based on the formula:

$$UGR = 8\log_{10}\left(\frac{0{,}25}{L_b}\sum\frac{L^2\omega}{p^2}\right)$$ (Eq.4.17)

Where:

L_b = the illuminance of the background in cd*m^{-2}, calculate as the E_{ind} * $\prod^{-1}$, where the E_{ind} is the vertical indirect illuminance in the eye of the observer.

L = is the illuminance of the luminous parts of each lamp in the direction of the eye in cd*m^{-2}.

ω = Is the solid angle (stereoradians) of the luminous parts of each lamp in the eye of the observer.

p = Is the index of the Guth position for each lamp that refers to its displacement of the vision line.

5.5.2.10 COLOUR TEMPERATURE:

The colour temperature of a luminous source it's measured for its chromatic appearance and it's based in the theory that all the objects when rise their temperature, emit light. The colour of that light changes depending on the temperature increase, expressed in Kelvin (K).

5.5.2.11 COLOUR YIELD:

It's the index that shows the level or the precision grade in what one illuminated object can reproduce its own real colour under the influence of one light source.

5.5.3 CASE STUDY MINIBUS

The fundamental parameters that determine the ambient or luminous environment are:

- The distribution on the lamps.
- Illuminance.
- Dazzling.
- Light direction.
- Colour yield and light appearance.
- Flicker effect.
- Natural light or day-light.

5.5.3.1 DISTRIBUTION OF THE LAMPS:

The distribution in the visual area controls the level of the adaptation of the eyes that affect the visibility of the task. A good balance of the illumination it's necessary to rise:

- The visual sharpness.
- The contrast sensibility.
- The efficiency of the ocular functions (accommodation, convergence, pupil contraction, eyes movements…)
- The distribution also affects the visual comfort, it's necessary to avoid the next facts to avoid the consequences:
- High luminance levels may cause dazzling.
- Too high luminance contrasts may cause fatigue due to the constant readapting of the eyes.

Too low illuminances and luminance's contrasts make the environment monotonous and unstimulated.

5.5.3.2 ILLUMINANCE

The illuminance in the surroundings must be relation with the illuminance with the task area and must provide one distribution of luminances well balanced in the visual area. Big spatial variations in the surroundings of the working area might cause tensions and visual discomfort.

Illuminance of task (lux)	Illuminance of the surroundings (lux)
≥ 750	500
500	300
300	200
≤ 200	E_{task}
Uniformity: ≥ 0,7	Uniformity: ≥ 0,5

Table 5-1: European recommendations for the illuminance of working places and surroundings EN 12464-1.

5.5.3.3 DAZZLING

Is the sensation made by the brightly areas inside the visual area and can be uncomfortable. It's important to avoid the dazzling to avoid errors, fatigues and accidents. In interiors the origin can be either the lamp or the windows.

Light direction:

The general appearance indoor places it's better when the structural characteristics, the persons, and objects inside are illuminated in a way that the shape and texture are revealed clearly and pleasantly. This happens when the light mainly come form on direction, and then the shadows are essential for a good shaping and then are formed without confusion. Although, if it's mainly directional it might provoke strong shadows and if it's totally diffused it might provoke no shaping.

5.5.3.4 COLOR YIELD AND COLOR APPEARANCE:

Colour appearance:

It refers to the apparent colour of the light, it's quantified by its colour temperature correlated (T_{cp}).

Apparent colour	Colour temperature correlated (T_{cp}) K
Warm	≤ 3300
Intermediate	3300 to 5300
Cold	≥ 5300

Table 5-2: EN-12464-1 Color appearance.

The election of the colour appearance will depend on the colours of the zone, the furniture, and the application. It is a psychological theme although it is known that in warm climates people prefer the light appearance to be colder, and in colder climates people prefer a warmer light appearance.

Colour yield:

It's important that the people, environment, objects and human skin are reproduced in a natural way so they look attractive and healthy. To give an objective indication of the yield colour properties of a luminous source it's been introduced the colour yield index, R_a. The minimum value of R_a is 100. This quantity decrease when decreases the quality of the color yields.

Lamps with a colour yield lower than 80 must not be used in indoors where people work or remain there for longer time. The minimum value for colour yield for different indoor areas, task or activities appears in the figure above.

Ophtalmological Office			
Place or activity	Em (lux)	UGR_L	Ra
General light	300	19	80
Working desk	500	19	90
waiting room	200	22	80
corridors during the day	200	22	80
corridors during the night	50	22	80

Table 5-3: EN-12464-1 Levels of Em, UGR_L and Ra that ophtalmological office must accomplish.

5.5.3.5 FLICKER EFFECT

The flicker can cause distraction and can cause headache, it can be avoided if the lamps are used in high frequency (around 30 KHz).

5.5.3.6 MAINTENANCE FACTOR

To prevent the diminution of the luminous flux, and consequently the illuminance, it's necessary to change the lamps and clean them periodically. For places with dust this factor would be the lowest, 0.6. For clean places as the mobile unit should be, the factor would be 0.8.

5.5.3.7 NATURAL LIGHT OR DAY-LIGHT

Windows can provide visual contact with the exterior, wich is preferred for the majority of the people. In indoors with side windows, the light diminishes faster with the distance to the window, that's why it would be important to have an artificial light to assure the required illuminance levels in the working place and in the area.

6 EXPERIMENTAL WORK

6.1 CONSULTATION DISTRIBUTION

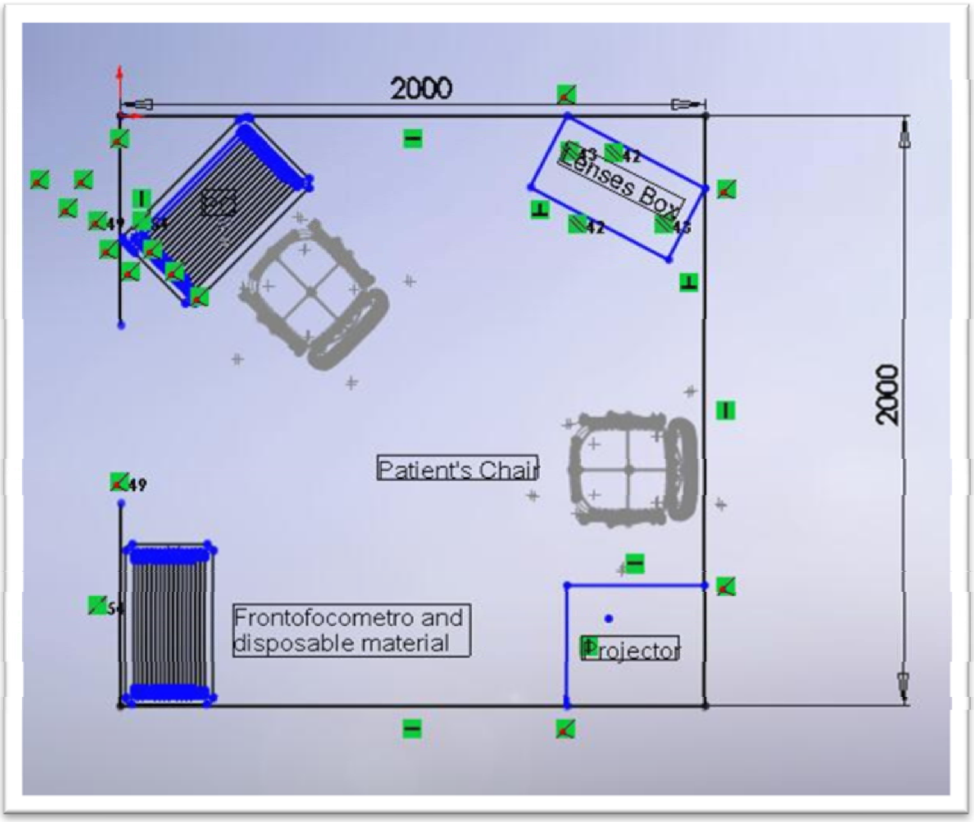


Figure 6-1: Distribution of one box at the department of ophthalmology at Hospital Sao Joao, Porto, Portugal.

Apart from this $4m^2$ the also use another little room that could have between 2 and 3 square meters for the autorefractometer and the tonometer.

The screen was 5 meters away from the projector, but exist other models of optotype projector that only need 2 meters.

6.2 NECESSITIES AND FUNCTION ANALYSIS

6.2.1 NECESSITIES

In order to differentiate the main requirements (that this project is intended to tackle, from others which are irrelevant, the correlation matrix of necessities is a good tool to display the most important characteristics or attributes that a new mobile unit should possess, as it was expressed by the costumers.

		Importance	%	Order	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	Sum
N1	Modulable	5	12,4	**1**		2	3	1	3	2	2	2	2	3	20
N2	Safe	3	9,9	**6**	2		2	3	2	2	1	2	1	3	16
N3	Controlled price	3	9,3	**7**	3	2		1	2	2	2	2	1	3	15
N4	Aesthetic confidenc	5	12,4	**2**	2	3	2		1	3	2	3	3	3	20
N5	Easy adaptability	4	11,2	**5**	3	2	2	2		3	2	2	2	3	18
N6	Tough	2	7,5	**8**	3	2	2	2	1		1	2	1	1	12
N7	Comfortable	1	6,8	**10**	2	1	2	2	1	1		2	1	1	11
N8	Reliable	4	11,8	**3**	2	3	2	3	2	3	1		2	3	19
N9	Estandard	2	7,5	**9**	2	1	2	2	2	1	1	2		1	12
N10	Easy desinfection	4	11,2	**4**	3	3	2	3	3	2	1	2	2		18

Table 6-1: Analysis of Necessities matrix.

Accordingly to the results of an inquiry, the correlation matrix ranks the ten most representative necessities. In addition, in order to quantify the relation between necessities, a scale from 1 to 3 was assigned, 3 meaning that the two necessities are highly relationated (interdependent) and correspondingly 1 reveals total independency. After the corresponding score is assigned for each necessity, the sum is computed and then the necessities are ranked according to their importance.

6.2.2 FUNCTIONS

Functions are established according to the requirements that engineers think that a mobile unit should accomplish, that’s why the functions are also defined by a criteria , a level and a tolerance interval.

Then, the same correlation matrix and procedure is done like above. As a result, the most important functions can be identified and ranked.

Functions	Criteria	Level	Tolerance	Importance	%
To be flexible	number of functions	11	3	4	18,18
To assure the resistance	Kg	100	20	5	22,72
To provide desinfection	m3/h	64	10	5	22,72
To transmit trust	colors	3	1	4	18,18
To provide security	Index of Protection	66	2	4	18,18

Table 6-2: Description of the functions.

		Importance	%	Order	F1	F2	F3	F4	F5	SUM
F1	To be flexible	4	18,18	**3**		3	1	2	2	8
F2	To assure the resistance	5	22,72	**1**	3		1	3	2	9
F3	To provide desinfection	5	22,72	**4**	2	1		3	1	7
F4	To transmit trust	4	18,18	**2**	2	2	3		2	9
F5	To provide security	4	18,18	**5**	1	2	2	3		8

Table 6-3:Correlation matrix of functions.

6.3 FUNCTIONAL ANALYSIS. FAST

FAST or Functional Analysis System Technique is a tool mainly used with the purpose of defining the functions that the project must accomplish, but it can also detect other functions that weren't predicted.

The first step for the elaboration of FAST is to define each element that is part of the project. Once these components are clearly established, one should define which is the function that corresponds to each, and then here is where functions would become reaffirmed and other that were omitted or forgotten would be studied.

After this, one should look over the whole diagram asking the next questions:

From left to right: HOW?

From right to left:WHY?

From up to down:WHEN?

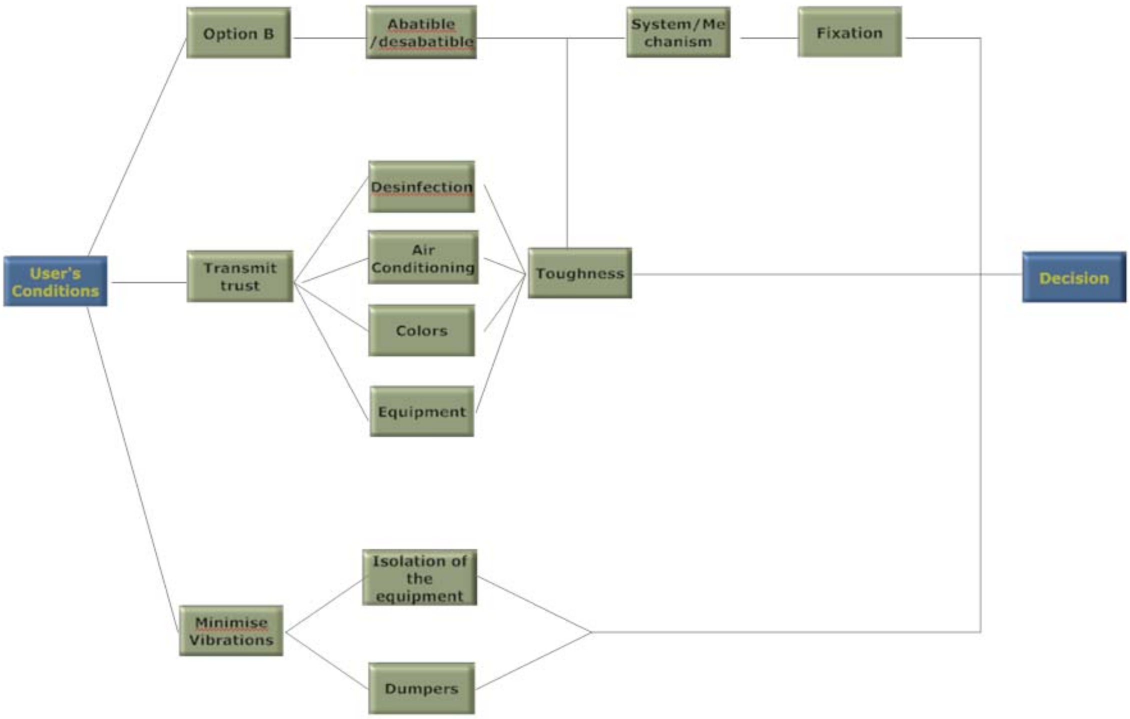


Figure 6-2: Diagram of the Functional Analysis System Techinique (FAST).

6.4 RISK ANALYSIS

6.4.1 CAUSE-EFFECT DIAGRAMS

he elaboration of the cause-effect diagrams three criteria related with the possible effects has been chosen.

1. Effects with more probability of success.
2. Effects that would provoke more danger for the users.
3. The effects that would affect more the integrity of the bus.

With these three criteria some main effects have been selected and then developed in terms of drawing their diagrams.

1. The air conditioning doesn't work.
2. There's neither power nor light.
3. There is no more disposable material.
4. Some of the ophthalmological equipment doesn't work.
5. Some of the furniture is broken or doesn't work properly.

Finally, the effects have been analyzed independently so one can determine the causes. These causes have been classified in:

Environmental: This will include meteorological or climate causes such rain, snow, dust and others.

Method: it's related to how the users develop their roles with the bus.

Materials: including the causes, constraints, and affects etc. that have to be known before choosing one material or another.

Manpower: This will include all the manipulation of the mobile unit since its construction until its common use.

Machines / Engines: Causes related to the engine that will be the source of power, some articulations or mechanisms will be accosted.

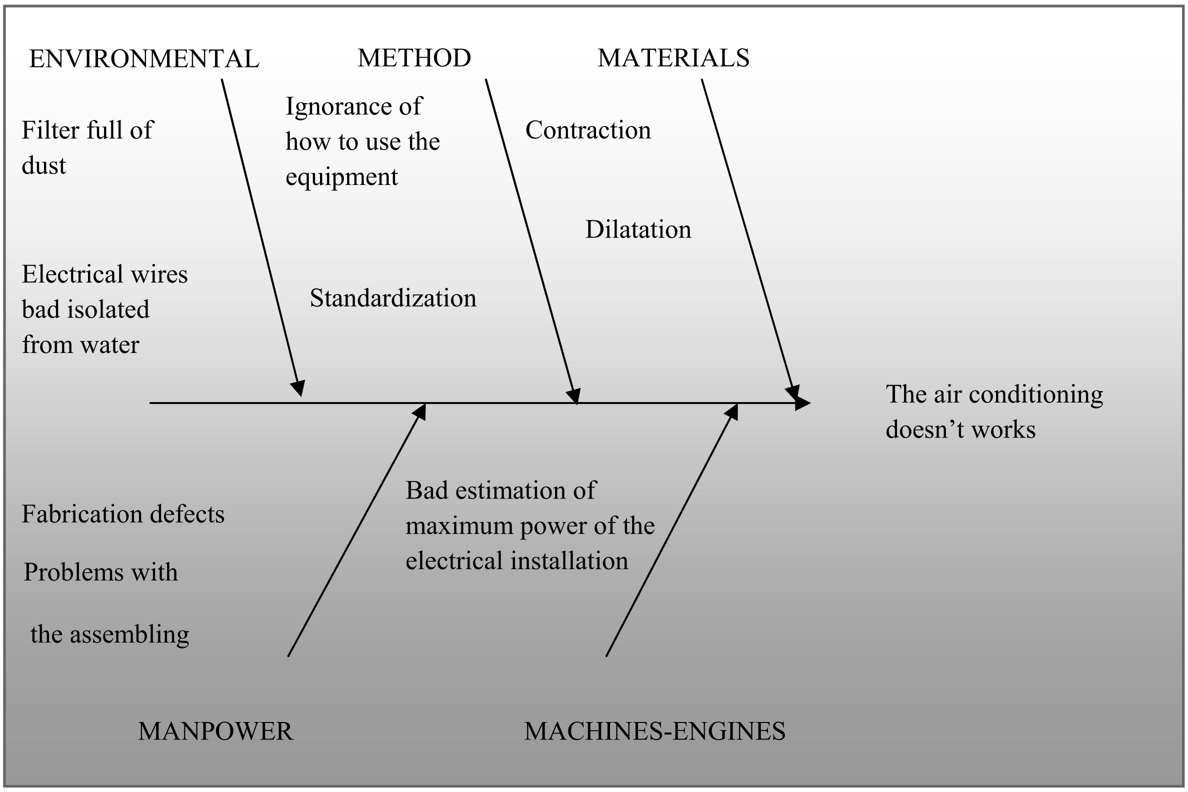


Figure 6-3: Cause-effect diagram.

