The General Jonas Žemaitis Military Academy of Lithuania
Department of Engineering Management

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COATING OF VEHICLES – EFFECTIVENESS ANALYSIS OF A MILITARY-OWNED COATING-WORKSHOP

Final bachelor‘s thesis
Title of the study programme: Management of Modern Defence Technologies
Study area: Social Sciences

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Vilnius, 2016

Generolo Jono Žemaičio Lietuvos karo akademija
Inžinerinės vadybos katedra

OVIDIJUS KUZMINAS

TRANSPORTO PRIEMONIŲ DAŽYMAS – KARIUOMENĖS DAŽYMO CECHO EFEKTYVUMO ANALIZĖ

Bakalauro baigiamasis darbas
Studijų programa: Moderniųjų gynybos technologijų vadyba
Studijų kryptis: Socialiniai mokslai

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2016-01-…

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2016-01-…

Darbas skaitmenine forma priimtas

2016-01-…

Darbą parengė

122 būrio kariūnas

Ovidijus Kuzminas

2016-01-…

Vilnius, 2016

Generolo Jono Žemaičio Lietuvos karo akademija
Inžinerinės vadybos katedra

Ovidijus Kuzminas
(Studijuojančiojo vardas ir pavardė)

Moderniųjų gynybos technologijų vadyba
(Studijų programa)

BAIGIAMOJO DARBO (PROJEKTO) SĄŽININGUMO IR ATITIKTIES DEKLARACIJA

2016-01-
(Data)

Patvirtinu, kad parengtas baigiamasis darbas (projektas) tema „Transporto priemonių dažymas – kariuomenės dažymo cecho efektyvumo analizė“,
patvirtinta 2016 metų sausio __ d. Akademijos viršininko įsakymu Nr. _____,
yra parengtas savarankiškai ir niekada nebuvo pateiktas atsiskaityti LKA arba kitoje mokslo ar mokymo institucijoje.

Šiame darbe (projekte) pateikta medžiaga nėra plagijuota. Visi šiame darbe panaudoti informacijos šaltiniai yra cituojami bei įtraukti į literatūros sąrašą.

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Renkant bei įvertinant medžiagą ir rengiant baigiamąjį darbą (projektą) mane konsultavo mokslininkai ir specialistai: Evaldas Pakalnis, Kent Andersson, Peter Jutfjord, Laimutis Vaičys, Daugirdas Antulis.

Darbo (projekto) vadovas _____ prof.dr. Aušrius Juozapavičius
(parašas)

☐ Darbas atitinka keliamus kvalifikacinius reikalavimus ir gali būti ginamas

☐ Darbas negali būti ginamas. Priežastys:

Darbo autorius _____ _____
(parašas) (vardas ir pavardė, įrašyti ranka)

Kuzminas, O. (2015). Transporto priemonių dažymas – kariuomenės dažymo cecho efektyvumo analizė / Socialinių mokslų bakalauro baigiamasis darbas. Vadovas prof.dr. A. Juozapavičius. Vilnius: Generolo Jono Žemaičio Lietuvos karo akademija, Inžinerinės vadybos katedra.

SANTRAUKA

Lietuvos kariuomenės doktrina numato dalį operacijų miškingose vietovėse, kur būtina išlaikyti netikėtumo faktorių ir tai lengviausiai pasiekiama maskuojantis. Tam pritaikyta tiek kario apranga, tiek didžioji dalis ekipuotės, tačiau iki šiol technika būdavo tos spalvos, kurios ji originaliai nupirkta iš tiekėjo.

Papildoma nauda dažant moderniomis technologijomis yra ta, kad paviršiai yra papildomai apsaugoti nuo korozijos ir tai suteikia ilgaamžiškumo pačiai technikai. Negana to, amerikiečiai yra sukūrę technologiją, kuri padengia paviršių specifine medžiaga, kuri apsaugo net nuo cheminio ir bakteriologinio ginklo.

2015 metų pabaigoje Lietuvos kariuomenė perėmė pirmąsias dažymo dirbtuves, kurių tikslas yra padengti technikos paviršius taip, kad tai atitiktų kariuomenės transportui keliamus reikalavimus, t.y. būtų maskuojančių spalvų ir suteikti antikorozinių sąvybių, kas gali prailginti eksploatacinį transporto priemonės laiką.

Kadangi šis dažymo cechas yra naujas ir tik ką pradėjęs savo veiklą, gali pasitaikyti spragų tiek vadybiniuose cecho procesuose, tiek dažymo technologijų naudojime, tiek ekonominiame planavime.

Pagrindiniai darbo uždaviniai - atliekant praktiką susipažinti su Švedijos kariuomenės dažymo dirbtuvių struktūra, darbo apimtimis ir ekonominiais rodikliais bei palyginant įvertinti Lietuvos cecho galimybes ir pritaikomumą Lietuvos kariuomenės turimiems dažymo poreikiams, nes yra tikimybė, kad cechas yra nepakankamų pajėgumų ar net atvirkščiai, juos gerokai viršija. Taip pat, ekonominiai rodikliai leis palyginti ar šis projektas yra naudingas Lietuvos kariuomenei ir ar ši paslauga negalėjo būti perkama iš civilinių įstaigų už mažesnę kainą.

Tiriant santykį tarp darbo apimčių ir dažyklos galimybių buvo remiamasi Švedų kariuomenės patirtimis ir palygintos metinės dažymo apimtys tenkančios vienai dažymo kamerai. Galiausiai buvo atmesta hipotezė, kad dažyklos galimybės stipriai viršija darbo apimtis.

Ekonominė analizė atskleidė projekto atsiperkamumo laikotarpį, kuris tėra vos pusketvirtų metų ir leido palyginti dažymo kainas, kai transporto priemonė dažoma savoje dažykloje ir kai tai atlieka privačios įmonės. Dažymo kainų skirtumas pagrindžia teisingą Lietuvos kariuomenės pasirinkimą: savoje dažykloje proceso vertė yra tris kartus mažesnė nei tos pačios paslaugos pirkimas iš civilinių įmonių.

Naudojantis daugiakriterinių sprendimų priėmimo metodu ir remiantis specialistų nuomone buvo sukurta idealios dažyklos, kuri reikalinga kariuomenei, koncepcija. Deja, kariuomenės turima dažykla su esamomis darbo apimtimis ir naudojamomis technologijomis galutiniame vertinime buvo įvardinta kaip mažiausiai atitinkanti lūkesčius.

Kuzminas, O. (2015). Coating of vehicles – effectiveness analysis of a military-owned coating-workshop / Final bachelor‘s thesis in Social sciences. Supervisor prof. dr. A. Juozapavičius. Vilnius: Department of Engineering Management, The General Jonas Žemaitis Military Academy of Lithuania.

SUMMARY

According to the doctrine of Lithuanian armed forces there are some operations that have to be conducted in the wooded terrain where it is really important to maintain the factor of surprise and is easily achieved by camouflage. Because of that military battle dress uniforms and the bigger part of military equipment is camouflaged originally. However, to this day vehicles came from the suppliers in various colours and not all of them meet the tactical requirements.

Modern coating technologies could prevent surfaces from corrosion and they increase the lifetime of the vehicles. Moreover, Americans have created techniques, which help to protect technique from the chemical and biological agents as well.

In the late 2015s Lithuanian armed forces bought the first coating-workshop used for the military purposes. The aim is to coat vehicles’ surfaces considering the military transport usage demands, e.g. spraying in camouflage colours or adding additional anti-corrosion layers that could increase vehicles’ lifecycle.

Because of the fact that this project is new for our military, it could be that there are some challenges in the management processes, in painting processes and even in the economical planning.

The main tasks of this work are to become familiar with Swedish military coating-workshop’s structure, workload and economical indicators during the author’s traineeship there. Moreover, to evaluate Lithuanian military workshop’s capabilities and adaptability in terms of Swedish experience. There is a possibility that coating-workshop does not fit the necessities or, what would be even worse, it outweighs the painting amounts. What is more, economical indicators might give opportunity to compare if this project is relevant for Lithuanian armed forces or e.g. outsourcing painting service from civilian institutions is even better.

The research of ratio between paint shop‘s capabilities and painting amounts was based on Swedish armed forces experience. Annual painting amounts per spray booth were compared and the final

result shows that the ratio is comparable to optimal and so the hypothesis that capabilities overweigh painting amounts could be rejected.

Economic analysis has shown the project‘s payback period which is about 3,5 years. Moreover, it helped to compare the costs per vehicle when painting in the own paint shop and when the service is outsourced. The difference was enormous: own workshop provides 3 times smaller cost per vehicle.

Multi-criteria decision analysis (MCDA) was accomplished with the specialists’ opinion and it gave opportunity to create the concept for the requirements of the military-owned workshop. Unfortunately, the existing paint shop with the current scope and technologies was identified as the worst option after the final computations.

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INTRODUCTION

Through the ages soldiers wanted to increase their survivability on the battlefield. From WWII military forces started camouflaging not only themselves but the technique as well. It helped to sustain undercover, especially, during the aerial observation and prevented damage from air strikes. In the 21st century vehicles' coating is not only camouflaging but also protecting surfaces from corrosion and even the crew from chemical and biological agents.