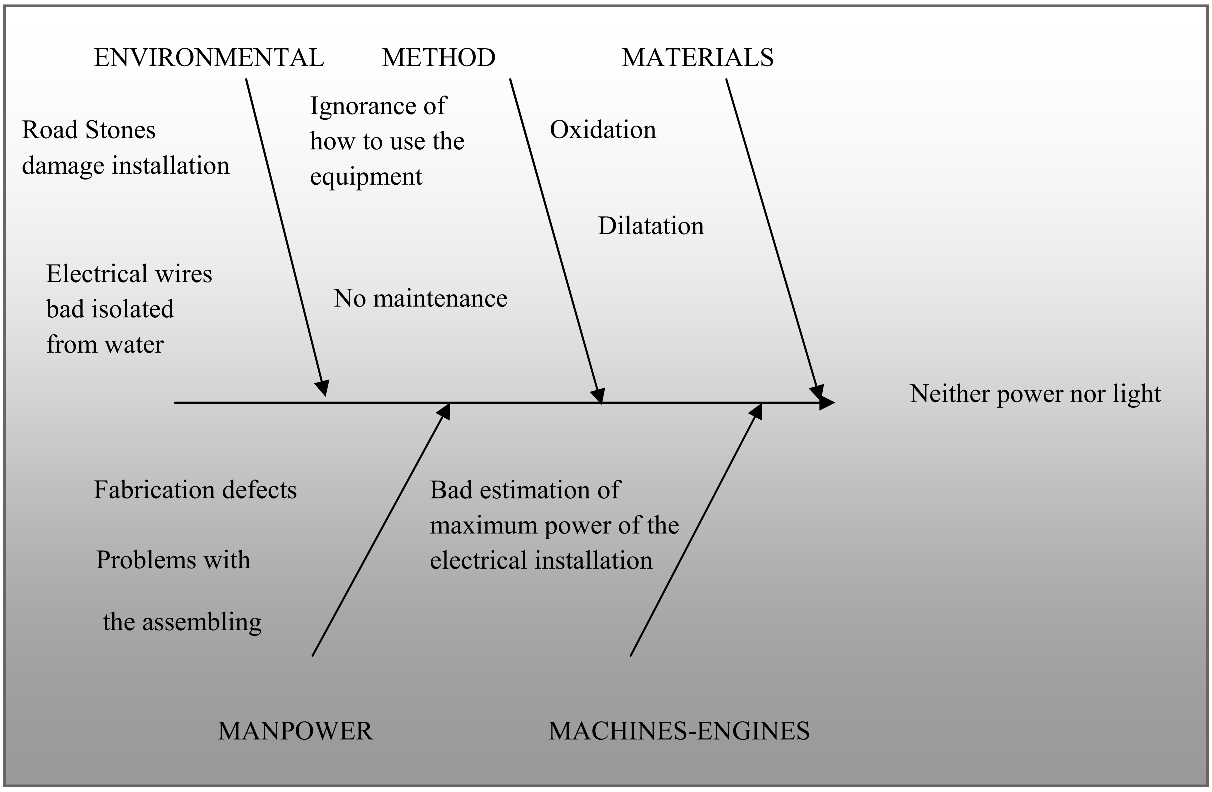


Figure 6-4: Cause-effect diagram.

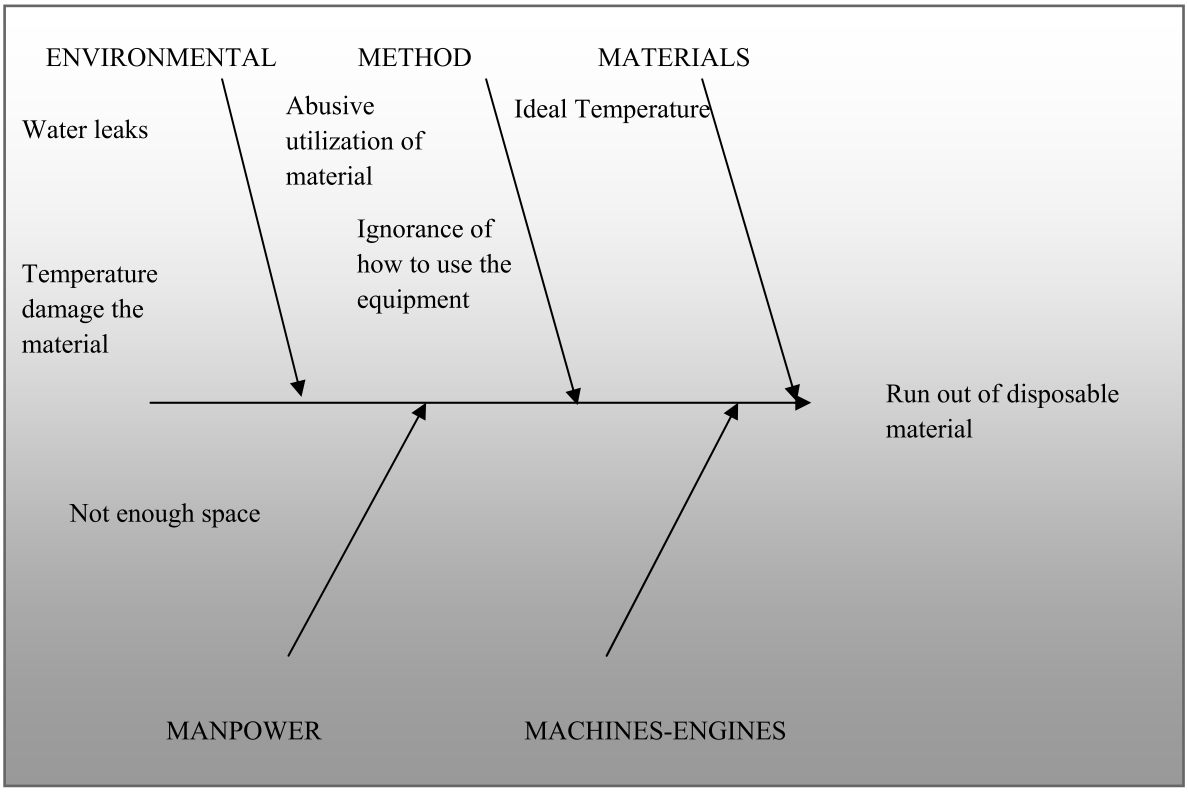


Figure 6-5: Cause-effect diagram.

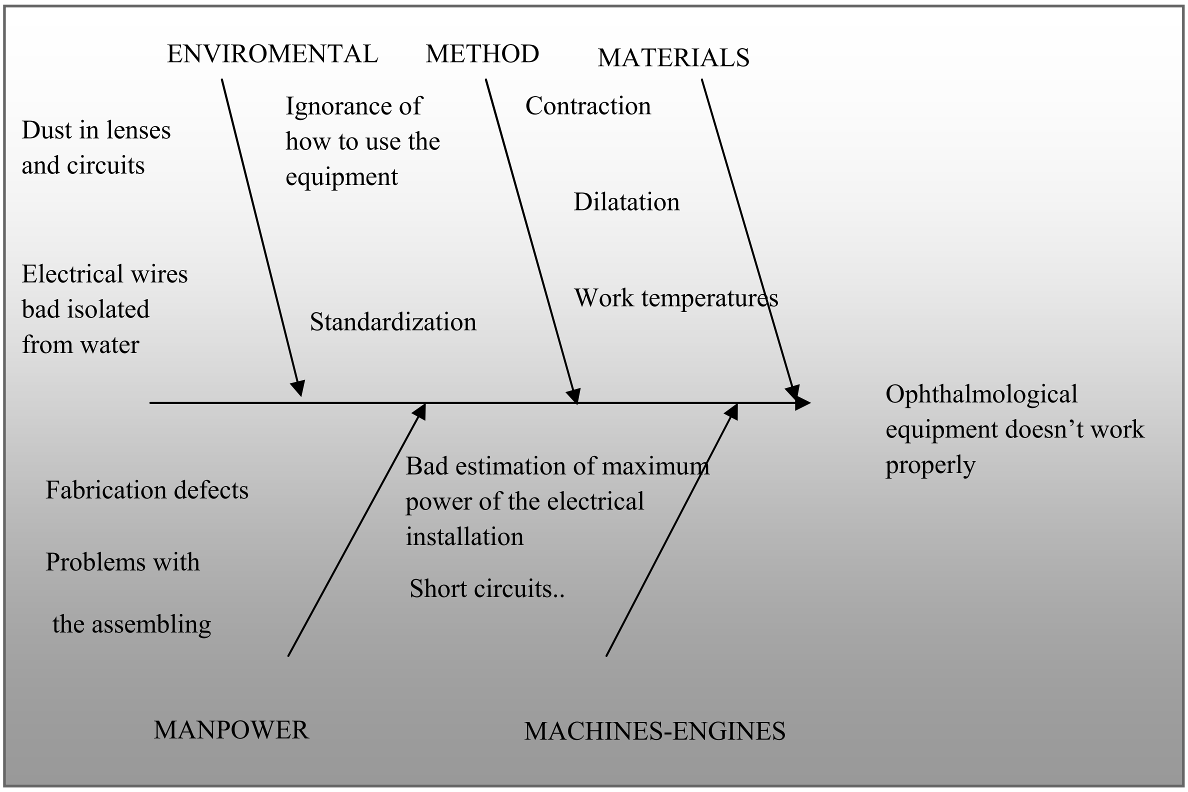


Figure 6-6: Cause-effect diagram.

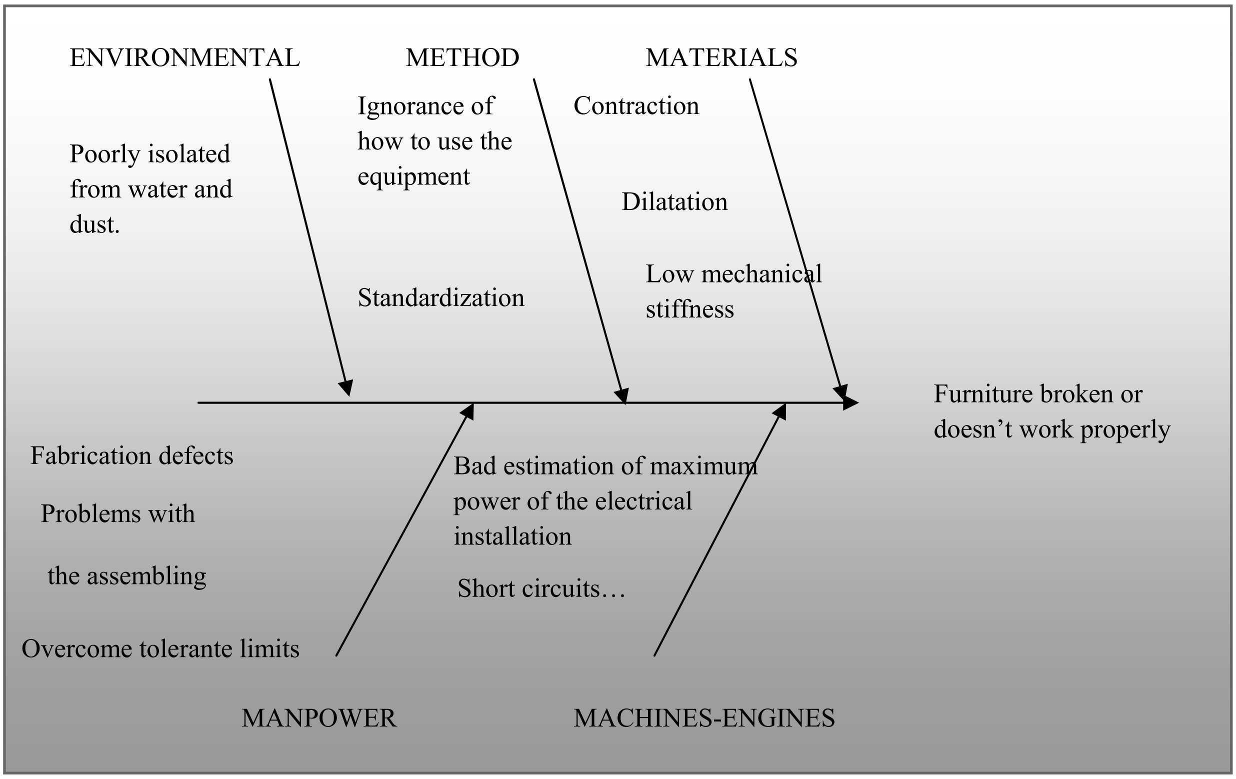


Figure 6-7: Cause-effect diagram.

As a result of the analysis of the cause-effect diagrams, one can consider that the three main causes are:

Poor isolation from water and dust: As the bus may go through dirty tracks with mud and dust, it's important to consider good cleaning and buying special dust filters. Another probable scenario is in humid zones. High IP indexes of protection must be chosen for lights, electrical wires and instrumentation if possible.

Poor estimation of maximum alimentation power: This could be due to the fact that more electrical equipment is plugged than was supposed, or even that short circuits can occur. To avoid this, the estimation should be done considering all the possible equipment that is necessary to be plugged in at the same time, and the duration of time.

Ignorance of how to use the equipment: It refers to people with some education as an ophthalmological technician, and doctors must be the ones that manipulate the equipment, others may not know how to do it and therefore cause damage whilst also obtaining wrong results.

In addition to this, one can consider that the three main consequences are:

Ophthalmological equipment doesn't work properly: To avoid this problem one can find solutions such as, isolate all equipment from vibrations, dust and quick tension variations. If the equipment doesn't work properly it might be difficult to find spare pieces or technical support in remote areas.

Neither power nor light: If there's no energy supply to all the ophthalmological equipment it will not work, but some other power source, spare parts could be readily available in the remotes areas to prevent this.

The air conditioning doesn't work: Poor electrical design, empty power source, full dust filters; these are things that should be considered and calculated for to avoid this consequence.

6.5 ALTERNATIVES FOR THE SOLUTION

6.5.1 COMMON CHARACTERISTICS

6.5.1.1 AIR CONDITIONING

A simulation of the power needed for the conditioning of the interior of a bus, made with an on-line program at "Carrier" website, establishes that 4 Kw of cooling capacity are needed for the cooling power. The equipment that will be chosen must be equipped with a special filter considering that the mobile unit might run in dirty roads.

Figure 6-8: The Carrier AC420 I Air conditioning.

The model AC 420 I of Carrier perfectly fit our bus and our requirements, it's a compact roof model, specially designed to work in hot countries. It has a cooling capacity of 6 KW and heating capacity of 7 KW.

6.5.1.2 LIGHTS

The interior distribution is not important, because a uniform lighting distribution has been chosen, which constitutes an advantage in the fact that at some time in time changes in the distribution will be made.

6.5.1.3 TABLE OVER THE TYRE SPACE

This design of the table will allow us to take advantage of the space that assumingly was non-profitable because of the elevations of the tyres. The table provides enough space to place all the necessary equipment for consultancy. It also allows attaching two

footstools one for the patient and other for the doctor or ophthalmologic technician.

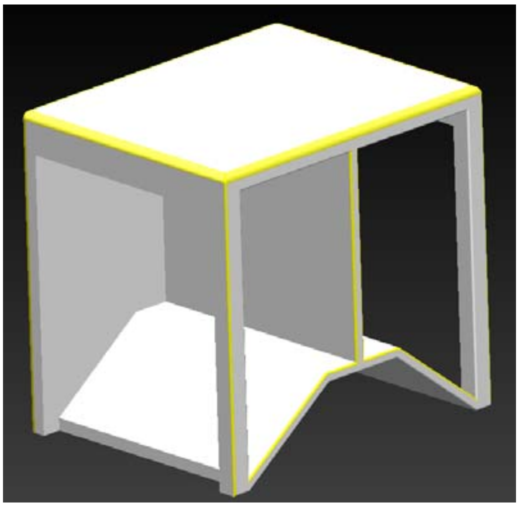


Figure 6-9: Table for the ophtalmological exploration.

6.5.1.4 FRIDGE

As in the consultancy the use of cold eyedrops or ointment's is common, the mobile unit must be equipped with a medium fridge.

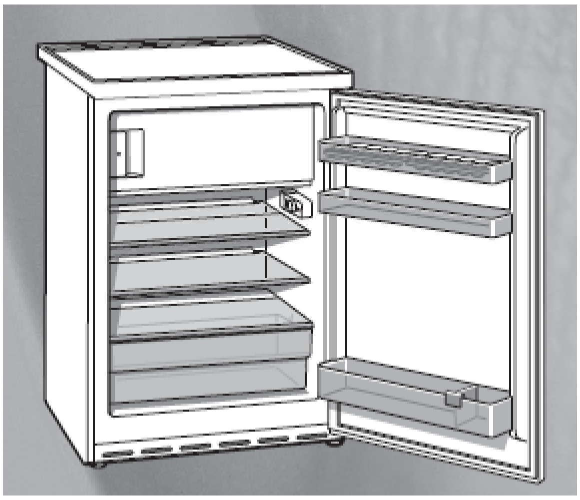


Figure 6-10: Bosch KTR14V21.

Dimensions: 85 x 50 x 60 cm

Efficiency Class: A

Active Power: 150 Kw.

6.5.1.5 DIESEL GENERATOR

With the intention of having an engine that provides enough power to plug all the equipment that might be in use at the same time. First it's interesting to have a look at how much power is installed in the mobile unit:

		Active Power (W)	Number	Total Active Power (W)
Ophtalmological equipment				
	Autorefractometer	100	1	100
	Tonometer	80	1	80
	Slit Lamp	30	1	30
	Phoropter	150	1	150
	Ortotype projector	20	1	20
	Defraction Lens Analyzer	1,5	1	1,5
	Retinoscope	5	1	5
	Ophtalmoscope	5	1	5
Lighting				
	Osram Fluorescent GmbH 72581-10	20	5	100
	Osram Fluorescent GmbH 72585-10	36	1	36
Air Conditioning				
	Carrier AC 420 II	3000	1	3000
Fridge				
	Bosch KTR14V21	150	1	150
Office				
	Computer Compaq CQ2000ES	100	1	100
	Computer Screen Compaq FV297AA	37	1	37
	Printer HP Multifunctional C6300	42	1	42
		TOTAL ACTIVE POWER (W)		**3856,5**

Table 6-4: Total active power calculations.

Then it would be necessary to distribute all the electrical equipment in different circuits so that if any problem occurs, it could be easy to detect when it's time to fix it, and thus cause less problems.

.

Circuit 1: Air Conditioning and fridge.

Circuit 2: All lights, computer, screen and printer.

Circuit 3: Ophthalmological equipment.

The installation should have to be settled:

At 230 V monophasic, because it is better for standardization of the plugs, and AC current also has less losses due to the Joule effect.

		P(W)	Number	Total P (W)	cos φ	S(VA)	Total Q (VAr)
Ophtalmological equipment							
	Autorefractometer	100	1	100	0,8	125	75
	Tonometer	80	1	80	0,8	100	60
	Slit Lamp	30	1	30	0,8	37,5	22,5
	Phoropter	150	1	150	0,8	187,5	112,5
	Ortotype projector	20	1	20	0,8	25	15
	Defraction Lens Analyzer	1,5	1	1,5	0,8	1,875	1,125
	Retinoscope	5	1	5	0,8	6,25	3,75
	Ophtalmoscope	5	1	5	0,8	6,25	3,75
Lighting							
	Osram Fluorescent GmbH 72581-10	20	5	100	0,8	125	75
	Osram Fluorescent GmbH 72585-10	36	1	36	0,8	45	27
Air Conditioning							
	Carrier AC 420 II	3000	1	3000	0,8	3750	2250
Fridge							
	Bosch KTR14V21	150	1	150	0,8	187,5	112,5
Office							
	Computer Compaq CQ2000ES	100	1	100	0,8	125	75
	Computer Screen Compaq FV297AA	37	1	37	0,8	46,25	27,75
	Printer HP Multifunctional C6300	42	1	42	0,8	52,5	31,5
	TOTAL			**3856,5**	**0,8**	**4820,625**	**2892,375**

Table 6-5: Computations of the active, reactive and apparent power that will be installed in the mobile unit.

For the choice of the diesel engine one should consider the worst scenario possible. This would be the case when all the lights, the air conditioning, the fridge, all the office equipment, and at maximum three out of all the equipment can be plugged at the same time. The three that can be working at the same time are: The phoropter, autorefractometer and the tonometer.

As percentual reduction for the computations is very little, if one considers the worst scenario or all the equipment plugged.

$$\%reduction = \left(\frac{3836{,}5 - (3836{,}5 - 30 - 20 - 1{,}5 - 5 - 5)}{3836{,}5} \right) * 100 = 1{,}59\%$$

It's fair to choose the engine power considering all the equipment could be plugged at the same time, with the aim of having the most compact equipment, minimum consumption and noise. The engine choice is Genergy Inverter Mallorca. The ideal would be to connect in parallel, so that more equipment could be installed in the future. The advantages of not working at maximum power are: a diminution of the consumption and the possibility of plug more equipment in the future.

Figure 6-11: Genergy Generator.

Nominal power: 3200 W.

Acoustic level: 58 dB.

Frequency / Voltage: 50 Hz / 230V.

Autonomy at 70%: 7 hours.

Deposit: 13 L.

6.5.1.6 PHOTOVOLTAIC SYSTEM:

Stand-alone photovoltaic power systems are low-maintenance, versatile solutions to the electric power needs of any off-grid application. These self-contained power stations have proven to be a reliable, cost-effective alternative to conventional power. They frequently replace the noise and the smoke that petrol generators produce.

In this chapter the aim is to size the system based on the electrical load estimated, the project needs and goals. Sizing a system includes the following steps (5):

- Estimating the electric load.
- Sizing and specifying batteries.
- Sizing and specifying an array.
- Sizing and specifying an inverter.

A part from the sizing analysis it's also important to define the sitting and the orientation. The site should be clear of shade to increase the system efficiency and the orientation must be south. As the solar panels would be installed in the roof of the bus, a proper orientation mechanism could be installed to increase the efficiency.

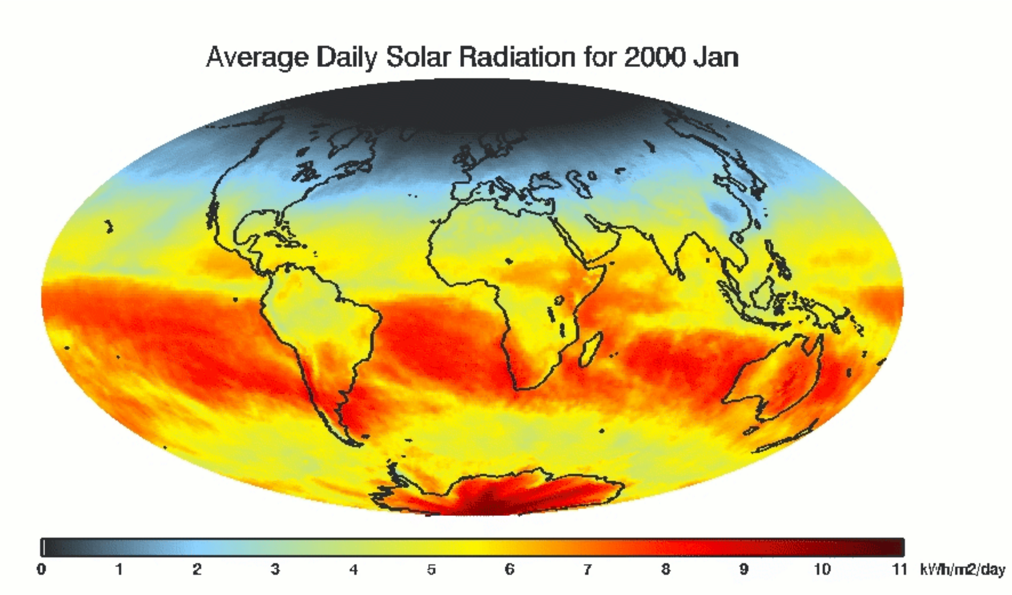


Figure 6-12: Average daily solar radiation (6)

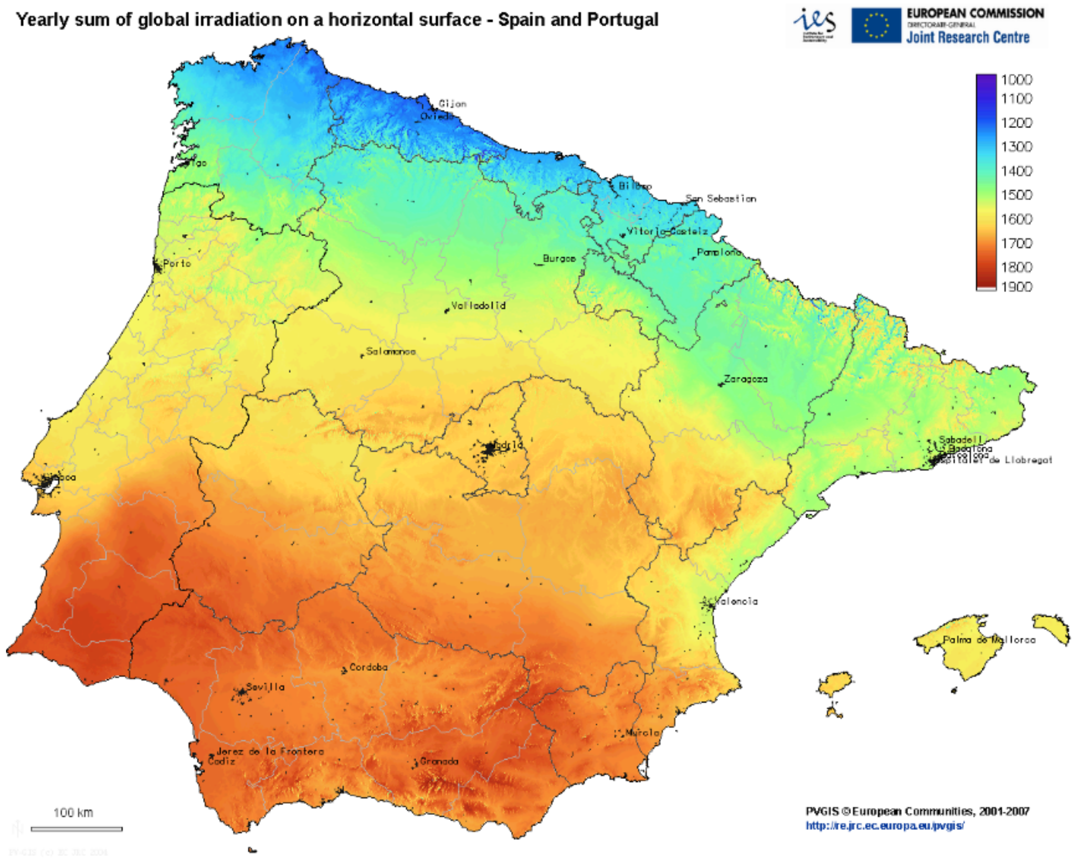


Figure 6-13: Portugal and Spain map of yearly sum of global irradiation on a horizontal surface. (7)

For the project study has been chosen as location the city of Porto (Portugal) and its climate data. However, in this project the location is not unique because the mobile unit is supposed to travel to different locations with different climate data. With the aim of avoiding problems, the system has been oversized so that in locations with less solar irradiation than Porto, the photovoltaic system can still work properly.

For the whole sizing the RETscreen software has been chosen. RETscreen is a well known and reliable program used in not only hundreds of universities around the world but also used in companies.

The program is based in Excel macros and only allows the user to modify the yellow and grey cells, the blue cells content come from the program database. Finally, the white cells are filled automatically by the program with the results of the computations.

The first step to use the program is to define the type of project, in this case, photovoltaic off-grid. The analysis type, which concerns about the load characteristics, would be defined in a future step... The heating value reference, LHV (Lower heating value) is the value used in Europe for determining the internal combustion engine efficiency.

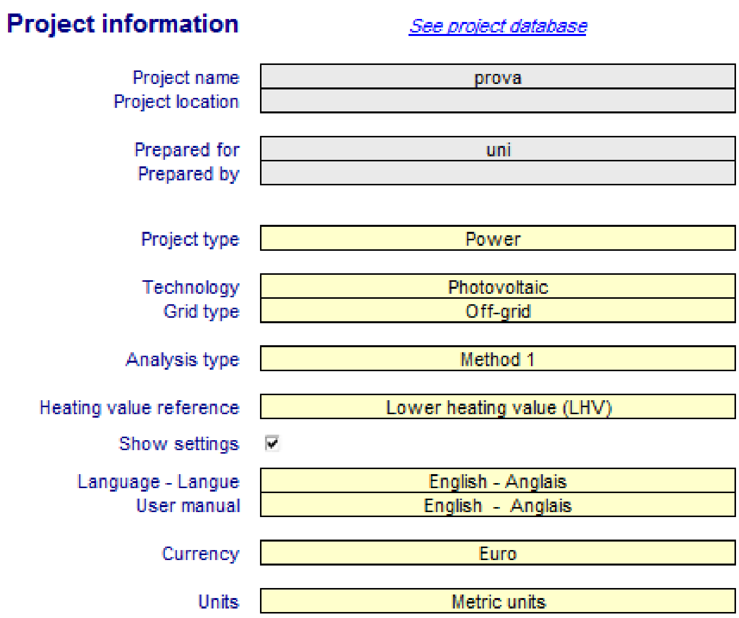


Figure 6-14: Project description.

Then, one can choose to see the data of the location used as reference for the computations.

	Unit	Climate data location	Project location
Latitude	°N	41,2	41,2
Longitude	°E	-8,7	-8,7
Elevation	m	73	73
Heating design temperature	°C	3,0	
Cooling design temperature	°C	27,9	
Earth temperature amplitude	°C	17,3	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		9,6	80,2%	1,88	98,7	3,5	7,1	260	0
February		10,5	79,0%	2,76	98,6	3,4	8,4	210	14
March		12,2	75,5%	4,08	98,4	3,4	11,8	180	68
April		13,0	76,6%	5,39	98,1	3,5	14,1	150	90
May		15,1	78,4%	6,36	98,1	3,3	18,2	90	158
June		17,8	77,9%	7,10	98,3	3,0	22,8	6	234
July		19,1	79,3%	7,02	98,3	2,8	25,1	0	282
August		19,2	79,4%	6,21	98,2	2,7	23,9	0	285
September		18,1	79,8%	4,75	98,3	2,6	20,8	0	243
October		15,6	81,5%	3,10	98,2	3,0	15,6	74	174
November		12,5	82,2%	2,03	98,3	3,2	10,9	165	75
December		10,8	80,7%	1,56	98,5	3,5	8,3	223	25
Annual		14,5	79,2%	4,36	98,3	3,2	15,6	1.359	1.648
Measured at	m					10,0	0,0		

Figure 6-15: Climate data of Porto,Pedras Rubras, Portugal.

In the second step the user must choose the Base case power system, in this off-grid case, the base power system is the diesel generator. Then one, fill the gaps with the fuel rate, that in this case is the price in Portugal in July 2009. The heat rate gap has to be filled with the heat rate of the engine; the heat tells how efficiently the generator converts that fuel into electrical energy. The anneal O&M refers to the annual cost of the operation and maintenance.

Base case power system		
Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	€/L	1,100
Capacity	kW	900,00
Heat rate	kJ/kWh	21.396
Annual O&M cost	€	100
Electricity rate - base case	€/kWh	0,642
Total electricity cost	€	2.269

Figure 6-16: Base case diesel power system (the diesel generator).

The one must fill the load characteristics with the description of the load, the type of current (AC or DC). The intermittent resource-load correlation is a qualitative estimate of how the load is correlated with an intermittent resource. The three options from the drop-down list are: "Negative," "Zero" and "Positive" . The "Negative" (i.e. negative correlation) corresponds to cases where the load is very irregular or occurs mostly when the resource is not available (e.g. at night in the case of a PV system). In this case, the model considers that the load is always met from the battery. A light used exclusively at night, for the PV system example, falls into this category. "Zero" (i.e. zero correlation) corresponds to steady loads. The model considers that the load is constant throughout the day and is met partly from the battery, partly directly by the power system without going through the battery. A cathodic protection system would fall into this category. “Positive” (i.e. positive correlation) corresponds to loads that are turned on only when there is enough electricity produced by the resource to power them directly. In this case, the model then considers that the load is met directly by the power system and the battery does not play a role. The base case load is the sum of the power of this type of load. Then the next two steps are to define the hours of use per day, and the days of use per week. Then the software estimates the daily AC electricity is the weekly averaged daily amount of AC electricity required by the load.

Load characteristics

Method 1
Method 2

Description	AC/DC	Intermittent resource-load correlation	Base case load W	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
Oficina	AC	Negative	159,00	7,00	5		
lights	AC	Negative	136,00	7,00	5		
fridge	AC	Zero	150,00	24,00	7		
ophtalmological	AC	Negative	391,50	7,00	5		

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh	0,00	0,00
Electricity - daily - AC	kWh	7,03	7,03

Percent of month used

		Base case	Proposed case	Energy saved	Incremental initial costs
Electricity - annual - DC	MWh	0,000	0,000		€ -
Electricity - annual - AC	MWh	2,567	2,567	0%	€ -
Peak load - annual	kW		900,00		

Figure 6-17:Load characteristics, daily electricity demand.

Afterwards, the inverter and the batteries are sized. In this case an oversized inverter is chosen just in case the unit has more loads to be plugged in. The efficiency expressed in %, of the electronic devices (e.g. inverter) used to transform the DC output to AC. Values between 80 and 95% are typical. Next, the user enters power conditioning losses (%), if any, not taken into account elsewhere. For example, this could include losses incurred in DC-DC converters or in step-up transformers. In most cases this value will be zero. In our case, this value will be zero.

For the batteries one must choose the days of autonomy, in other words this is the number of days that the system, starting from a state of full charge, would be able to meet the load using the batteries only. The voltage is chosen at 12 Volts wich is the common voltage, others like 6 V, 24 V, 48V can be choose as well. The nominal battery voltage has no influence on the energy predictions of the model. In the efficiency gap, the user enters the average efficiency (%) of the battery, as specified at the nominal temperature of 25ºC. In the absence of information from the battery supplier, an efficiency of 85% may be used. In the field of Maximum depth of discharge, one must enter the percentage of the rated battery capacity that can be withdrawn repeatedly without abnormal loss of battery life.

Battery type	Default maximum depth of discharge
Lead-acid (car)	20%
Lead-acid (gel)	20%
Lead-acid (PV, vented)	60%
Nickel-Cadmium	85%

Figure 6-18: Maximum depth of discharge depending on the battery type. (8)

As seen in the figure above, depending on the battery type one can choose from different value of depth of discharge. For this project, Nickel-Cadmium batteries will be choose because they have the best power/weight ratio, they are more compact and last much more than the others. On the other hand, they are the most expensive. Because controllers often draw a fixed current from the system - regardless of its size, controller efficiency tends to be higher in larger systems and lower in smaller systems, then for the charge controller efficiency a value of 95 % is recommended by the software. The temperature control method is used to determinate the battery capacity according to the temperature conditions it experiences. An ambient temperature is chose so it is subject to fluctuations depending on the country where it will be in service. The average battery temperature derating depends mainly on the temperature at which the battery operates. Lower temperatures result in a larger temperature derating. The software calculates the loss of nominal (25ºC) battery capacity resulting from temperature conditions experienced by the battery. This value is averaged over the season of use. Finally, the software calculates the capacity of the battery and the output energy from the battery. For the capacity the program estimates the value that would provide the system with the autonomy specified by the user in the "Days of autonomy required," given the temperature conditions experienced by the battery. This value is displayed in the cell to the right of the input cell. In the input cell the use must enter the value, oversized in order to assure the whole estimation, taken from the battery manufacturer. In the battery cell the system provides the kWh of battery capacity, not the accumulated kWh of energy stored and discharged through the battery over its lifetime.

				Incremental initial costs
Inverter				
Capacity	kW	1.200,0	Peak load - annual - AC	€ 935
Efficiency	%	90%		
Miscellaneous losses	%	0%		
Battery				
Days of autonomy	d	1,0		
Voltage	V	12,0		
Efficiency	%	85%		
Maximum depth of discharge	%	85%		
Charge controller efficiency	%	95%		
Temperature control method		Ambient		
Average battery temperature derating	%	5,4%		
Capacity	Ah	1.100	835	
Battery	kWh	13		€ 770

Figure 6-19: Inverter and Battery characteristics.

Then one must choose the Photovoltaic panels, first the solar tracking mode, here the user can select if the system could be orientated. In our case, as said before, the vehicle must have installed a mechanism that could provide one more DOF. The other DOF is the same orientated controlled by the same orientation of the bus. So the system has two DOF in relation with the earth reference. As seen in Figure 5-20. The annual solar radiation-horizontal and the annual solar radiation-titled has a different value. This is because the solar tracking mode is two axis, so the solar panels can be orientated 90º angle to the sun's rays, which is optimal.

Technology		Photovoltaic		
Resource assessment				
Solar tracking mode		Two-axis		
Show data				
	Month	**Daily solar radiation - horizontal kWh/m²/d**	**Daily solar radiation - tilted kWh/m²/d**	**Electricity delivered to load MWh**
	January	1,88	4,01	0,03
	February	2,76	4,87	0,04
	March	4,08	6,34	0,05
	April	5,39	7,75	0,06
	May	6,36	8,45	0,07
	June	7,10	9,30	0,07
	July	7,02	9,37	0,07
	August	6,21	8,84	0,07
	September	4,75	7,06	0,05
	October	3,10	4,94	0,04
	November	2,03	4,04	0,03
	December	1,56	3,40	0,03
	Annual	**4,36**	**6,54**	**0,61**
Annual solar radiation - horizontal	MWh/m²	1,59		
Annual solar radiation - tilted	MWh/m²	2,39		

Figure 6-20: Daily and annual solar radiation horizontal and titled.

Later, one must pick from the drop-list the type of photovoltaic, in this case mono-Si cells have been selected because are the ones that are more efficient although they are more expensive.

Cell type	Default efficiency (%)
Monocrystalline silicon (mono-Si)	13
Polycrystalline silicon (poly-Si)	11
Amorphous silicon (a-Si)	5
Cadmium telluride (CdTe)	7
Copper indium diselenide (CIS)	7.5

Figure 6-21: Efficency depending on the cell type. (8)

Then Sunpower manufacturer is selected because they provide a model that has the highest efficiency in the RETscreen data base. The power capacity is the capacity of the three panels that have been selected to achieve the power requirements. Then, the model calculates the Nominal Operating Cell Temperature (NOCT), in ºC. NOCT is defined as the module temperature that is reached when the PV module is exposed to a solar radiation level of 800 W/m^2, a wind speed of 1 m/s, an ambient temperature of 20ºC, and no load. The temperature coefficient is the efficiency of photovoltaic cells and varies with their operating temperature. Most cell types exhibit a decrease in efficiency as their temperature increases. The PV temperature coefficient, µ (expressed in % / ºC), is defined as:

$$h(T) = h(T_{ref})(1-m(T-T_{ref})) \qquad \text{(Eq. 5.1)}$$

where

$\eta(T)$ = the efficiency of the solar cell at temperature T,

$\eta(T_{ref})$ = the efficiency of the cell at temperature T_{ref},

T = the operating temperature of the module, and

T_{ref} = the reference temperature (usually 25ºC).

The solar collector area is optimal because the more efficient model has been chosen, that means that with less horizontal collector area the system can provide the same power than another less efficient panel. Note that the 8,2 m^2 fit in the roof of the mobile unit. The PV array controller that is used to interface the PV array to the rest of the system. A Maximum Power Point Tracker (MPPT) is an electronic device used to maintain the operating voltage of the array at a value that maximises array output, regardless of changes in load impedance or changes in array operating conditions due to variations in temperature or insolation. The miscellaneous losses include, for example, losses due to the presence of dirt or snow on the modules. The software also calculates the capacity factor, which represents the ratio of the average power produced by the power system over a year to its rated power capacity. Typical values for photovoltaic system capacity factor range from 5 to 20%. After all, the electricity delivered to load is estimated,

Photovoltaic				
Type		mono-Si		
Power capacity	kW	1,60	0,2%	
Manufacturer		Sunpower		
Model		mono-Si - SPR-320E-WHT		5 unit(s)
Efficiency	%	19,6%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0,40%		
Solar collector area	m²	8,2		
Control method		Maximum power point tracker		
Miscellaneous losses	%	10,0%		
Summary				
Capacity factor	%	21,0%		
Electricity delivered to load	MWh	2,41	93,9%	

Figure 6-22: Characteristics of the photovoltaic panels.