In 2015 Chief of Defence of the Republic of Lithuania declared that without support of NATO allies Lithuania has to be able to withstand any aggressive force for a month on its own. Using mobility and guerrilla warfare tactics it could possibly be done even against larger number of troops. From this perspective, Lithuanian armed forces have to be well camouflaged, especially in wooded terrain which is common across Lithuania.

Camouflaging could be one of the main reason why there is a necessity to have a coating-workshop for military purposes in Kaunas. Coating military transport could help to successfully perform land operations and prevent losses not only by merging with the terrain but by having lower visibility with other vision devices (e.g. night vision goggles or thermo visors).

On the other hand, even such strong countries as United States outsource coating service from civilian institutions while Lithuanian armed forces want to invest into this large project. There is a possibility that having own workshop is not the most efficient way financially because of the insufficient of armament and military transport.

In this work it will be discussed how coating-workshop works, what kind of technologies are used, how management processes are planned and the necessity of this workshop will be assessed. Moreover, coating system in the military of Lithuania will be compared with Swedish experience. Finally, this project will be analysed from economic perspective by its benefit and payback to defence system of Lithuania because finances in this case is definitely one of the highest priority factors.

Thesis relevance: coating infrastructure in the armed forces of Lithuania is a new project that is still not analyzed well. Moreover, there is a hypothesis that this coating unit is redundant because all the services could be outsourced from the civilian institutions. This research object is suggested by the Commander of Logistics of Lithuanian armed forces.

Thesis problem is a potentially unbalanced ratio between the painting demand in the Lithuanian armed forces and the capabilities of painting workshop which could be determined in terms of Swedish military painting capabilities.

The research object of thesis is a coating-workshop activity (owned and controlled by Depot Storage Service of Lithuanian armed forces).

Thesis' aim is analysis of coating facility's efficiency in the national defence system of Lithuania.

Thesis objectives:

1. To introduce the necessity of the coating-workshop for the armed forces;
2. To become familiar with the coating techniques used in the workshop;
3. To explore the management processes in the military coating-workshop;
4. To analyze economic efficiency of the military-owned coating-workshop;
5. To analyze the painting demand and capabilities in Lithuanian armed forces;
6. To compare experience of Swedish and Lithuanian armed forces in military coating processes;
7. To provide recommendations related to the coating-workshop for higher efficiency rate.

Methods of the research:

- Literature analysis (project's documentation, nonfiction literature and articles);
- Economic analysis (financial efficiency of the project, it's payback);
- Comparative analysis (Swedish and Lithuanian experience in the coating techniques and management processes);
- Multi-decision criteria analysis (comparison of best-suitable painting variant for Lithuanian armed forces);
- Interviews.

ABBREVIATONS

AM – amplitude modulation

APC – armoured personnel carrier

ATTP – Army Tactics, Techniques, and Procedures

CARC – chemical agent resistance coating

CCD – camouflage, concealment, deception

ED – electrodeposition

EM – electromagnetic

EPA – Environmental Protection Agency

FLIRS – forward-looking infrared system

FM – Field Manual

FM – frequency modulation

FSD – Swedish defence standard

HF – high frequency

IFV – infantry fighting vehicle

IR – infrared

ISAF – International Security Assistance Force

MCDA – multi-criteria decision analysis

NATO – North Atlantic Trade Organization

NIR – near-infrared

NVDs – night vision devices

STANAG – standardization agreement in NATO

TV – television

U.S. – United States

UAV – unmanned aerial vehicle

USD – U.S. Dollars

UV – ultraviolet

VOC – volatile organic component

WMD – weapon of mass destruction

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1. COATING OF WEAPONS AND MILITARY EQUIPMENT

1. 1. COATING DEMAND

In this subchapter the necessity of transport coating is discussed. As every soldier camouflages himself or herself with the reference to the terrain, every vehicle has to be inconspicuous as well. It could not be reached without knowledge of applying recognition factors, possible enemy's sensor systems or various CCD ways. Moreover, camouflaging is not the only one objective of painting vehicles in the military: there are corrosion prevention and chemical agent resistance as well.

1. 1. 1. Camouflaging

Most of the people understand camouflaging as very narrow process used by the soldiers to paint their faces with woodland colours. The definition given by Oxford Dictionary (Oxford Dictionary) is much wider because camouflaging as well includes disguising of any activity which could reveal the position of the unit or oneself, leaving no footprints or new tracks, smoke, light and sound control or even taking the trash after leaving the patrol base. According to the specialists (Politzer) sight is our dominant sense and especially in the daylight people would rather trust their eyes than any other sense. Because of that the primary camouflaging objective has to be concealing and misleading the sight sense. However, IR and UV footprints also could be reduced. More information on the camouflaging demand and where it comes from could be found in Appendix 1.