Finally, the electricity delivered to the load shows the MWh per year that are delivered and also the percentage of the electricity delivered to the load over the proposed case power system electricity. Note that the electricity delivered to the load is not the 100% of the estimated energy, that because one cannot install as much solar panels as one wants, there’s one constraint that is the area of the roof.

Figure 6-23: Top view of the solar panels.

GHG emission		
Base case	tCO2	4,1
Proposed case	tCO2	0,0
Gross annual GHG emission reduction	tCO2	4,1
GHG credits transaction fee	%	0,0%
Net annual GHG emission reduction	tCO2	4,1
GHG reduction income		
GHG reduction credit rate	€/tCO2	0,00

is equivalent to	0,8	Cars & light trucks not used

Figure 6-24: Green House Gas (GHG) emissions.

6.6 DIFFERENT ALTERNATIVES

Some different designs for the mobile unit were made having in mind the functions, necessities and risks identified in the pre-design stage.

6.6.1 PREMIUM:

The aim of the distribution of this alternative was to give the sensation of seriousness and confidence to the costumer. It might happen that some people in certain occidental countries can distrust the minibus as a place to have a medical visit. To prevent this, it was designed a nice waiting room equipped with a TV, and some furniture.

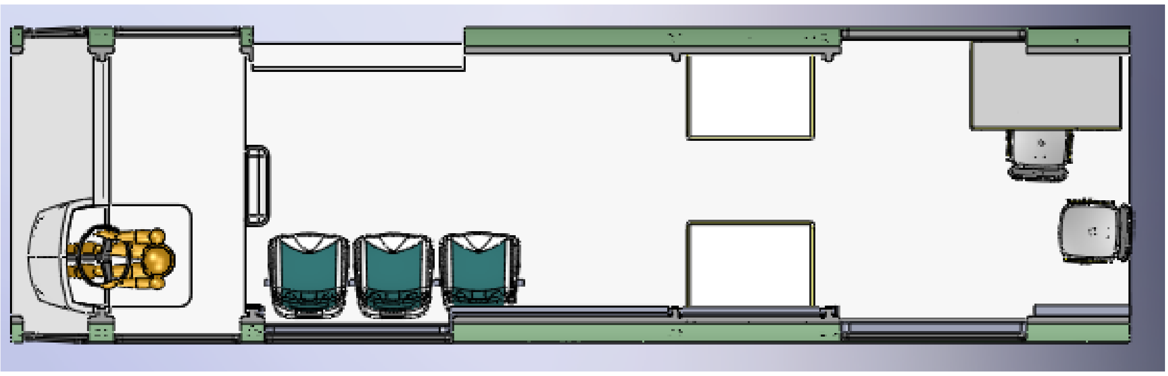


Figure 6-25: Top view of the interior of the Premium model.

6.6.2 DELUXE:

Here the main objective was to obtain the maximum space so that one bus can stay away from home a much time as possible. This means that the mobile unit can spend more days without having to buy disposable material, food etc. To transform these thoughts in facts, the unit is maximized in terms of shelves and bookcases. There is no waiting room because the potential customers of this unit aren't as demanding as the one's in occidental countries.

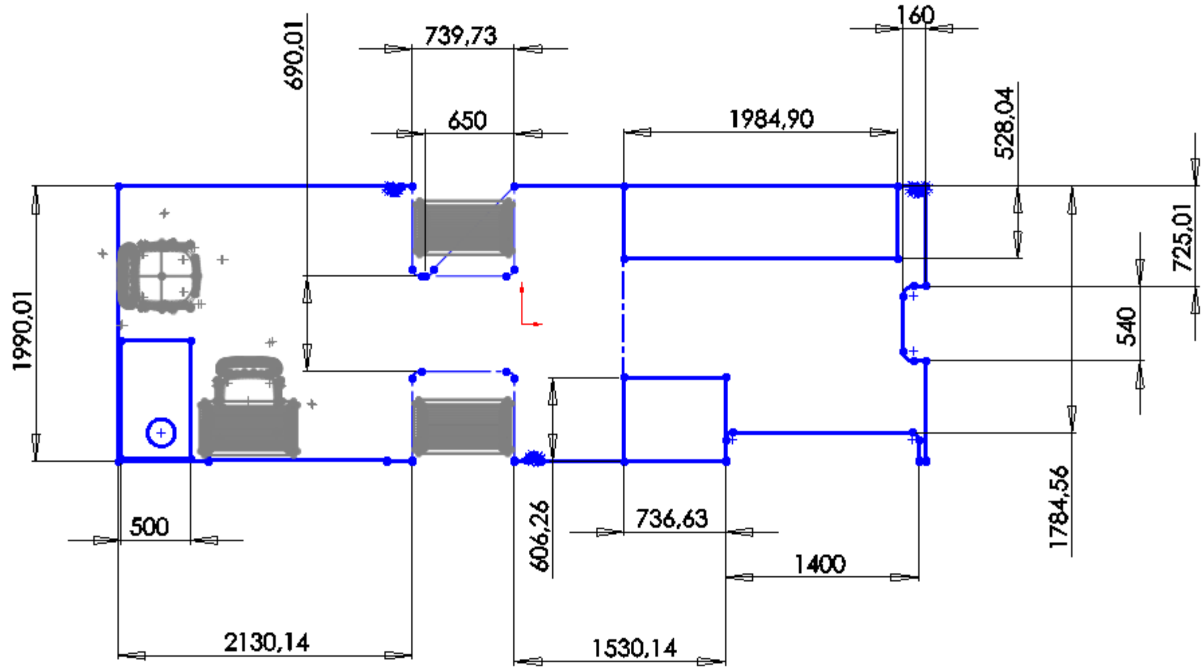


Figure 6-26: Deluxe model distribution, The wardrobes are situated on the right.

6.6.3 AVANT:

This design was born as a combination of the both before. The theme here is to achieve the balance between space and giving trust to the people. New furniture has been designed, so the bus can be more flexible. For example, here the ophthalmological technician has a desk where he can have his office stuff. The seats of the patients have been place in another place in order to take more benefit of the available space.

Figure 6-27: Different views of the Avant model.

Special Components:

Bookcase: Designed to take benefit of the maximum room and situated in the area where pitch and bounce motions introduces less vibrations to the system.

Module patient seat: This module includes the chair of the patient, the projector and the table and shelves to be used for the doctor. These shelves permit to contain all the material the doctor will have to use in a general consultancy.

6.7 RIDE ANALYSIS

6.7.1 INTRODUCTION

The first step is to choose the frequencies of the suspensions that provide vertical stiffness in consequence with the load that is assumed on the tires. Note that the permanent tire-road contact is assumed by computations.

In order to calculate the spring stiffness the first step is to choose the frequency of the damping system (spring+ tire). The higher frequency, the higher stiffness of the system for a constant load.

There are some rank frequencies (9) that one must valuate in order to characterize the stiffness of the system.

0,5-1,5 Hz for passenger cars.

1,6-2,9 Hz for sportive cars and formulas with moderate aerodynamic load.

3,0-5,0 Hz for cars with high aerodynamic load.

For a given load, low frequencies made the system less stiff so then the transitory response is faster, the displacements between the tire and the chassis are bigger so the vehicle behavior is softest.

Commonly, the frequencies of the front suspension and the rear suspension aren't the same. In the Figure 6-27 one can observe that the front suspension frequency is bigger than the rear suspension frequency.

The phase angle between the front and the rear axle is due to the lateness among the front wheel and the rear wheel when they hit the bump or pothole. This effect is known as pitch, if the car goes through a pothole and bounce if the car hits a bump. This undesirable movement of the car will not finish until the oscillations are dumped or when the two signals are found each other. In order to mitigate this movement, rear suspension system must have a higher natural frequency to catch the front oscillation.

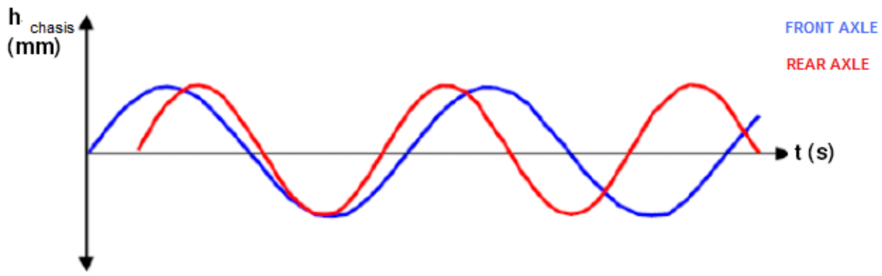


Figure 6-28. Oscillations of a vehicle passing over a road bump. (10)

6.7.2 COMPUTATIONS:

Once one choose the front and rear oscillation frequencies, and decided the hypothetical weight of the vehicle and its distribution, is possible to calculate the suspension stiffness or ride rate for each axle.

From the equations:

$$RR = \frac{K_s * K_t}{K_s + K_t} \qquad \text{(Eq. 5.2)}$$

$$\omega_n = \sqrt{\frac{RR}{M}} \qquad \text{(Eq. 5.3)}$$

One can determine:

$$RR = (2\pi f_0)^2 * M_s / 2 \qquad \text{(Eq. 5.4)}$$

Where:

f_0 =Natural frequency of the suspension system.

If one wish to calculate the chassis oscillation frequency, f_s of sprung mass of the axle M_s , it's necessary to know before the suspension stiffness K_s . Its value can be estimated with the ride rate, RR, neglecting the unsprung mass and knowing the tire rate K_T . This last, is obtained experimentally and can be consulted in the (11) *SAE Tire Test Consortium*. Starting from the estimation, one have a 1 DOF model with two series springs. Where:

$$RR = \frac{K_s * K_t}{K_s + K_t} \qquad \text{(Eq. 4.1)}$$

Solving this expressing the suspension stiffness is:

$$K_s = \frac{RR * K_t}{K_t - RR} \qquad \text{(Eq. 5.5)}$$

And then, if one assumes that the tire is in stationary state, the chassis oscillation frequency is:

$$f_s = \frac{1}{2\pi}\sqrt{\frac{K_w}{M_s / 2}} \qquad \text{(Eq. 5.6)}$$

If now we estimate that the chassis is in stationary state, is also possible to calculate the natural frequency of the wheel system (unsprung mass), f_u . One must have in mind that the system is situated between the spring, K_s, and the tire, K_t. Then the movement equation for the unsprung mass for one of its axles is:

$$(M\ddot{u}/2)\ddot{y} + c\dot{y} + (k_w + k_t)y = 0 \tag{Eq. 5.7}$$

Now the two springs are located in parallel, in consequence the global stiffness is the sum of them.

$$f_u = \frac{1}{2\pi}\sqrt{\frac{K_s + K_t}{M_u/2}} \tag{Eq. 5.8}$$

Finally, one can check the computations above studying the system with 2 DOF. Inertia Matrix, M, stiffness K and damping C can be identified from the movement equations.

For this ride analysis one can apply the Newton second law to the sprung and the unsprung mass in vertical direction, (Eq. 5.7).

If one grup together:

$$\begin{aligned} M_s\ddot{Z}_s + C_s(\dot{Z}_s - \dot{Z}_u) + K_s(Z_s - Z_u) = 0 \\ M_u\ddot{Z}_u + C_s(\dot{Z}_u - \dot{Z}_s) + K_s(Z_u - Z_s) + K_t Z_u = 0 \end{aligned} \tag{Eq. 5.9}$$

The movement matrix equation is:

$$q = \{x, y\}^T$$

$$M\ddot{q} + C\dot{q} + Kq = 0 \tag{Eq. 5.10}$$

Where:

q = General coordinates vector.

$$M = \begin{pmatrix} M_s & 0 \\ 0 & M_s \end{pmatrix} \quad , \quad C = \begin{pmatrix} C_s & -C_s \\ -C_s & C_s \end{pmatrix} \quad , \quad K = \begin{pmatrix} K_s & -K_s \\ -K_s & K_s + K_t \end{pmatrix}$$

And:

D=Dynamic matrix of the system. [s^{-2}]

$$D = M^{-1} * K \tag{Eq. 5.11}$$

Diagonalizating this matrix D, and making the adequate base change one obtain the eigenvectors p_i [m] that describes how are the movements, also called normal vibration modes, and the Eigen values [s^{-2}] that characterize the oscillation frequencies.

In that way, two independent harmonic movements are obtained. Those frequencies are calculated with the Eigen values in this way:

$$f_i = \frac{1}{2\pi}\sqrt{\lambda_i} \qquad \text{(Eq. 5.12)}$$

In addition the new weight distribution is going to be calculated, once one knows the weight of the different elements and the center of gravity of each one.

Assumptions:

- Longitudinal symmetry of the distribution of the new elements installed in the mobile unit.
- The sprung mass / unsprung mass distribution is would be calculated in two different ratios, 80/20 and 90/10.

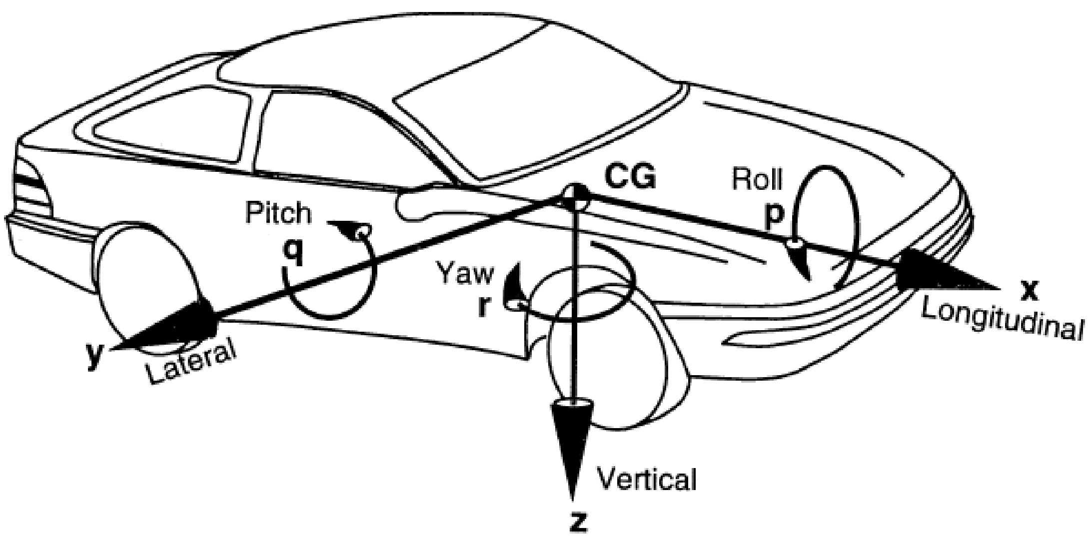


Figure 6-29: Vehicle Coordiantes axes.(1)

element	weight (Kg)	X (mm)
combo chair	70	318,57
footstool 1	3	1876,04
footstool 2	3	3235,16
footstool 3	3	4850,54
desk tire 1	20	2569,35
desk tire 2	20	2569,35
wardrobe door	18	4078,84
wardrobe	20	4109,34
techinician desk	10	5041,78
Medical stuff	210	4470,40
Patients bench	34	5442,43
Autorefractometer	*20*	4078,84
Tonometer	*18*	4078,84
Slit lamp	*18*	4109,34
Phoropter:	*10*	4109,34
Optotype projector:	*4*	4078,84
Refraction lens analyzer	*7*	4109,34
Retinoscope	-	-
Ophthalmoscope	-	-
Diesel generator(x2)	74	3478,43
Computer, screen and printer	*15*	4109,34
Solar panels(x5)	75	4144,32
Batteries	62,8	3746,07
Inverter	15	3746,07
Total	**763,8**	

Table 6-6: Masses and gravity centers of all the components of the mobile unit.

The next step would be to calculate the Xcg position for the Imaginary box that includes all the equipment; it would be treated as a whole body.

$$Xcg = \frac{\sum_{i=1}^{n} m_i * X_i}{\sum_{i=1}^{n} m_i} \qquad \text{(Eq. 5.12)}$$

Where:

m_i = mass of the I-element.

X_i = X coordinate of the gravity center of the i-element.

	Weight (Kg)
Toyota Coaster	
Tare	4100
Tare without seats	**3900**
Medical equipment and office	**92**
Autorefractometer	*20*
Tonometer	*18*
Slit lamp	*18*
Phoropter:	*10*
Optotype projector:	*4*
Refraction lens analyzer	*7*
Retinoscope	-
Ophthalmoscope	-
Three mirror lens or superfield	-
Computer, screen and printer	*15*
Fridge	**15**
Diesel engine (x2)	**74**
Photovoltaic system	**152,8**
Solar panels(x5)	*75*
Batteries	*62,8*
Inverter	*15*
Others	**10**
Furniture (density 485 kg/m3)	**210**
Footstool (x3)	9
Tire Table (x2)	40
Patients bench	34
Equipment wardrobe	20
Equipment wardrobe (door)	18
Technician desk	10
Chair (x3)	9
Combo patient chair	70
Doctor, nurse and technician	**210**
TOTAL WEIGHT (Kg)	**4663,8**

Table 6-7: List of all the weights considered for the computations. (12)

6.8 DIALUX SIMULATION

Other of the purposes of this project is to study the illumination so that one can find the best distribution of the lamps, the best models, electronic equipment. All of this is made so that the installation consumption is reduced to the maximum. On the other hand, the UNE-EN 12464-1 has been followed so that the Em, the UGR and the Ra can be achieved in each of the differenced zones inside the minibus.

In order to study this features, the program DIALux 4.7 would help to recreate the place or area one has to study. The method is to create the scenario, in 3 dimensions, and after that one can choose from their library thousands of materials and furniture to recreate the real place.

The next step will be to choose from their lamp library, wich has plenty of different lamps from the main manufacturers in the world, the more suitable for our work necessities.

The method consist of iterating, changing the disposition, the height, the number s, the orientation and models of our lamps. The computations are made each time one change any of the parameters, and a renders can be taken from the POV –Ray v3.6.

Note that the dimensions are the real ones, but the furniture might have some variations although the distribution is the real one. These little variations are because the impossibility of importing Solidworks or other CAD software files.

6.9 FINANCIAL ANALYSIS

This mobile unit can be very helpful for the productivity increase of the countries, it could give the option to work to people that before were not able to do it, or they could but with difficulties. Also governments can gain a better reputation if they take care of people who need to have a visit by the ophthalmologist, so investing in a mobile unit that would travel around some regions would be good not just for the inhabitants of the region but also for the popularity of the government. At first sight, the public finance of governments seems to be a good option. Although other international organizations like the World Bank, FMI, United Nations, European Union, NGO's and others can potentially be the costumers. Finally, private hospitals could have the option to buy it, and travel around regions of western countries, where people could pay a certain amount of money, and make business and publicity of the hospitals around the country.

For the elaboration of the financial analysis some premises have been taken:

- A constant RPI (Retail Price Index) of 2% for the 10 years of the plan.
- For the computations of the disposable material, it has been supposed that the unit will work 7 hours per day, 5 days per week and 10 months per year.
- The mean time for each patient is 15 minutes.
- The customer has been considered to be one Government and then there's no payment of taxes.

6.9.1 EXPENSES:

- Purchase of the Toyota Coaster (2nd hand)

- Cost of the transformation of the bus: Includes the Air Conditioning, the electrical installation, the exterior awning, and the coverings of walls, roof and floor.

- All the ophthalmological and office equipment: Autorefractometer, tonometer, slit lamp, phoropter: optotype projector, refraction lens analyzer, retinoscope, ophthalmoscope, three mirror lens or superfield ,computer, screen and printer
- The Fridge.
- Two Diesel engines and the diesel cost associated.
- The Photovoltaic system: The solar panels, the batteries and the inverter.
- The disposable material, calculated as follows:

Material	Consum per paient	Daily	Monthly	Anual	Cost	Total Anual Cost
Gloves	1 pair	28 pairs	560 pairs	5600	5 €/box of 50 pairs	300
Antiseptic soap			2 bottles	20 bottles	5 € /bottle	100
Alcohol			3 bottles	30 bottles	1,70 € /bottle	51
Eye drops			20 units	240 units	1,95€ /unit	468
Napkins			10 packs	100 packs	0,70€ /pack	70
Others						100

Table 6-8: Annual costs for the disposable material.