1. 1. 2. Anti-Corrosion

All the vehicles have metal parts on the surface that could be affected by corrosion. This process is known for everybody as rusting of the metals but its scientific definition given by DIN EN ISO 8044 is: "Corrosion is the reaction of a metallic material to its environment, which effects measurable change in the material and can lead to impairment of the function of a metal construction part or of an entire system. In most cases this reaction is of an electro-chemical nature; but sometimes it can be also be of a chemical or metal-physical nature"(Lederer online).

Primary coating objective could be split between camouflaging and corrosion because camouflaging increases survivability and anti-corrosion coatings increase the lifetime of the vehicles' exploitation. There are many ways how to prevent corrosion on the surfaces that are presented in the Figure 1.

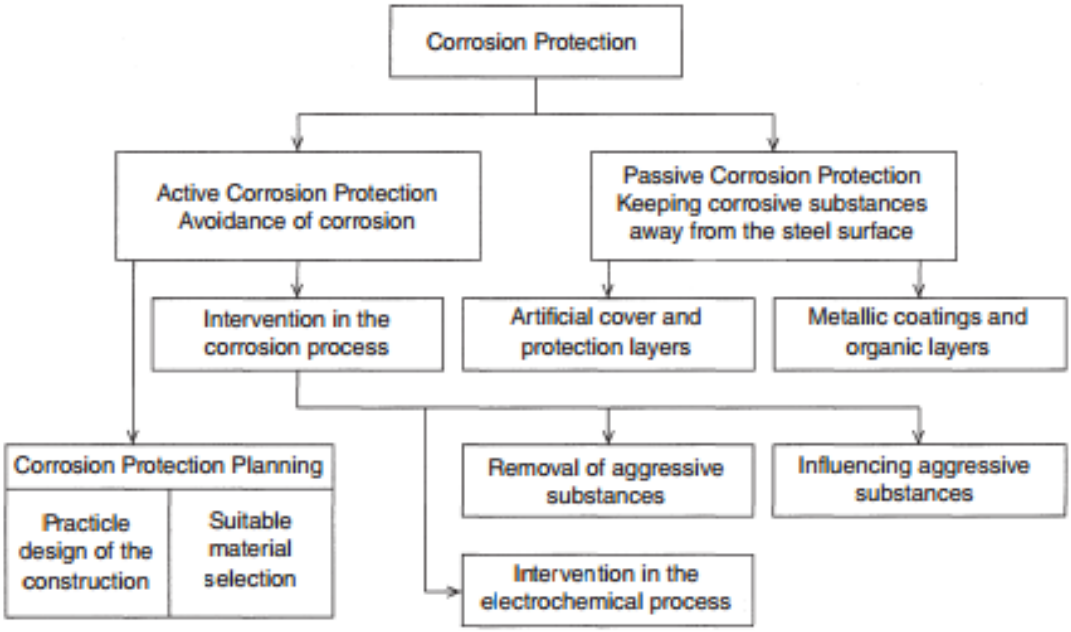

Figure 1. Methods, measures, and procedures of corrosion protection (Maab, p. 8)

Passive corrosion protection measures include variety of coating techniques. Some of them achieved by painting, others by coatings with anti-corrosion metals or organic layers. However, coating is only a preventive measure that could not be applied if the surface is already rusted.

To sum up, corrosion could be controlled but counter measures have to be used, nevertheless, they are quite expensive. Having spraying or any other coating technique against rusting in the coating workshop could increase its scope of operations and provide multi-functionality for the paint shop (Wright).

1. 1. 3. Protection against Chemical and Biological Agents

Additional painting objective could be counter measures against chemical and biological warfare that protects vehicle and especially the crew. In the WWI chemical WMDs played a major role and from that time soldiers are trained to detect them and protect themselves. Even in the transport soldiers could not feel safe because vehicles' surface is able to gather toxic materials meanings that even in the safe zone crew could be poisoned just after opening the doors or any hatch.

According to the medics, chemical warfare agents are chemical substances (in different states of aggregation) that used against the enemy lead to injuries or even death (D.M.G. Fernando and L.B.L. De Alwis, p. 5). The particular issue here is amount of the chemical substance because the most popular chemical agents are used as gases (some of them do not have any smell) and could even kill in the extremely small quantities (Phosgene) (Chlorine) (Chloropicrin) (Tabun) (Sarin).