- Operational and maintenance costs: Divided in the Ophthalmological equipment and for the Photovoltaic system.
- The human resources costs: Consists of the annual cost of the doctor, nurse and optical technician.

6.9.2 INCOMES:

- Portuguese “taxas moderadoras” . Depending of the kind of consultancy, and the personal incomes, the citizen has to pay one tax or another as stated in (Appendix C). For the calculations, a mean price for the consultancies has been calculated : 5 € per patient. And 14€ for a emergency consultancy.
- Fuel cost savings: This income is the annual cost on diesel fuel that does not have to be paid because the mini-bus has a photovoltaic system. For these calculations a 1,10 €/l price has been taken as base, as is the mean price in Portugal in July 2009.

7 ANALYSIS OF THE RESULTS:

7.1 JUSTIFICATION OF THE SOLUTION:

The Premium model was rejected as the best option because there was not a big reason to have such a big waiting room, without taking profit of the space. In addition to this, there are some occidental countries where the bus might not find the goods easily due to the extension or less populated areas. As a consequence, the unit cannot stay there for a long time cause in this model there aren't a lot space to have the goods needed for a long trip.

The Luxe model has also some big disadvantages as the fact that the ophthalmologic technician doesn't have place to make the registrations. Moreover, there is no waiting room inside the bus, wich mean that if the patients need some medicines, these have to be served or applied outside the bus wich means less comfort and privacy.

Finally, the option chosen is the model Avant. It has some clear advantages versus the other two options like:

Figure 7-1: 3D view of the exterior of the mobile unit.

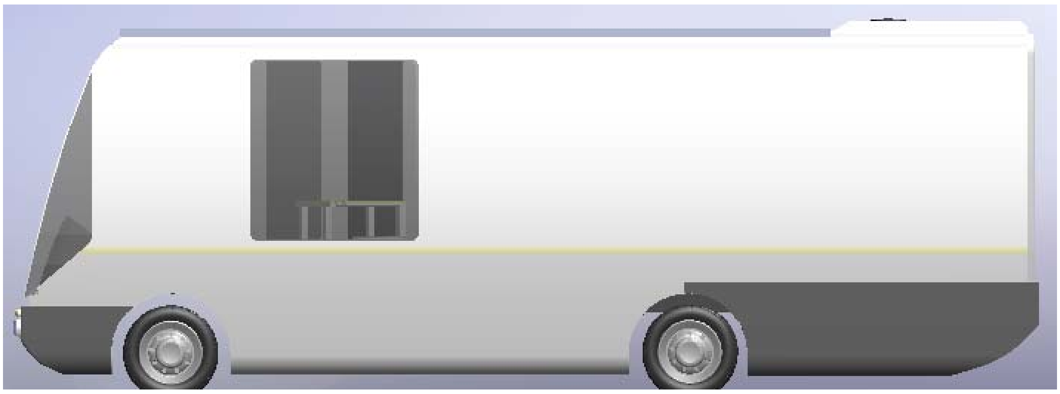


Figure 7-2: Left side viex of the exterior.

- More flexibility: Some furniture as the doctor's desk is situated in the bottom of the bus wich leads to have more space.
- More comfortable: The optician technician can seat outside the office and make the registrations, and the patients can seat in a more comfortable bank.
- Better situation of the shelves: The shelves that are to keep the ophthalmological equipment during the trip, are situated strategically where the bounce and pitch vibrations introduces less gain to the system.

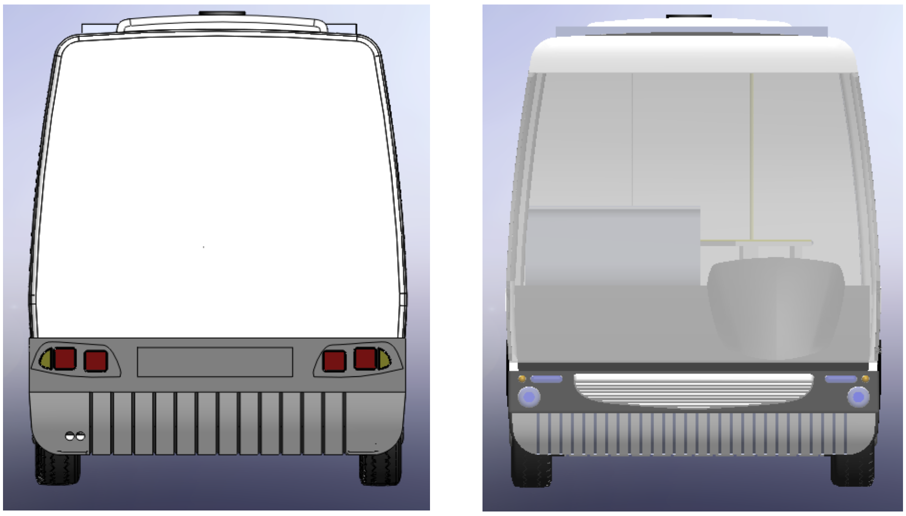


Figure 7-3: Back and front view of the avant model.

7.2 RIDE ANALYSIS:

7.2.1 DESIGN PARAMETERS:

Toyota Coaster:

centre of gravity elements	
Xcg (mm)	3254,08
Total Mass (Kg)	**763,8**
distribution	
X Rear axle (mm)	2558,27
X Front axle(mm)	6382,53
Dist Xcg-Rear axle (mm)	695,81
Dist Xcg-Front axle (mm)	3128,45

Proportional distribution(%)	
Rear Axle	81,81
Front Axle	19,91
Weight distribution (Kg)	
Rear Axle	624,86
Front Axle	152,07

Mass Initial Distribution	weight (Kg)
Rear Axle	1123,2
Front Axle	1996,8
New Mass Distribution	weight (Kg)
Rear Axle	1748,06
Front Axle	2148,87

Table 7-1: Center of gravity of all the components, its distribution between front and rear axle initially (without equipment) and the distribution considering all the components.

7.2.2 WEIGHT DISTRIBUTION:

Two different situations are going to be studied in order to show different ride behaviours by modifying the weight distribution in the sprung or unsprung mass.

7.2.2.1 MODEL A

The weight distribution was made as follows:

Weight without equipment= 3900 Kg

If one consider the weight distribution between the sprung and unsprung mass as 80% and 20%.

Initial weight of the sprung mass (without equipment, furniture...) = 3900*0,8= 3120 Kg.

Weight of the unsprung mass= 3900*0,2= 780 Kg

For the distribution of the sprung mass in front or rear one have took into consideration the distribution of the original bus: 64% Front and 34% rear. (See the Appendix D)

Weight front sprung mass $= 3120 \times 0,64 + 152,07 = 2148,87 Kg$

Weight rear sprung mass= $3120 \times 0,36 + 624,86 = 1748,06 Kg$

Total Sprung mass (includes equipment, furniture and others) = 3883,8 Kg

For the distribution of the unsprung mass one made an estimation that is that the front sprung mass would be higher because the engine is there and it's suppose to have front traction.

Front unsprung mass = 780 * 0,55 = 429 Kg.

Rear unsprung mass = 780 * 0,45 = 351 Kg.

7.2.2.2 MODEL B

The difference between this model and the model A is the sprung/unsprung mass percentuals, these differentiation was made in order to study different vehicle ride behaviours. In the Model B the unsprung mass weight is less than in Model A and the sprung mass is heavier.

Weight without equipment= 3900 Kg

If one consider the weight distribution between the sprung and unsprung mass as 90% and 10%.

Initial weight of the sprung mass (without equipment, furniture...) = 3900*0,9= 3510 Kg.

Weight of the unsprung mass= 3900*0,1= 390 Kg

For the distribution of the sprung mass in front or rear one have took into consideration the distribution of the original bus: 64% Front and 34% rear. (See the Appendix D)

Weight front sprung mass $= 3510 \times 0,64 + 152,07 = 2398,7 Kg$

Weight rear sprung mass= $3510 \times 0,36 + 624,86 = 1888,46 Kg$

Total Sprung mass (includes equipment, furniture and others) = 4286,53 Kg

For the distribution of the unsprung mass one made an estimation that is that the front sprung mass would be higher because the engine is there and it's suppose to have front traction.

Front unsprung mass = 390 * 0,55 = 214,5 Kg.

Rear unsprung mass = 390 * 0,45 = 175,5 Kg.

7.2.3 RIDE AND MASS FREQUENCY ANALYSIS

7.2.3.1 MODEL A

	Front		Rear	Units
Ride Frequency	1,1		1,4	Hz
Overall mass		4463,5		Kg
Sprung mass		3883,8		Kg
Unsprung mass		780		Kg
Sprung mass distribution	2148,87		1734,93	Kg
Unsprung mass distribution	429		351	
Tyre vertical rate	250.000		250.000	N/m
Wheelbase		3800		m

Table 7-3: Design parameters for model A

	Front	Rear	Units
Ride Rate, RR	51324,56228	67630,4298	N/m
Suspension Stiffness, Ks	64583,43	92710,68	N/m

	Front	Rear	Units
Sprung mass frequency (fs)	1,24	1,63	Hz
Unsprung mass frquency (fu)	6,1	7,03	Hz
First vibration eigenvalue λ1	47,357114	76,2123117	s ^-2
Second vibration eigenvalue λ2	1479,34151	1982,62778	s ^-2
First frequency of oscillation, f1	1,1	1,39	Hz
Second frequency of oscillation, f2	6,12	7.09	Hz
First vibration mode p1	{1 , 0,212486}	{1 , 0,2815084}	m
Second vibration mode p2	{-0,0423533 , 1}	{0,0565252 , 1}	m

Table 7-4: Ride and mass frequency analysis of the model A.

7.2.3.2 MODEL B

	Front		Rear	Units
Ride Frequency	1,1		1,4	Hz
Overall mass		4463,5		Kg
Sprung mass		4286,93		Kg
Unsprung mass		390		Kg
Sprung mass distribution	2398,07		1888,86	Kg
Unsprung mass distribution	214,5		175,5	
Tyre vertical rate	250.000		250.000	N/m
Wheelbase		3800		m

Table 7-5: Design parameters for the model B.

	Front	Rear	Units
Ride Rate, RR	57276,5654	73062,3443	N/m
Suspension Stiffness, Ks	74298,9112	103231,7626	N/m

	Front	Rear	Units
Sprung mass frequency (fs)	1,25	1,66	Hz
Unsprung mass frquency (fu)	8,75	10,1	Hz
First vibration eigenvalue λ1	47,5421	76,7566	s ^-2
Second vibration eigenvalue λ2	3038,31126	4058,0056	s ^-2
First frequency of oscillation, f1	1,1	1,4	Hz
Second frequency of oscillation, f2	8,8	10,1	Hz
First vibration mode p1	{1 , 0,232766}	{1 , 0,29793}	m
Second vibration mode p2	{-0,0208202 , 1}	{0,0276875 , 1}	m

Table 7-6: Ride and mass frequency analysis of the model B.

The results obtained for the model A, demonstrate that the mobile unit has the second frequency of oscillation at 6,12 Hz in the front axle and 7,09 Hz in the rear axle. That is because the unsprung mass is heavy and will provoke great transmission of road inputs in this range of lower frequencies. This phenomenon is undesirable because vibrations transmitted at lower frequencies are more difficult to isolate. A new analysis test, model B, with the unsprung weight of 10% the sprung mass shows higher second frequencies that would improve the ride performance

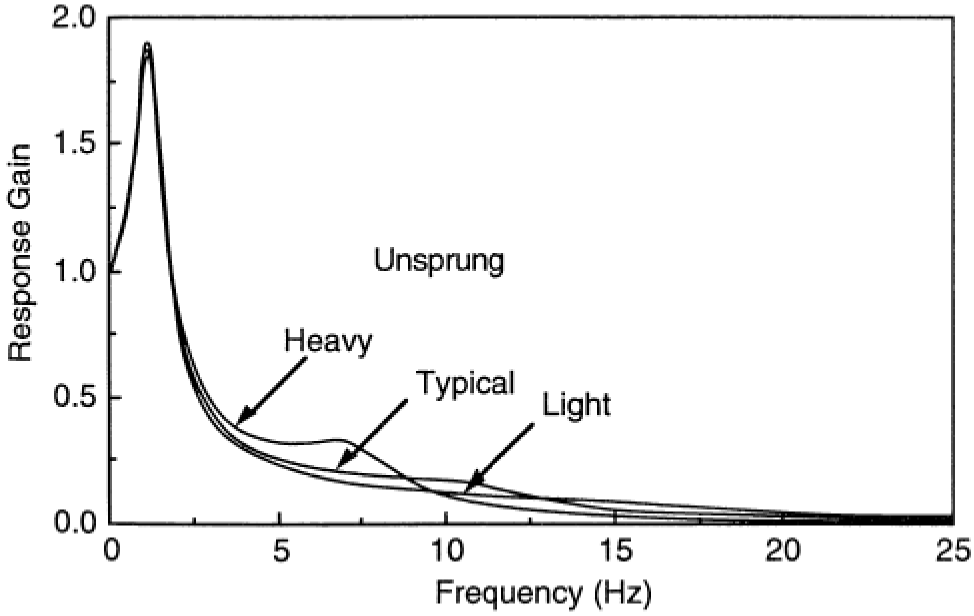


Figure 7-4:

7.3 SIZING THE PHOTOVOLTAIC SYSTEM:

As a result of the computations made with the RETscreen software, one can look for the inverter and batteries that fit or accomplish the values determinate by the software. In the case of the solar panels, one already knows the brand and the model.

Figure 7-5: From left to right, solar panels, battery and the inverter selected for this study.

It’s important to state that the solar panels must have installed a solar guide system if one wants to achieve the results obtained in the simulation that implies more cost and weight to the whole project. The brand and model selected are the most efficient photovoltaic panels in the market, it means that other solar panels with lower efficiency would have cover much more surface, that’s critical because the area that the mini-bus have for the installation of the panels is limited. That is why the most efficient have been chosen although its price is higher than others.

Figure 7-6: Solar panels orientation.

In the computations made with RETscreen, the Battery capacity is oversized to avoid problems in the future. As said by (13) it is better to oversized them. Concretely, the program estimate that are necessary 835 Ah, and the batteries installed would have around 1100 Ah, wich is 22% more than theorically needed. To reach this capacity, there is not necessity of a parallel installation of two batteries if the model chosen is the one described before. Its dimensions are 405 x 195 x 352, so it can perfectly be installed in some compartment of the bus, preferably in one the trunks.

7.4 ILLUMINATION

7.4.1 EQUIPMENT SELECTED:

Brand	Model	Luminous flux (lm)	Nominal Power (W)	Ra class by CIE	Color temperature correlated , Tcp (K)	Number (units)
Osram	GmbH 72581-10 Reflector for OSRAM ECOPACK® 18W	1300	20	90	4000	5
Osram	GmbH 72585-10 Reflector for OSRAM ECOPACK® 36W	3200	36	90	4000	1
TOTAL	**-**	**9700**	**136**	**-**	**-**	**6**

Table 7-2: Main characteristics of the chosen lights.

7.4.2 RESULTS:

	illuminance (lux)	illuminance of the immediate surroundings (lux)	Uniformity factor, U	UGR
Working desk	500	400	0,8	19
Analisys desk 1	500	400	0,8	19
Analisys desk 2	500	400	0,8	17
Corridor consultory	300	200	0,67	-
Floor waiting room	300	200	0,67	-

Table 7-3: Results obtained in different study surfaces of the mobile unit.

After some iterations changing the distribution of the lights, the models, brands and power. With the objective of reducing as much as possible the power consumption and calculating the illuminance , the uniformity factor and UGR, so that the illumination accomplish the EN-12464, that also guarantees best productivity, less fatigue for the people that must work there and also for the patients and all the potential users. It is important to say that there’s not a only optimal solution because as the catalogue of the DIAlux program have more than thirty brands of manufacturers and its characteristics is easy to find very similar models. These, can provide very similar results.

If one compare the results obtained, in the table above with the recommended ones at Figure 4-3, one must notice that the illuminance, uniformity factor and UGR levels had been reached, these results are for the situation when all the lights are switched on.

Figure 7-7: Render of the interior with all the lights switched on.

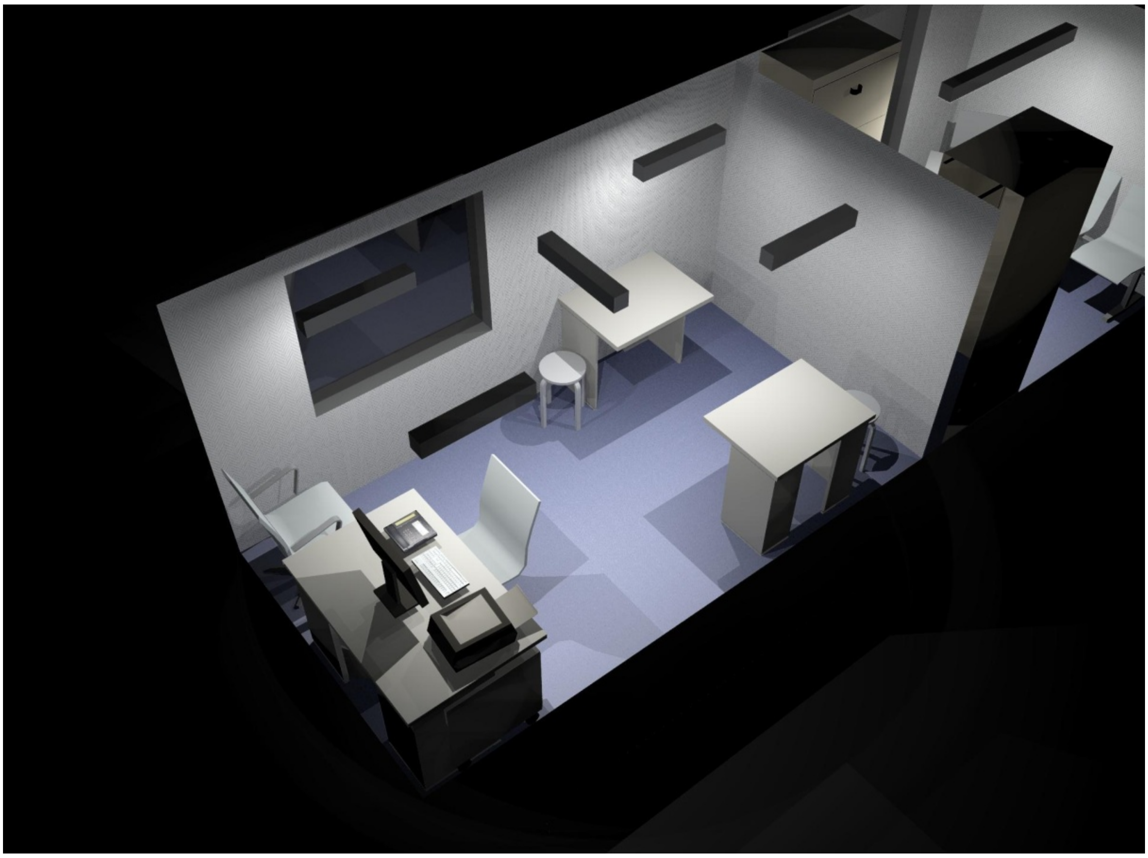


Figure 7-8: Top view of the consultory illumination effect.