Biological agents have the same goals but the chemical agents are changed to the microorganisms which are used for transporting pathogens, toxins, bioregulators, and prions (US Army Training and Doctrine Command, 2005, p. 23). Viruses and bacteria are the most common biological WMD and it is nearly impossible to detect them without special equipment. They are not quick-active as chemical agents but still cause death in short periods of time: e.g. Anthrax disease (Anthrax) or Plague (Berezow, 2015). Moreover, some of them do not have any cure: e.g. Nipah virus (Tenenbaum, 2013) or Ebola (Ebola virus treatment).

Coating used against these agents is called chemical agent resistance coating (CARC) and it gives protection not only from chemical and biological agents but from any liquids as well. Moreover, when the surface is coated it has lower IR footprint (Olive Drab). This technology will be introduced in more detailed way in the section 1. 2. 2. 2.

1. 2. COATING TECHNOLOGICAL FEATURES

Technologically coating is a versatile process which requires deep knowledge of the specific coated surface, its preparation, and coating technique which is the most efficient in every different case. While in the military coating is used for camouflaging, anti-corrosion and protection against WMD agents, in the civilian automotive industry it is used to reduce the impact of degrading environmental effects (M. Mohseni, H. Yari, B. Ramezanzadeh, p. 21). In this chapter, author represents the basic principles of coating and the most common painting techniques.

1. 2. 1. Coating Stages

Coating steps depend on the multilayer system which is the basis of using any coating technique. Coating stages are applied one after another and create multiple layers, where every single layer is responsible for the specific function. Schematic view of multilayer system is provided in the Figure 2. Basically, it represents that there are two functions: visual (colour) and protection (against corrosion, mechanical impact or weather) and with the basic understanding of layering, it is possible to explore the stages of coating process (M. Mohseni, H. Yari, B. Ramezanzadeh, pp. 21-22).

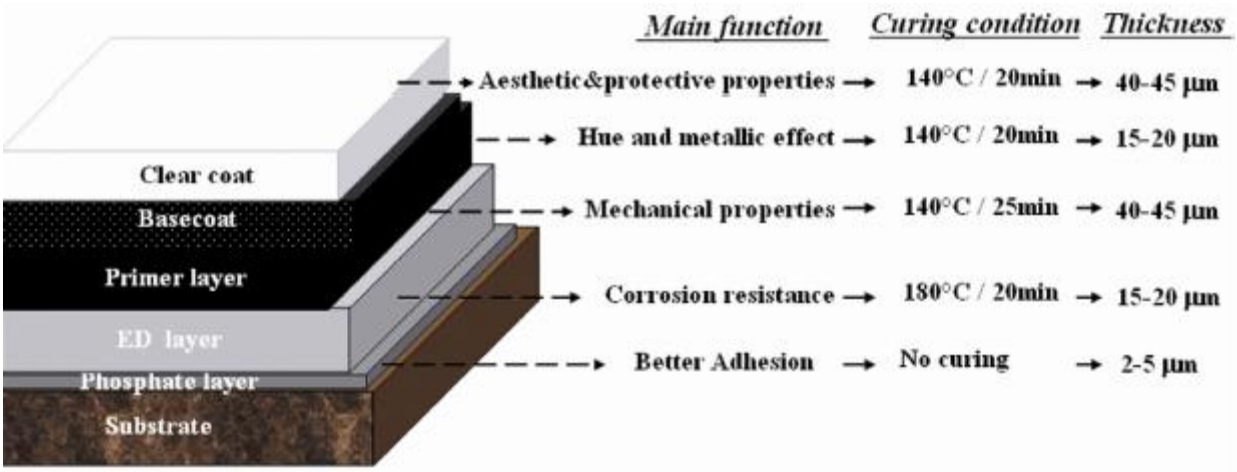

Figure 2. Specifications of a multilayer automotive coating (M. Mohseni, H. Yari, B. Ramezanzadeh, p. 22)

This difficult coating process could be divided into the smallest steps. However, to get the main idea it is not difficult to provide phases in a structured way (based on the layers distribution showed in Figure 2):

1. **Surface preparation**. The surface's preparation starts with the pre-cleaning procedure of old coating layers because if it is not cleaned, it might cause rapid peeling, cracking, and scaling. After that, surface is cleaned with the detergent or solvent (A. S. Savich, V. P. Ivanov, V. K. Yaroshevich, 2009, p. 173). Moreover, every piece of dirt, rust, scaling paint has to be removed. After the complete cleaning procedure, sanding is recommended because it increases the lifetime of new painting. At the very last, all the extraneous surfaces (glass, external technological devices, etc.) have to be covered with paper or masking tape (HQ, Department of the Army, 1991, p. 36).
2. **Undercoat application** covers all the layers from phosphate to the primer. While surface preparation is almost the same every time, undercoat applications differ depending on the surface characteristics, topcoat application, and conditions. It is possible to separate these undercoat layering types: fillers and primers. In general: primers are applied firstly and then curing procedure has to be conducted. Afterwards, fillers should be applied which also requires curing (A. S. Savich, V. P. Ivanov, V. K. Yaroshevich, 2009, p. 173). E.g. if the bare metal is being coated, epoxy primer should be applied in advance. Examples of military used undercoat substances provided in the Table 1 (HQ, Department of the Army, 2008, pp. 29-38).

Table 1. Military undercoat substances

Type	Technique	Purpose
Fillers	Applying sealing compound, adhesive	Preparation of wooden or metal surfaces for the topcoat, as a conjunction with the topcoat
Primers	Applying epoxy coating	Providing corrosion-resistant coating, moreover, it gives firmly adhere with the topcoat

3. **Topcoat application** consists of clear coat and basecoat. Finishing systems are applied for metal and wooden surfaces to protect them from the external factors (resistance to cleaning, weather, oil, fumes, etc.). Additional function is colour which creates the appearance and in terms of survivability it camouflages the vehicle. There are several layers used to fulfil the topcoat's function because there is no single material which could meet all the requirements at once. Really important thing is curing of every single layer and as it is shown in Figure 2 the right conditions could not be created without special equipment, which is described in Appendix 2. Before and after the topcoat application, surface's enamelling is recommended (A. S. Savich, V. P. Ivanov, V. K. Yaroshevich, 2009, p. 173).

1. 2. 2. Techniques

This subchapter introduces the reader with common coating techniques used in layering system and especially those that are used in the military. Variety of coating techniques is the reason why coating is so miscellaneous, e.g. the best-known spraying differs from electro coating in the applying process as day and night but still all of the techniques work for the same functions: visual appearance and protection. However, without applying several layers one after another, it is impossible to fully complete vehicles' coating, i.e. spraying is useless if the undercoat is not applied in advance. Some of the techniques and necessary equipment are described in Appendix 2.

1. 2. 2. 1. Spraying

Spraying (or injection) is the most common technique in the private sector. It requires lots of meticulous work because people have to use spraying guns and cover the surface with the specific amounts of paints. As in every complete coating technique, everything starts from surface preparation and pre-cleaning with solvents. Undercoats (preparation coatings, primer-surfacers, primer-sealers, and sealers) and topcoats are applied with the specific equipment (in major cases with spray guns) that could be siphon or pressure fed (Iowa Waste Reduction Center, 1998, pp. 1-7).

Because this technique requires direct human contact, it is a huge threat without following strict safety precautions. Moreover, spraying also emits VOCs to atmosphere and that is why governments regulate these processes (e.g. in U.S. it is done by EPA) and even solvent's level in the paints. There are many possible ways how to reduce the levels of emission: efficient and modern equipment, using materials with low level of VOCs (Iowa Waste Reduction Center, 1998, p. 51).

Advantages: low cost, easy to operate for simple coating procedures (e.g. repainting topcoat).
Disadvantages: many ecological issues, professional personnel needed to achieve high topcoat's quality.

1. 2. 2. 2. CARC

Chemical agent resistance coating is very popular coating technique across the armed forces. In U.S. most of the camouflaged vehicles are painted this way and the reasons are simple: it has longer lifetime than simple coatings, it protects from the chemical agents and it is easy to apply. Biological or chemical agents do not stick on the surface (as it is shown in Figure 3) and just flow down. Every vehicle which is coated this way has to be marked because during the post-cleaning against WMDs it could be purged in seconds. CARC is a coating system which consists of three basic layers: precoating, primer, and topcoat (HQ, Department of the Army, 1991, pp. 1-2).

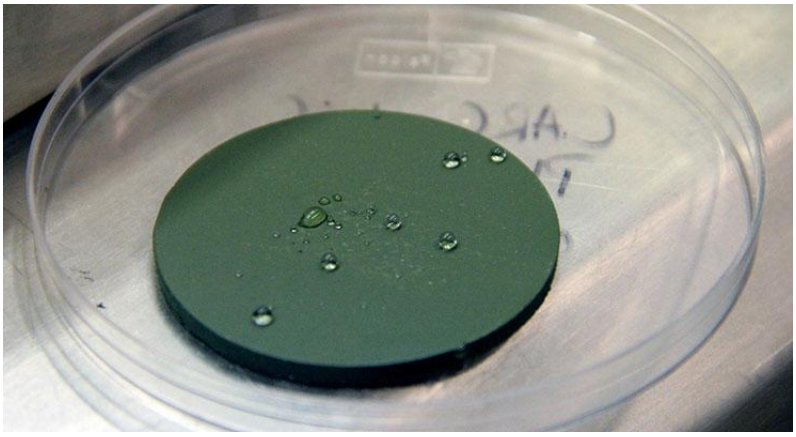

Figure 3. Biological agents on the CARC (Global Biodefense, 2015)

Mostly, CARC is applied with spraying guns; however, some of the parts are covered with brushes. As it was mentioned in the section 1. 2. 1, the undercoat is applied first. In this case, it is epoxy primer and enamel. The real disadvantage here is really difficult curing because it could take up to 2 weeks to completely dry up all the layers (HQ, Department of the Army, 1991, pp. 3-7).