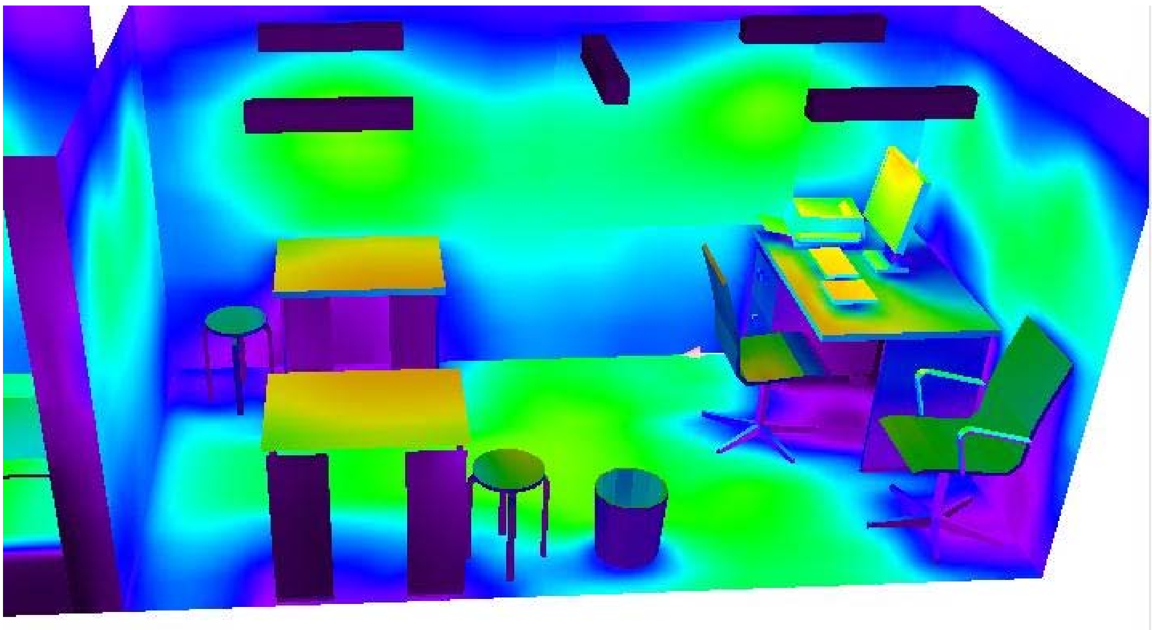


Figure 7-9: False colors representation of the illuminance levels.

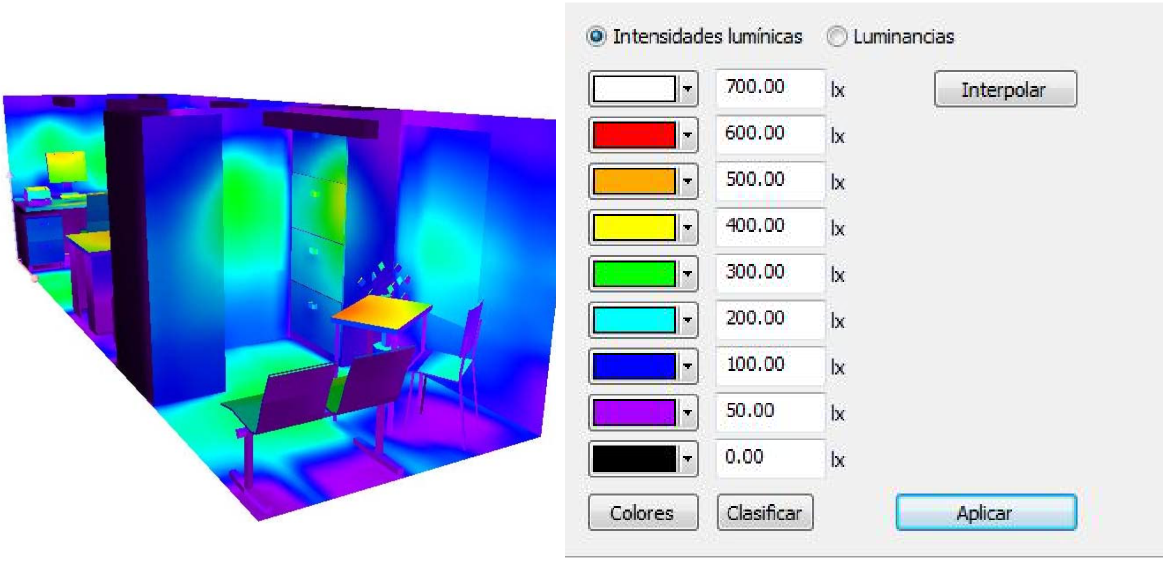


Figure 7-10: Waiting room false colors representation of illuminace levels and the correspondent values, this values are also valid for Figure 6-9.

7.5 FINANCIAL ANALYSIS:

7.5.1 RESULTS:

		Year	0	1	2	3	4	5
Incomes								
	"Taxas moderadoras"			39116,0	39898,3	40696,3	41510,2	42340,4
	Fuel generator cost saving			1765,0	1800,3	1836,3	1873,0	1910,5
Total expenses			77535	75247,0	76751,9	78287,0	79852,7	81449,8
Total incomes				40881,0	41698,6	42532,6	43383,2	44250,9
		Year	0	1,0	2,0	3,0	4,0	5,0
Cash flow (€)			-77535	-34366,0	-35053,3	-35754,4	-36469,5	-37198,9
Accum Cash flow (€)			-77535	-111901,0	-146954,3	-182708,7	-219178,2	-256377,0

Table 7-4: Feasibility analysis for the first five years.

		Year	6	7	8	9	10
Incomes							
	"Taxas moderadoras"		43187,2	44051,0	44932,0	45830,6	46747,2
	Fuel generator cost saving		1948,7	1987,7	2027,4	2068,0	2109,3
Total expenses			83078,8	84740,3	86435,2	88163,9	89927,1
Total incomes			45135,9	46038,6	46959,4	47898,6	48856,6
		Year	6,0	7,0	8,0	9,0	10,0
Cash flow (€)			-37942,8	-38701,7	-39475,7	-40265,2	-41070,6
Accum Cash flow (€)			-294319,9	-333021,6	-372497,3	-412762,6	-453833,1

Table 7-5: : Feasibility analysis for the last five years.

The difference between incomes and expenses is known as cash flow. At year 0, the cash flow is -77535 €, because is the present year, and it is considerate that the mobile unit is not ready, so it is not working until year 1. From year 1 to year 10, one must see that there's no positive numbers at accumulated cash flow, wich means that there's no positive benefit along the ten years financial analysis. Every year, there are more expenses than incomes and the results start from 34366 € of losses and finish with 41070,6 € in year 10. This losses are mostly due to the fact that the salaries of the ophthalmological crew are included in the balance, and that represent a payment of 74000 € every year.

This situation reflects that there not enough incomes, or also that there are too much costs. Cost reducing could be achieved by buying for example second hand ophthalmological equipment, negotiating cost reducing of the equipment, for example by introducing the logo of the solar panels brand in the bus.

From this point of view, one can state the high importance of the human resources costs in the 10 year study of the project. Human resources expenses represent almost 80% of the total annual expenses.

8 CONCLUSIONS:

During the realization of this project the objectives have been accomplished by following product engineering procedures. That involves some analysis, techniques and calculations that have been done before the design. These procedures are optimal so as to avoid mistakes and consequently loose time. The collaboration with doctors and technicians has provided a necessary feedback for the final solution. After establishing the priorities that the design should achieve, some other important or critical themes for an ophthalmological mobile unit have been studied.

The first step was to design the mobile unit, to determine the ophthalmological equipment required and design special parts and furniture. All of this was made taking into account the user-machine relationships and the priorities and functions established in the pre-design analysis.

Once the interior was defined, the illumination of the consultancy and waiting room was studied with DIAlux software. Some alterations were made with different types and brands of lights so one can achieve the required illumination parameters diminishing the power consume.

For studying the vibrations transmitted by the road, it has been necessary to make some simplifications. The first and more important is to use the quarter-car model, this model does not consider suspension non-linearity. However, it provides an optimal approximation of the behaviour of the vehicle versus road roughness inputs. For the ride analysis test, the real distribution of the unsprung and sprung mass can be determined more accurately for further studies. Although the results obtained are satisfactory because they reflect the general behaviour that the minibus is going to have.

After that, it seems interesting to study whether the minibus could have an off-grid photovoltaic installation. Using the RETscreen software, it has been determined that it is possible to power all the electrical equipment but not the air conditioning. Concluding the analysis it is important to say the weight of the whole vehicle, considering all the equipment and furniture is within the legal parameters. In future studies it could be interesting to mount more efficient solar panels, and to design or develop the solar guide system that should be installed in the roof.

Finally, a feasibility plan for the project was made, and it reflects the importance of human resource costs, the whole cost was estimated as if the unit would be constructed and working in Portugal. For having the unit working in another country, some modifications might have to be done. Some approximations were made such as the incomes that come from the payment of "taxas moderadoras", which is an important theme but needs an accurate data that can only be provided from the public health care.

The goal of this project was to establish the basis for further studies. Future projects involving an ophthalmological mobile unit could include more accurate material selection and feasibility plans, the simulation of the suspension system using software such as the Msc Adams Car and the study and selection of plastic rubbers in order to achieve the second phase of the ophthalmological equipment isolation.

9 WORKS CITED

1. **Organization, World Health.** *WHO: Prevention of Blindness and Visual Impairment.* [Online] WHO, 2004. [Cited: July 25, 2009.] http://www.who.int/blindness/en/.

2. —. Vision 2020 the right to sight. [Online] WHO, 1999. [Cited: July 23, 2009.] http://www.v2020.org/.

3. **D.Gillespie, Thomas.** *Fundamentals of Vehicle Dynamics.* Warrendale, PA : Society of Automotive Engineers.

4. **O.Kropá and P.Múka.** *Effect of obstacles on roads with different waviness values on the vehicle response.* Bratislava : Taylor & Francis, 2007.

5. **Solar Energy International.** Photovoltaics, design and installation manual. Gabriola Island, Canada : New Society Publishers, 2005.

6. **Paul W. Stackhouse, Jr., Ph.D. and Charles H. Whitlock, Ph.D.** Surface meteorology and Solar Energy. [Online] NASA, April 23, 2000. [Cited: July 20, 2009.] http://eosweb.larc.nasa.gov/sse/RETScreen/.

7. **Dunlop, Dr. Thomas Huld and Dr. Ewan D.** Photovoltaic Geographical Information System (PVGIS). *Sunbird.* [Online] European Comission Joint Research Centre, November 20, 2008. [Cited: july 23, 2009.] http://sunbird.jrc.it/pvgis/index.htm.

8. **Canada, Natural Resources.** *RETscreen software.* [Software] Ottawa, Canada : Natural Resources Canada, 2009.

9. **L.Milliken, William F. Milliken and Douglas.** *Race car vehicle dynamics.* Warrendale (USA) : SAE International Publications, 1995.

10. **Giró, Jaume.** *Disseny de les suspensions del Formula Student CAT-01.* Barcelona : s.n., 2007.

11. **Consortium, Formula SAE Tire test.** Test #3. Buffalo (USA) : s.n., 2007.

12. Madeiras do Brasil. *aguademeninos.* [Online] [Cited: July 23, 2009.] http://www.aguademeninos.com.br/Madeireira/madeirasbrasil.html.

13. **Sánchez, Javier.** Javier Sánchez. Sales Manager RBS/SBG. Madrid : s.n., 2009. Mail Answer.

10 BIBLIOGRAPHY

1. **Organization, World Health.** *WHO: Prevention of Blindness and Visual Impairment.* [Online] WHO, 2004. [Cited: July 25, 2009.] http://www.who.int/blindness/en/.

2. —. Vision 2020 the right to sight. [Online] WHO, 1999. [Cited: July 23, 2009.] http://www.v2020.org/.

3. **D.Gillespie, Thomas.** *Fundamentals of Vehicle Dynamics.* Warrendale, PA : Society of Automotive Engineers.

4. **O.Kropá and P.Múka.** *Effect of obstacles on roads with different waviness values on the vehicle response.* Bratislava : Taylor & Francis, 2007.

5. **Solar Energy International.** Photovoltaics, design and installation manual. Gabriola Island, Canada : New Society Publishers, 2005.

6. **Paul W. Stackhouse, Jr., Ph.D. and Charles H. Whitlock, Ph.D.** Surface meteorology and Solar Energy. [Online] NASA, April 23, 2000. [Cited: July 20, 2009.] http://eosweb.larc.nasa.gov/sse/RETScreen/.

7. **Dunlop, Dr. Thomas Huld and Dr. Ewan D.** Photovoltaic Geographical Information System (PVGIS). *Sunbird.* [Online] European Comission Joint Research Centre, November 20, 2008. [Cited: july 23, 2009.] http://sunbird.jrc.it/pvgis/index.htm.

8. **Canada, Natural Resources.** *RETscreen software.* [Software] Ottawa, Canada : Natural Resources Canada, 2009.

9. **L.Milliken, William F. Milliken and Douglas.** *Race car vehicle dynamics.* Warrendale (USA) : SAE International Publications, 1995.

10. **Giró, Jaume.** *Disseny de les suspensions del Formula Student CAT-01.* Barcelona : s.n., 2007.

11. **Consortium, Formula SAE Tire test.** Test #3. Buffalo (USA) : s.n., 2007.

12. Madeiras do Brasil. *aguademeninos.* [Online] [Cited: July 23, 2009.] http://www.aguademeninos.com.br/Madeireira/madeirasbrasil.html.

13. **Carlos Marino Rizzolo**. *Manual de procedimientos para la ingeniería de iluminación de interiores y áreas deportivas*. Universidad Simón Bolívar. Sartenejas (Venezuela) 2007.

14.**Luis Henrique Soares Gonçalves de Lima and Luciene Barbosa de Sousa**. *Análise de viabilidade econômica da unidade móvel de um serviço de referência em oftalmología.* Departamento de Oftalmologia do Hospital Oftalmológico de Sorocaba, (Brasil). 2005

APPENDIX A:

BATTERY SAFT SUNICA PLUS CHARACTERISTICS:

Tipo de elemento	Capacidad		Altura		Anchura		Longitud por bloque																		Peso	
	C120 120 h 1,0V Ah	C5 5 h 1,0V Ah	mm	pulg.	mm	pulg.	1 elemento mm	pulg.	2 elementos mm	pulg.	3 elementos mm	pulg.	4 elementos mm	pulg.	5 elementos mm	pulg.	6 elementos mm	pulg.	8 elementos mm	pulg.	9 elementos mm	pulg.	10 elementos mm	pulg.	por elemento kg	lb
SUN⊕45	45	43	405	15,9	195	7,68					88	3,46	113	4,49	137	5,39	162	6,38	212	8,35	237	9,33	261	10,3	3,2	7,06
SUN⊕90	90	85	405	15,9	195	7,68					121	4,76	157	6,18	192	7,56	228	8,98	300	11,8	336	13,2	371	14,6	4,9	10,8
SUN⊕105	105	100	405	15,9	195	7,68					157	6,18	205	8,07	252	9,92	300	11,8	396	15,6	444	17,5			6,2	13,7
SUN⊕140	140	128	405	15,9	195	7,68					157	6,18	205	8,07	252	9,92	300	11,8	396	15,6					6,7	14,8
SUN⊕185	185	171	405	15,9	195	7,68					193	7,60	253	9,96	312	12,3	372	14,7							8,4	18,5
SUN⊕230	230	213	405	15,9	195	7,68			159	6,26	232	9,13	305	12,0	377	14,8									9,9	21,8
SUN⊕275	275	256	405	15,9	195	7,68			183	7,21	268	10,6	353	13,9	437	17,2									11,5	25,4
SUN⊕320	320	300	405	15,9	195	7,68			228	8,98	336	13,2													15,1	33,3
SUN⊕370	370	341	405	15,9	195	7,68			252	9,92	372	14,7													16,8	37,0
SUN⊕415	415	384	405	15,9	195	7,68	146	5,75	278	11,0															18,3	40,4
SUN⊕460	460	427	405	15,9	195	7,68	159	6,26	304	12,0															19,8	43,7
SUN⊕505	505	469	405	15,9	195	7,68	171	6,73	328	13,0															21,4	47,2
SUN⊕555	555	512	405	15,9	195	7,68	183	7,21	353	13,9															23,0	50,7
SUN⊕645	645	597	405	15,9	195	7,68	219	8,62																	28,2	62,2
SUN⊕735	735	682	405	15,9	195	7,68	244	9,61																	31,3	69,0
SUN⊕830	830	768	405	15,9	195	7,68	268	10,6																	34,5	76,1
SUN⊕920	920	853	405	15,9	195	7,68	304	12,0																	39,6	87,3
SUN⊕1110	1110	1024	405	15,9	195	7,68	352	13,9																	46,0	101

Sunica.plus cumple las especificaciones de la norma CEI 62259.

INVERTER ECOSFERA 1500W CHARACTERISTICS:

10.1

MODELO	ECOESFERA 600W	ECOESFERA 1500W	ECOESFERA 3000W
Tipo de onda	Senoidal pura	Senoidal pura	Senoidal pura
Potencia nominal	600 W	1500 W	3000 W
Voltaje nominal de entrada	12/24 V	12/24 V	24 V
Voltaje nominal de salida	230 Vca	230 Vca	230 Vca
Frecuencia nominal de salida	50 Hz	50 Hz	50 Hz
Variaciones en la frecuencia de salida	< 0,1%	< 0,1%	< 0,1%
Variaciones en la tensión de salida	< 5%	< 5%	< 5%
Voltaje mínimo de entrada	10/20 Vcc	10/20 Vcc	10/20 Vcc
Voltaje máximo de entrada	16/32 Vcc	16/32 Vcc	16/32 Vcc
Rendimiento	85-97%	85-97%	85-97%
Rendimiento con carga nominal	> 85%	> 85%	> 85%
Autoconsumo	< 70 mA	< 70 mA	< 70 mA
Sobrecarga dur. 3 seg.	1080 W	2700 W	5400 W
Sobrecarga dur. 50 seg.	900 W	2250 W	4500 W
Sobrecarga dur. 6 min.	720 W	1800 W	3600 W
Longitud	315 mm	460 mm	535 mm
Altura	118 mm	130 mm	178 mm
Ancho	192 mm	255 mm	285 mm
Peso	7 kg	15 kg	25 kg
Caja	aluminio + epoxi	aluminio + epoxi	aluminio + epoxi

SOLAR PANELS SUNPOWER 315 CHARACTERISTICS:

SUNPOWER

PANEL SOLAR 315

EFICIENCIA Y RENDIMIENTO EXCEPCIONALES

Datos Eléctricos

Medidos en condiciones de prueba estándar (STC): Irradiancia 1000W/m², AM 1,5, temperatura de células 25° C

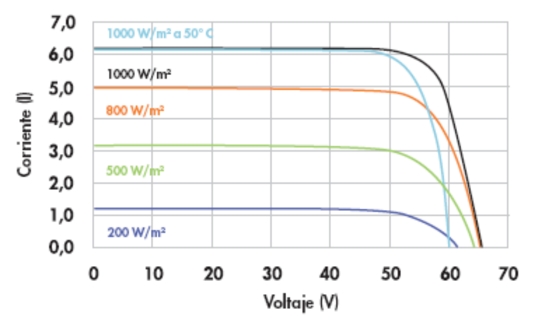
Potencia nominal (+5/-3%)	P_{nom}	315 W
Voltaje en el punto de máxima potencia	V_{mpp}	54,7 V
Corriente en el punto de máxima potencia	I_{mpp}	5,76 A
Voltaje de circuito abierto	V_{oc}	64,6 V
Corriente de cortocircuito	I_{sc}	6,14 A
Voltaje máximo del sistema	IEC	1000 V
Coeficientes de temperatura		
	Potencia	-0,38% / K
	Voltaje (V_{oc})	-176,6mV / K
	Corriente (I_{sc})	3,5mA / K
NOCT		45° C +/-2° C
Corriente nominal de fusibles en serie		15 A
Límite de corriente inversa (3 strings)	I_R	15,3 A