Advantages: longer lifetime than alkyd paint, lower any consistence gathering on the surface.

Disadvantages: does not fit for parkerized and anodized surfaces, high temperatures during the curing, short lifecycle on wooden surfaces, long curing, could not be applied to parts that will be used under high temperatures.

1. 2. 2. 3. Camouflage Pattern Painting

Non-CARC or CARC applications depend only on the used paints. In U.S. new vehicles are already painted with CARC and camouflaged in factories and depots originally; while three-colour camouflage painting (Non-CARC) is used for older vehicles (mainly combat and combat support vehicles). Camouflage patterns have to be adaptable to different geographical surroundings. That is why green-brown-black range is used in wooded terrain and tan-brown-black in deserts. U.S. Army has a document (TB 43-0209) where every single vehicle is presented with the scheme of camouflaged pattern painting, e.g. Figure 4.

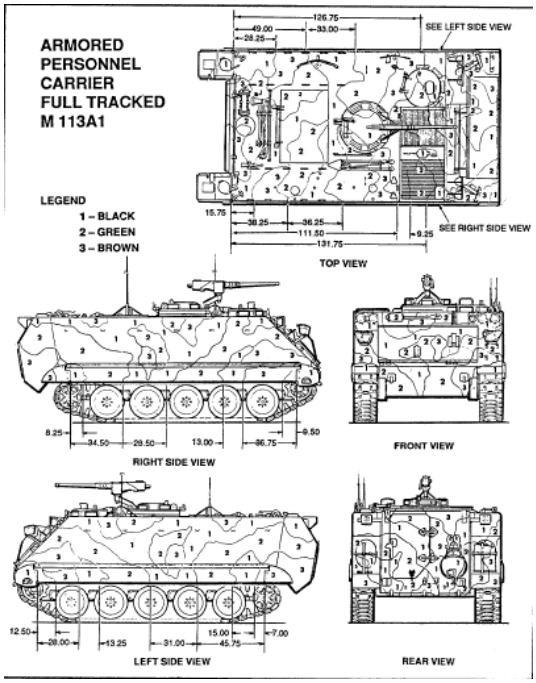

Figure 4. M113 camouflaged pattern painting (HQ, Department of the Army, 1991, p. 35)

Surface preparation and undercoat techniques are the same as they were described in 1. 2. 2. 1 section, whether the camouflaged application has chemical resistance or not. Spraying is simpler and more common but basically brushing is used for the touching up or larger surfaces. To paint the direct spots more accurately robots are used (HQ, Department of the Army, 1991, pp. 34-39).

1. 3. PAINTING FACILITIES IN LITHUANIAN AND SWEDISH ARMED FORCES

In this chapter Swedish armed forces' experience will be compared with Lithuanian expectations of the painting workshop. It might be that data provided by Lithuanian armed forces is not fully corresponding to reality because the expectations could be inaccurate compared to the long-term statistics. However, situation is totally different in Swedish case because coating infrastructure there

could be described as the independent system because it is much more adapted for military needs than Lithuanian workshop and it has strategy, clear vision and several paint shops. This chapter provides basic information about the purpose of painting, painting scope and amounts, actual technical parameters of these facilities and lastly the management processes which are related to the painting workshops.

1. 3. 1. Painting Purpose

Expectations in Lithuania are quite primitive; the only aim is to paint vehicles for restoring manufacturer's default parameters. Every painting technique prevents from the corrosion if it is applied with the specific surface preparation. Preventing corrosion could help to increase the vehicles' lifecycle what is planned to be the main objective for Logistics' workshop (Antulis, 2015).

Swedish focus not only on the anti-corrosion qualities but on the tactical issues as well. It was mentioned during an interview that by using simple methods they protect vehicles with lower IR footprint which is important against aerial reconnaissance and even with the chemical agent resistance coatings. Moreover, they use multi-colour paints for different operational surroundings. E.g. Swedish forces had been participating in ISAF mission in Afghanistan where their vehicles were repainted in khaki; after the deployment the colour was restored to dark green, three colour camouflage (green-olive-black) or two colour camouflage (white-black) which is used during the winter as it is shown in Figure 5 (Jutfjord, 2015).