Datos Eléctricos

Medidos en temperatura nominal de operación de célula (NOCT): Irradiancia 800W/m², AM 1,5

Potencia nominal	P_{nom}	231 W
Voltaje en el punto de máxima potencia	V_{mpp}	50,1 V
Corriente en el punto de máxima potencia	I_{mpp}	4,62 A

Curva I-V



Características corriente/voltaje dependiendo de la irradiancia y la temperatura del módulo

Condiciones de Prueba para Certificaciones

Temperatura	-40° C hasta +85° C
Carga máxima	245kg/m² (2400 Pa) frontal y posterior (p.ej. viento)
Resistencia al impacto	Granizo: 25 mm a 23 m/s

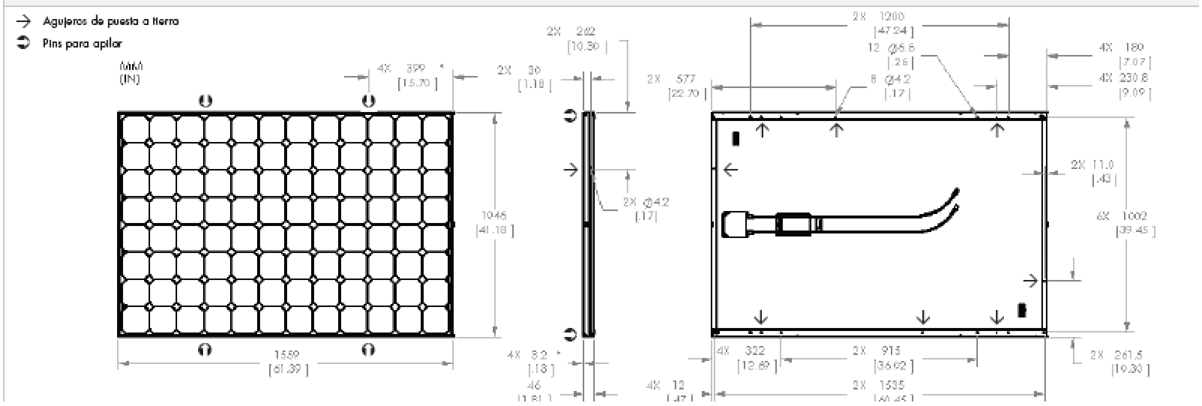
Garantías y Certificaciones

Garantías	Garantía limitada de potencia durante 25 años

Datos Mecánicos

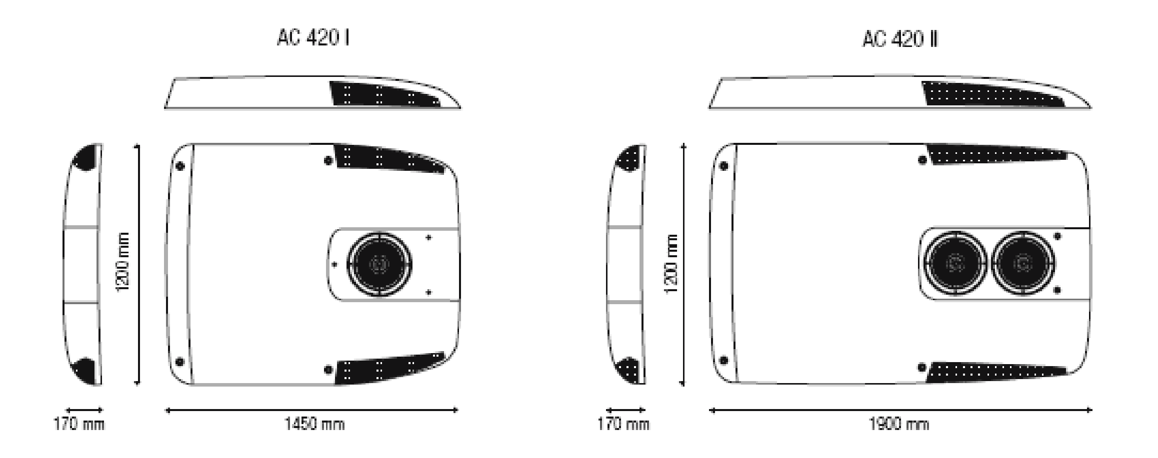
Células solares	96 células monocristalinas de contacto posterior SunPower	Cables de salida	Cable de 1000 mm de longitud / conectores MultiContact (MC4)
Vidrio frontal	Cristal templado anti-reflectante de gran transmisividad	Bastidor	Aleación de aluminio anodizado (negro) tipo 6063; pins para apilar
Caja de conexiones	IP-65 con 3 diodos de bypass 32 x 155 x 128 (mm)	Peso	18,6 kg

Dimensiones



AIR CONDITIONING CARRIER AC 420 I CHARACTERISTICS:

Technical Data	AC 420 I	AC 420 II	Technische Daten
Cooling capacity	6 kW	10 kW	Kälteleistung
Heating capacity	7 kW	9 kW	Heizleistung
Length	1450 mm	1900 mm	Länge
Width	1200 mm	1200 mm	Breite
Height	170 mm	170 mm	Höhe
Weight	41 kg	55 kg	Gewicht
Evaporator air capacity	2100 m^3/h	2400 m^3/h	Verdampfer Luftleistung
Power input at 12 VDC	47 A	61 A	Stromaufnahme bei 12 VDC
Refrigerant	R 134a	R 134a	Kältemittel



PC de sobremesa Compaq CQ2000ES

PC de sobremesa compacto, moderno, muy asequible y de gran eficiencia energética

Sistema operativo
- Windows® XP Home original de 32 bits

Procesador
- Procesador Intel® Atom™ 230
- Chipset Intel® 945 Express

Memoria
- 1 GB SDRAM DDR2
- 1 zócalo DIMM

Almacenamiento de datos
- 160 GB Unidad de disco duro SATA 3G (7.200 rpm) partición de hasta 13 GB para la recuperación del sistema
- Grabadora de DVD SATA DVD RAM y doble capa que admite tecnología Light Scribe
- Crear etiquetas de disco con calidad serigráfica directamente desde su PC con LightScribe: simplemente grabar, dar la vuelta y grabar.
- Lector de tarjetas de memoria "6 en 1"

Comunicación
- Interface IEEE 1394 FireWire®
- Interface de red Ethernet 10/100BT integrado

Vídeo
- Intel Graphics Media Accelerator 950 (puerto VGA)
- 64 MB de memoria dedicada, hasta 251 MB disponibles de memoria grafica para utilizar Windows Vista®

Sonido
- Audio 5,1 de alta definición (2 puertos de audio frontales, 3 puertos de audio analógico en la parte posterior)

Accesorios incluidos

Accesorios opcionales
- Monitores LCD (se venden aparte): monitor de pantalla plana panorámica Compaq WF1907v de 19", Monitor de pantalla plana panorámica Compaq W220q de 22"

Puertos y capacidad de expansión
- 1 PCI-Express de 1x
- 4 puertos USB 2.0 (2 frontales)

Software
- Microsoft® Internet Explorer 7.0
- Windows Mail
- Adobe® Reader 8.0
- Reproductor de Windows Media
- Windows Movie Maker
- Cyberlink Power2Go

Servicio y asistencia
- Partición de recuperación (incluida la posibilidad de recuperar el sistema, las aplicaciones y los controladores por separado)
- Reasignación opcional de partición de recuperación
- Herramienta de creación de CD/DVD de recuperación
- Symantec™ Norton Internet Security™ 2009 (actualización gratuita durante 60 días)

Información adicional
- P/N: NF347AA #ABE
- UPC/EAN code: 884420579656

Peso
- 4,3 kg
- 5,5 kg Empaquetado

Dimensiones
- 112 x 246 x 260 mm
- 216 x 330 x 495 mm Empaquetado

Garantía
- 1 año en piezas y mano de obra con recogida y devolución
- Puede ampliar hasta 3 años la cobertura de la garantía del producto; para obtener más información, consulte la sección Web "Opciones y accesorios" de las páginas del producto hp.com.

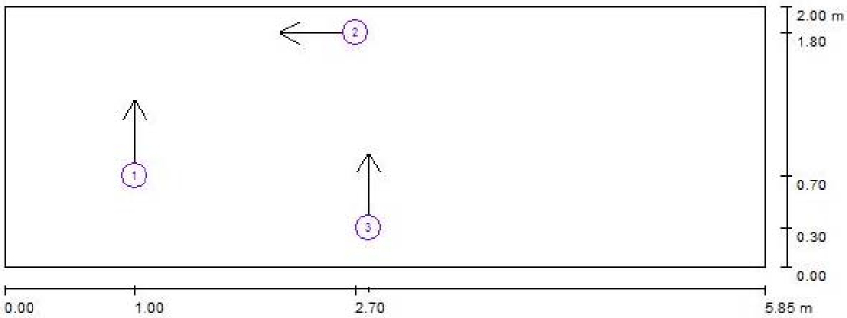
Impresora multifunción HP Photosmart C6380

	mm a 127 x 178 mm
Margen máx. de pesos de papel	Bandeja principal: 60 a 252 g/m², Bandeja foto.: 200 a 252 g/m²
Manejo de papel	Estándar: Bandeja de entrada de 125 hojas, bandeja fotográfica de 20 hojas
Manejo/alimentacion de papel	Hojas: Hasta 125, Sobres: Hasta 15, Tarjetas: Hasta 60, Transparencias: Hasta 40, fotografía 10 x 15 cm: Hasta 60
Impresión a doble cara	Manual (soporte para controlador suministrado)
Alimentación	Requisitos: Voltaje de entrada 100 a 240 V CA (+/- 10%), 50/60 Hz (+/- 3 Hz), Tipo: Externo
Consumo energético	Máximo: máximo 42 vatios, 24 vatios (activa, impresión), 6,6 vatios (preparada), 5,2 vatios (suspensión), 0,6 vatios (apagada)
Interfaz y conectividad	USB 2.0 (1 frontal, 1 trasero), Ethernet, PictBridge, Wireless 802.11g/b, ranuras de tarjeta de memoria
Memoria	Estándar: 64 MB; Máximo: 64 MB
Software incluido	HP Photosmart Essential, HP Smart Web Printing
Dimensiones (an x f x al)	Sin embalaje: 452 x 406 x 207 mm, embalado: 500 x 283 x 469 mm
Peso	Sin embalaje: 7,45 kg, embalado: 9,49 kg
País/región de origen	Producto de Malasia.
Capacidades de red	Ethernet, 802.11g/b inalámbrica
Sistemas operativos compatibles	Microsoft® Windows® XP, Windows Vista®, Mac OS X v10.4, v10.5
ENERGY STAR	Sí
Duración de los consumibles	Para más información sobre el rendimiento en páginas visite www.hp.com/go/learnaboutsupplies o vea el embalaje del producto
Garantía	Un año de garantía limitada estándar para el hardware. Las opciones de garantía y soporte varían según el producto, el país/región y los requisitos legales.

DIALUX OUTPUT FILES:

UGR RESULTS:

Local 1 / Observador UGR (sumario de resultados)



Escala 1 : 42

Lista de puntos de cálculo UGR

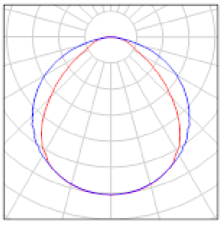
N°	Designación	Posición [m] X	Y	Z	Dirección visual [°]	Valor
1	Punto de cálculo UGR 2	1.000	0.700	1.200	90.0	19
2	Punto de cálculo UGR 3	2.700	1.800	1.200	180.0	19
3	Punto de cálculo UGR 4	2.800	0.300	1.200	90.0	17

BRAND AND MODEL OF THE LIGHTS:

Proyecto 1 / Lista de luminarias

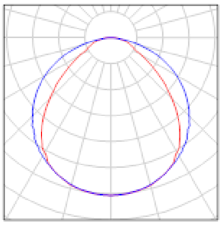
5 Pieza

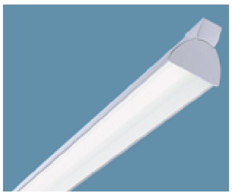
OSRAM GmbH 72581-10 Reflector for OSRAM ECOPACK® 18W
N° de artículo: 72581-10
Flujo luminoso de las luminarias: 1300 lm
Potencia de las luminarias: 20.0 W
Clasificación luminarias según CIE: 100
Código CIE Flux: 53 84 97 100 78
Armamento: 1 x L 18 W (T8) (Factor de corrección 1.000).

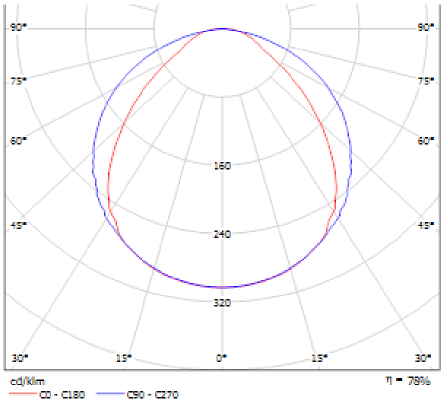


1 Pieza

OSRAM GmbH 72585-10 Reflector for OSRAM ECOPACK® 36W
N° de artículo: 72585-10
Flujo luminoso de las luminarias: 3200 lm
Potencia de las luminarias: 36.0 W
Clasificación luminarias según CIE: 100
Código CIE Flux: 53 84 97 100 78
Armamento: 1 x L 36 W (T8) (Factor de corrección 1.000).







Clasificación luminarias según CIE: 100
Código CIE Flux: 53 84 97 100 78

OSRAM ECOPACK® are general-purpose low-cost batten luminaires for 26 mm fluorescent lamps with ECG for continuous economical lighting.

OSRAM ECOPACK®
- Low-cost electronic batten luminaires for continuous economical lighting
- Free-burning lamp for maximum luminous flux
- With QUICKTRONIC® PROFESSIONAL electronic control gear
- With a white reflector (as accessory)

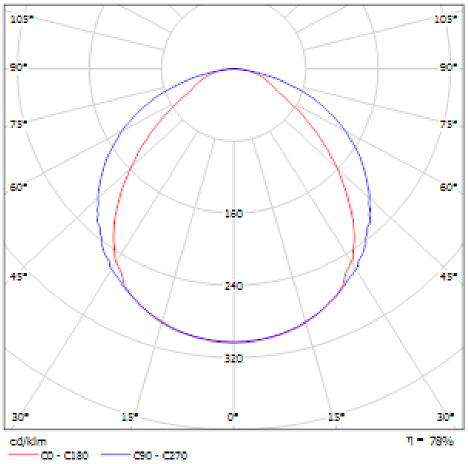
Technical data and equipment
- Supplied without lamps
- Mains voltage: 230-240 V/0, 50-60 Hz
- Protection class I
- IP20, F, MM, ENEC VDE
- Colour: white

Accessories

Emisión de luz 1:

Valoración de deslumbramiento según UGR

ρ Techo		70	70	50	50	30	70	70	50	50	30
ρ Paredes		50	30	50	30	30	50	30	50	30	30
ρ Suelo		20	20	20	20	20	20	20	20	20	20
Tamaño del local X	Y	Mirado en perpendicular al eje de lámpara					Mirado longitudinalmente al eje de lámpara				
2H	2H	17.8	19.0	18.1	19.2	19.5	20.0	21.2	20.3	21.4	21.7
	3H	18.5	19.7	18.8	19.9	20.2	21.5	22.6	21.8	22.9	23.1
	4H	18.9	20.0	19.2	20.2	20.5	22.1	23.1	22.4	23.4	23.7
	6H	19.3	20.3	19.6	20.6	20.9	22.4	23.4	22.8	23.7	24.0
	8H	19.5	20.4	19.8	20.7	21.0	22.5	23.4	22.8	23.7	24.1
	12H	19.6	20.5	20.0	20.8	21.2	22.5	23.4	22.8	23.7	24.0
4H	2H	18.4	19.4	18.7	19.7	20.0	20.2	21.3	20.5	21.5	21.8
	3H	19.3	20.2	19.7	20.5	20.8	21.9	22.8	22.2	23.1	23.4
	4H	19.8	20.6	20.2	20.9	21.3	22.6	23.4	23.0	23.7	24.1
	6H	20.3	21.0	20.7	21.4	21.8	23.1	23.8	23.5	24.1	24.5
	8H	20.5	21.2	21.0	21.6	22.0	23.1	23.8	23.6	24.2	24.6
	12H	20.7	21.3	21.2	21.7	22.1	23.2	23.7	23.6	24.1	24.6
8H	4H	20.1	20.7	20.5	21.1	21.5	22.7	23.3	23.1	23.7	24.1
	6H	20.7	21.2	21.2	21.7	22.1	23.2	23.7	23.7	24.2	24.6
	8H	21.0	21.5	21.5	21.9	22.4	23.3	23.8	23.8	24.2	24.7
	12H	21.3	21.7	21.8	22.2	22.7	23.4	23.8	23.9	24.2	24.7
12H	4H	20.1	20.7	20.5	21.1	21.5	22.6	23.2	23.1	23.6	24.1
	6H	20.6	21.2	21.3	21.7	22.2	23.2	23.7	23.7	24.1	24.6
	8H	21.2	21.5	21.6	22.0	22.5	23.4	23.8	23.9	24.2	24.7
Variación de la posición del espectador para separaciones S entre luminarias											
S = 1.0H		+0.2 / -0.3					+0.1 / -0.1				
S = 1.5H		+0.5 / -1.0					+0.2 / -0.3				
S = 2.0H		+1.0 / -1.5					+0.7 / -0.9				
Tabla estándar		BK04					BK05				
Sumando de		[illegible]					[illegible]				



Clasificación luminarias según CIE: 100
Código CIE Flux: 53 84 97 100 78

OSRAM ECOPACK® are general-purpose low-cost batten luminaires for 26 mm fluorescent lamps with ECG for continuous economical lighting.

OSRAM ECOPACK®
- Low-cost electronic batten luminaires for continuous economical lighting
- Free-burning lamp for maximum luminous flux
- With QUICKTRONIC® PROFESSIONAL electronic control gear
- With a white reflector (as accessory)

Technical data and equipment
- Supplied without lamps
- Mains voltage: 230-240 V/0, 50-60 Hz
- Protection class I
- IP20, F, MM, ENEC VDE

Emisión de luz 1:

Valoración de deslumbramiento según UGR

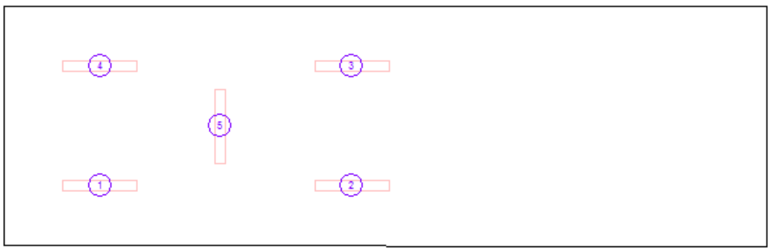
ρ Techo		70	70	50	50	30	70	70	50	50	30
ρ Paredes		50	30	50	30	30	50	30	50	30	30
ρ Suelo		20	20	20	20	20	20	20	20	20	20
Tamaño del local X	Y	Mirado en perpendicular al eje de lámpara					Mirado longitudinalmente al eje de lámpara				
2H	2H	17.0	18.3	17.3	18.5	18.7	19.2	20.5	19.5	20.7	20.9
	3H	17.8	18.9	18.1	19.2	19.4	20.8	21.9	21.1	22.1	22.4
	4H	18.2	19.2	18.5	19.5	19.8	21.3	22.4	21.7	22.7	23.0
	6H	18.5	19.5	18.9	19.8	20.1	21.7	22.7	22.1	23.0	23.3
	8H	18.7	19.7	19.1	20.0	20.3	21.7	22.7	22.1	23.0	23.3
	12H	18.9	19.8	19.2	20.1	20.4	21.7	22.8	22.1	22.9	23.3
4H	2H	17.8	18.7	18.0	19.0	19.3	19.5	20.5	19.8	20.8	21.1
	3H	18.5	19.4	18.9	19.8	20.1	21.1	22.0	21.5	22.3	22.7
	4H	19.0	19.8	19.4	20.2	20.5	21.9	22.8	22.2	23.0	23.3
	6H	19.6	20.2	20.0	20.6	21.0	22.3	23.0	22.7	23.4	23.8
	8H	19.8	20.4	20.2	20.8	21.2	22.4	23.0	22.8	23.4	23.8
	12H	20.0	20.6	20.4	21.0	21.4	22.4	23.0	22.9	23.4	23.8
8H	4H	19.3	20.0	19.8	20.3	20.8	21.9	22.5	22.3	22.9	23.3
	6H	20.0	20.5	20.4	20.9	21.4	22.5	23.0	22.9	23.4	23.9
	8H	20.3	20.7	20.8	21.2	21.7	22.6	23.0	23.1	23.5	24.0
	12H	20.6	21.0	21.1	21.5	22.0	22.6	23.0	23.1	23.5	24.0
12H	4H	19.4	19.9	19.8	20.3	20.8	21.9	22.5	22.3	22.9	23.3
	6H	20.0	20.5	20.5	20.9	21.4	22.5	22.9	23.0	23.4	23.9
	8H	20.4	20.8	20.9	21.3	21.8	22.6	23.0	23.1	23.5	24.0

Variación de la posición del espectador para separaciones S entre luminarias

COORDENATES AND UBICATION OF THE LIGHTS

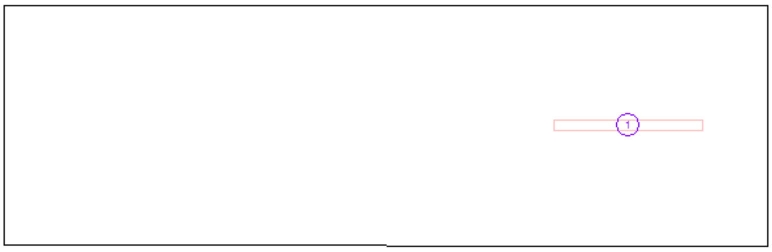
Local 1 / Luminarias (lista de coordenadas)

OSRAM GmbH 72581-10 Reflector for OSRAM ECOPACK® 18W
1300 lm, 20.0 W, 1 x 1 x L 18 W (T8) (Factor de corrección 1.000).



Nº	Posición [m] X	Y	Z	Rotación [°] X	Y	Z
1	0.800	0.500	1.940	0.0	0.0	90.0
2	2.900	0.500	1.940	0.0	0.0	90.0
3	2.900	1.500	1.940	0.0	0.0	90.0
4	0.800	1.500	1.940	0.0	0.0	90.0
5	1.800	1.000	1.940	0.0	0.0	0.0

OSRAM GmbH 72585-10 Reflector for OSRAM ECOPACK® 36W
3200 lm, 36.0 W, 1 x 1 x L 36 W (T8) (Factor de corrección 1.000).



N°	Posición [m]			Rotación [°]		
	X	Y	Z	X	Y	Z
1	5.200	1.000	1.940	0.0	0.0	90.0

APPENDIX B

MOBILE UNIT SEEN IN FEUP, OWNED BY A OPTICIAN'S SHOP:



APPENDIX C

DETAILED FEASIBILITY ANALYSIS:

		Year	0	1	2	3	4	5	6	7	8	9	10
Expenses													
	Toyota Coaster		**7000**										
	Transformation		**11000**										
	Benefit		**25000**										
	Medical equipment and office		**22900**										
	Autorefractometer		*5000*										
	Tonometer		*2000*										
	Slit lamp		*6000*										
	Phoropter:		*3000*										
	Optotype projector:		*800*										
	Refraction lens analyzer		*2000*										
	Retinoscope		*1500*										
	Ophthalmoscope		*1500*										
	Three mirror lens or superfiela		*200*										
	Computer, screen and printer		*900*										
	Fridge		**600**										
	Diesel generator (x2)		**2400**										
	Photovoltaic system		**8635**										
	Solar panels		*6000*										
	Batteries		*1400*										
	Inverter		*935*										
	Others		*300*										

Expenses	Disposable Oftalmological Material											
	Gloves		300,0	306,0	312,1	318,4	324,7	331,2	337,8	344,6	351,5	358,5
	Alcohol		51,0	52,0	53,1	54,1	55,2	56,3	57,4	58,6	59,8	60,9
	Eye drops		468,0	477,4	486,9	496,6	506,6	516,7	527,0	537,6	548,3	559,3
	Napkins		70,0	71,4	72,8	74,3	75,8	77,3	78,8	80,4	82,0	83,7
	Antiseptic soap		100,0	102,0	104,0	106,1	108,2	110,4	112,6	114,9	117,2	119,5
	Others		100,0	102,0	104,0	106,1	108,2	110,4	112,6	114,9	117,2	119,5
	generator fuel cost (x2)		3458,0	3527,2	3597,7	3669,7	3743,1	3817,9	3894,3	3972,2	4051,6	4132,6
	O&M											
	Oftalmological O&M		500,0	510,0	520,2	530,6	541,2	552,0	563,1	574,3	585,8	597,5
	Photovoltaic system O&M		*200,0*	204,0	208,1	212,2	216,5	220,8	225,2	229,7	234,3	239,0
	Human Resources											
	Doctor		50000,0	51000,0	52020,0	53060,4	54121,6	55204,0	56308,1	57434,3	58583,0	59754,6
	Nurse		10000,0	10200,0	10404,0	10612,1	10824,3	11040,8	11261,6	11486,9	11716,6	11950,9
	Ophtalmological Technician		10000,0	10200,0	10404,0	10612,1	10824,3	11040,8	11261,6	11486,9	11716,6	11950,9

		Year	0	1	2	3	4	5	6	7	8	9	10
Incomes													
	"Taxas moderadoras"			39116,0	39898,3	40696,3	41510,2	42340,4	43187,2	44051,0	44932,0	45830,6	46747,2
	Fuel generator cost saving			1765,0	1800,3	1836,3	1873,0	1910,5	1948,7	1987,7	2027,4	2068,0	2109,3
Total expenses			77535	75247,0	76751,9	78287,0	79852,7	81449,8	83078,8	84740,3	86435,2	88163,9	89927,1
Total incomes				40881,0	41698,6	42532,6	43383,2	44250,9	45135,9	46038,6	46959,4	47898,6	48856,6

		Year	0	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
Cash flow (€)			-77535	-34366,0	-35053,3	-35754,4	-36469,5	-37198,9	-37942,8	-38701,7	-39475,7	-40265,2	-41070,6
Accum Cash flow (€)			-77535	-111901,0	-146954,3	-182708,7	-219178,2	-256377,0	-294319,9	-333021,6	-372497,3	-412762,6	-453833,1

Assumptions	
RPI	2%

taxas moderadoras	Mean price	Percentual	patients x day	month	year	incomes
Consultancy	5€/patient	85%	23,8	476	5236	26180
Emergencies	14 €	15%	4,2	84	924	12936
					total €	**39116**
Mobile unit cost(€)	52535					
Benefit (€)	25000					
total (€)	**77535**					

"TAXAS MODERADORAS" DESCRIPTION:

MINISTÉRIO DA SAÚDE

Portaria n.º 34/2009

de 15 de Janeiro

O n.º 2 do artigo 1.º do Decreto-Lei n.º 173/2003, de 1 de Agosto, alterado pelos Decretos-Leis n.os 201/2007, de 24 de Maio, e 79/2008, de 8 de Maio, determina que o valor das taxas moderadoras é aprovado por portaria do Ministro da Saúde, sendo revisto e actualizado anualmente tendo em conta, nomeadamente, o índice de inflação.

As taxas moderadoras aprovadas pela Portaria n.º 395-A/2007, de 30 de Março, encontram-se desactualizadas quer quanto ao valor quer quanto à tipologia dos actos, pelo que se torna necessário proceder à sua revisão.

Assim:

Ao abrigo do disposto no n.º 2 do artigo 1.º do Decreto-Lei n.º 173/2003, de 1 de Agosto, e no artigo 148.º da Lei n.º 53-A/2006, de 29 de Dezembro:

Manda o Governo, pela Ministra da Saúde, o seguinte:

1.º As taxas moderadoras constantes da tabela anexa à Portaria n.º 395-A/2007, de 30 de Março, são actualizadas nos termos da tabela anexa à presente portaria.

2.º A presente portaria produz efeitos desde o 1.º dia do mês seguinte ao da sua publicação.

Pela Ministra da Saúde, *Francisco Ventura Ramos,* Secretário de Estado Adjunto e da Saúde, em 8 de Janeiro de 2009.

Oftalmologia:	
Terapia fotodinâmica macular	7,50
Queratomileusis	5,50
Fotoqueratotomia refractiva ou terapêutica	5,50
Angiografia oftalmológica	11,50
Fluorofotometria do segmento anterior ou posterior	5,50
Laser.	9,10
Exames electrofisiológicos	6,90
Contactologia	5,50
Exame oftalmológico completo sob anestesia geral	5,50
Subvisão.	5,50
Ecografia oftálmica/biometria	4,30
Campimetria.	3,50
Queratometria	3,10
Sondagem das vias lacrimais ou extracção de corpo estranho ocular	1,50

Código	Designação	Taxa moderadora (euros)
184	Gonioscopia	1,10
185	Tratamento de ortóptica ou pleóptica.	1,10
186	Oftalmoscopia e oftalmodinamometria . . .	1,10
187	Outros exames oftalmológicos.	3,50

APPENDIX D

TOYOTA COASTER CHARACTERISTICS:

(A) Número de matrícula
SQ-42-66 1

(B) Data da primeira matrícula do veículo
XXXX

(B.1) Matrícula anterior
XXXX

(D.1) Marca
TOYOTA

(D.2) Modelo, variante e versão
COASTER BB32L-MD
XXXX

(D.3) Denominações comerciais
XXXX

(E) Número de quadro
BB32-0000187

(F.1) Peso bruto
XXXX

(F.2) Peso bruto em circulação nacional
006600

(F.3) Peso bruto do conjunto em circulação nacional
XXXX

(G) Tara/Peso em vazio
04100

(H) Validade da matrícula (caso não seja ilimitada)
XXXX

(I) Data da matrícula a que se refere o certificado
1992-01-14

(K) Número de homologação do modelo
XXXX

(K.1) Homologação nacional
19841300107100001

(P.1) Cilindrada (cm³)
03660

(P.2) Potência útil máxima (em kW)
75.0

(P.3) Tipo de combustível ou fonte de energia
GASOLEO

(P.4) Regime nominal (em min-1)
3400

(Q) Relação potência/peso (kW/kg)
XXXX

(S.1) Número de lugares sentados (incluindo condutor)
028

(S.2) Número de lugares em pé
XXXX

(J) Categoria do veículo
XXXX

(J.2) Tipo de veículo
PASSAGEIROS

(M) Distância entre eixos (mm)
3800

(N.1) (N.2) (N.3) (N.4) (N.5) Peso máximo admissível
02900; 04100

(O.1) Peso bruto rebocável c/ travão (em kg)
XXXX

(R) Cor do veículo
CINZENTO E OUTRAS

(U.1) Nível sonoro estacionário (dB(A))
XXXX

(V.1) Gases de escape - CO (em g/km ou g/kWh)
XXXX

(V.5) Partículas (em g/km ou g/kWh)
XXXX

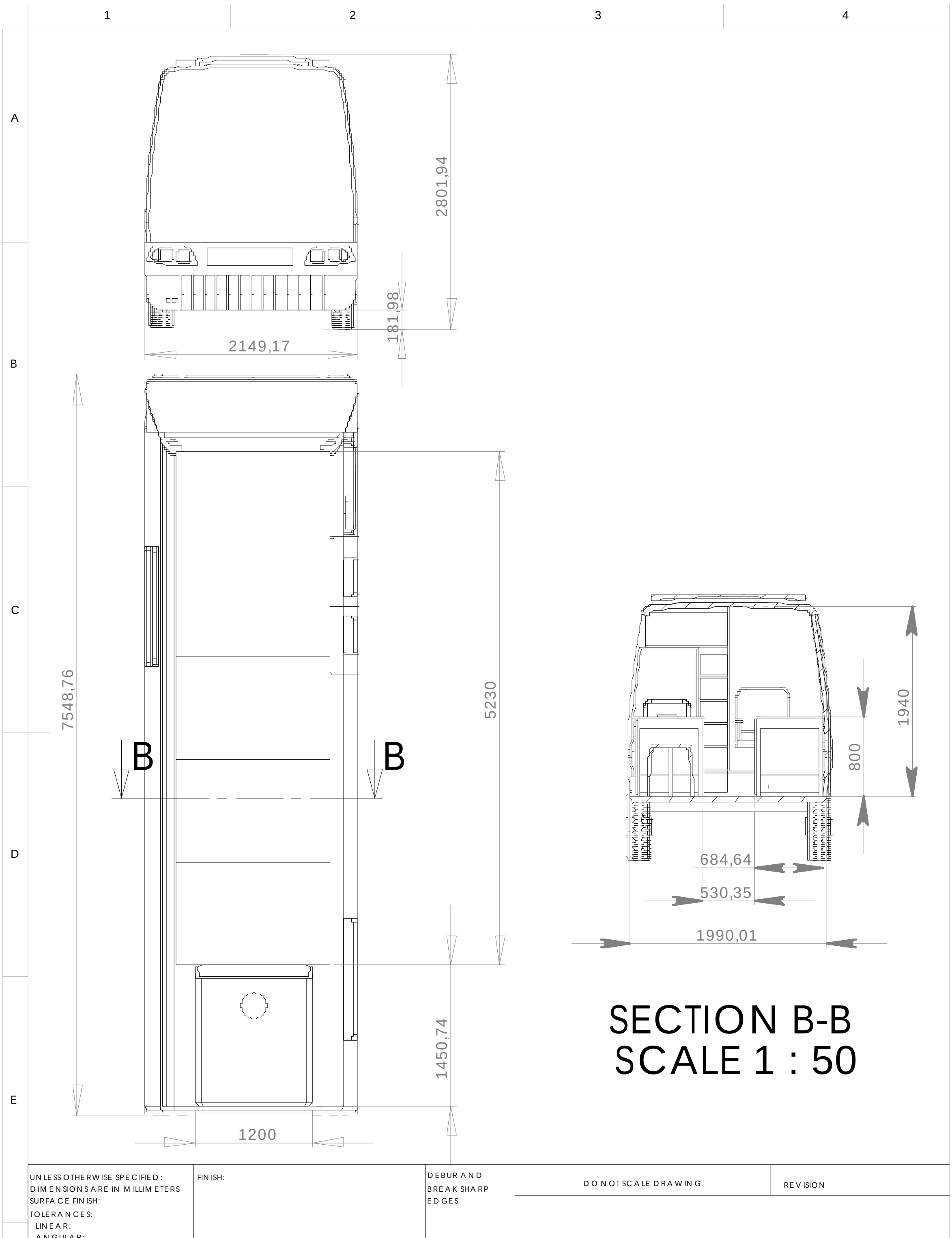
(X.1) Pneumáticos à frente
700-16

(Z.1) Comprimento máximo da caixa de carga
XXXX

(Z.3) Anotações especiais
XXXX
XXXX
XXXX

Dimensões

Comprimento total	mm	7300
Largura total	mm	2200
Altura total	mm	2800
Distância entre eixos	mm	3800
Largura do eixo da frente (via dianteira)	mm	1645
Largura do eixo traseiro (via de trás)	mm	1500
Distância ao solo	mm	430

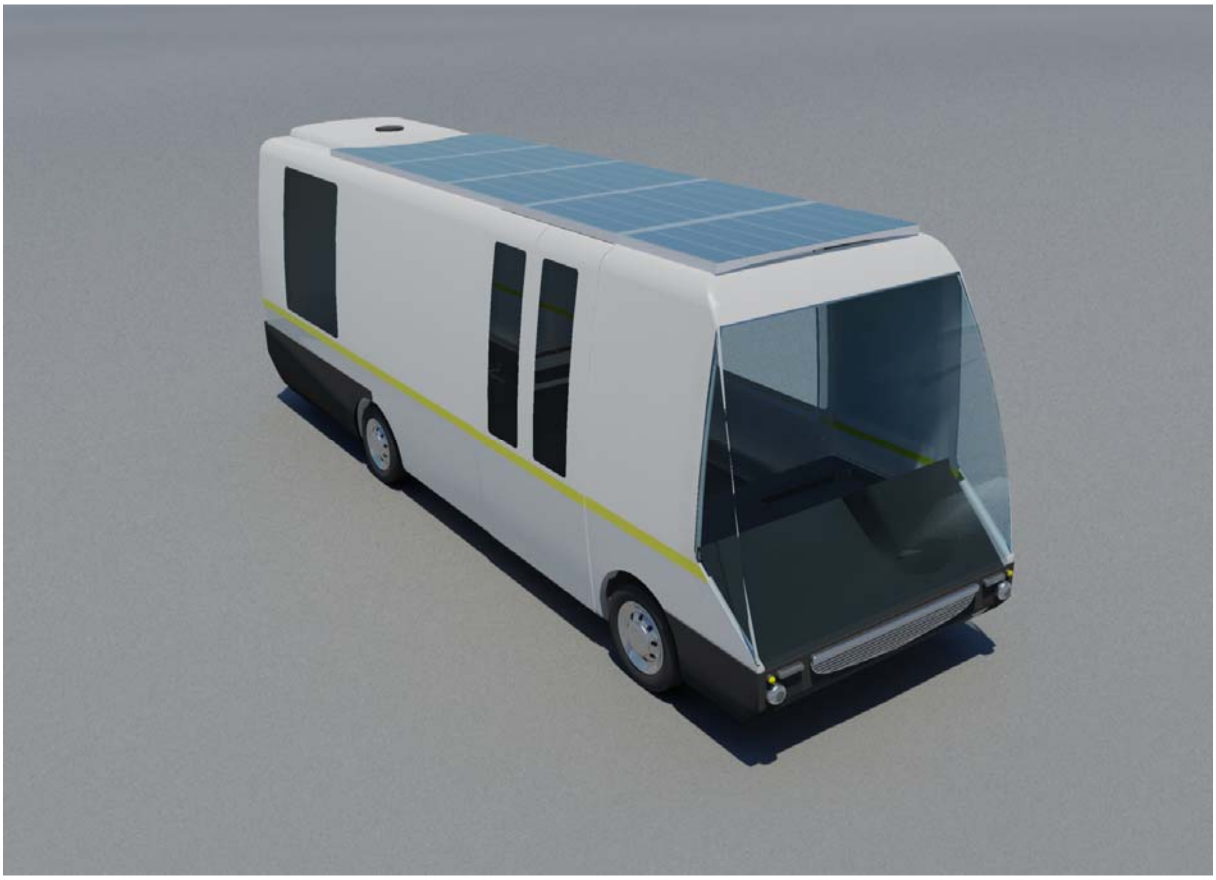


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION			
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. Vistes Assem 10	A4
				WEIGHT:		SCALE:1:100	SHEET 1 OF 1

F

APPENDIX E

OTHER RENDERS




ophthalmological
mobile unit
HOSPITAL
S. JOSÉ


ophthalmological
mobile unit


phthalmological
mobile unit
HOSPITAL
S. JOSÉ


HOSPITAL
S. JOSÉ
ophthalmological
mobile unit