Figure 5. Swedish IFV CV90 in different camouflaging (Army recognition) (Military today) (Army recognition) (Defence Industry Daily)

1. 3. 2. Painting Scope

At first, paint shop in Lithuania was focused only on the Logistics' vehicles of the armed forces. It means that paint shop would be served not for the whole military but for the several battalions in total. At first specialists claimed that this scope would be enough with the bigger partial and small refinishes even when the amount of vehicles is relatively small (Antulis, 2015). However, after the purchase of the workshop, the situation dramatically changed and now all of the vehicles (including trailers, artillery, and radars) of the Lithuanian armed forces will be painted there. According to the first expectation, 240 vehicles will be painted there annually (Vaičys, 2015) (Survila, 2015).

In Sweden paint shops are oriented to the whole armed forces. Partial and total refinishes are accomplished not only for the military owned vehicles but for the other governmental structures as well. Moreover, even civil vehicles used in the military for administrative purposes are painted there. It goes without saying that the highest priority objects in the Swedish armed forces' coating facilities are combat vehicles (Jutfjord, 2015).

1. 3. 3. Painting Techniques, Equipment, and Facilities

Lithuanian and Swedish armed forces are not going using and do not plan on using any modern techniques such as powder coating. Spraying is the most common among the paint shops today because it is the simplest one. However, some of the applications will have to be done with brushes and rollers where injection is not available (Antulis, 2015). In contrast to Lithuanians, rollers work perfectly for Swedish in spot camouflaging. Even without using any other painting equipment except spraying guns and rollers, Swedish achieve lower IR reflection which helps to conceal vehicles especially from the aerial observation. Moreover, they use CARC technology which protects from the chemical agents just by using specific paints (Jutfjord, 2015).

Lithuanian armed forces' Logistics has one painting chamber which has integrated curing chamber as well. This spray booth is bought from the USI Italia who is a leading company in the painting chambers' development. This chamber is able to operate not only with small vehicles but with huge trucks also (USI Italia, 2010). According to the specialists, in this paint shop bigger partial refinishes have to be applied for vehicles every 3 years (Antulis, 2015). Painting procedures in Lithuania have to be accomplished according to the instructions approved by the Chief of the Material Resource Department. It is planned that someday in the future painting in this workshop will meet STANAG 4360 standards (the basic painting standard in NATO). According to specialists, average painting time per light vehicle is about 30 hours while APCs or trucks are prepared and painted in 40 hours (Survila, 2015).

Swedish armed forces have 5 paint shops across the country with 8 spray booths in total. Paint shops do not differ from each other; just serve for the different regions. The lifecycle is from 3 to 5 years. Total refinishes could take up to 40 hours of work for combat vehicles and from 2 to 40 hours for the partial repainting. It depends on the surface area, difficulty, and the necessity for preparation. Total and partial refinishes used for maintenance cover 85% of all activity, while rest is painting for the tactical issues, e.g. changing colour for another environment (Jutfjord, 2015).

Talking about the paints, Swedish still mainly use solvent-based paints but have plans to update FSD standard due to new colours and environmental-friendly paints. All the application's requirements (paints qualities as well) are described in every single FSD standard. E.g. FSD 7553 is a dark green colour, two components urethane painting with CARC protection or FSD 7403 is a pattern painting standard for alkyd paints without CARC protection (Grop, 2015).

1. 3. 4. Organizational Structures and Personnel

Only 3 soldiers work directly with the painting procedures in Lithuania and they have one supervisor who works with the documentation and logistics of the paint shop. Personnel have to meet all the requirements needed for the professional service: physical fitness' tests and medical examination. Moreover, they must have a civil profession (vehicles bodies' preparation and painting course) for this specific work (Antulis, 2015) (Survila, 2015).

In Sweden soldiers who work in the paint shop are not organized in the strict way inherent to any military structure. Personnel communicate between themselves without subordination; just one of them is a supervisor who distributes the jobs. It means that there are only horizontal relationships and people create friendlier working environment. However, they still have to meet medical requirements and be fit. But the fitness tests in Sweden depend on the service place; e.g. it is definitely easier to pass it as a technician in the painting facility than as a reconnaissance unit soldier (Jutfjord, 2015).

1. 3. 5. Supply Chain Management

In Lithuania paints will be supplied using valid purchase and sale agreements with the private sector. It might be the most efficient way because when the paint shop is not big and the paints are delivered on time, there is no necessity of storage. Moreover, storage of paints (and other substances used during the coating processes) is much regulated and needs special rooms for that (Antulis, 2015).

In Sweden the painting amounts are much bigger and it leads to the necessity of storage. Paints and other substances are bought in two different ways: centralized and local. In the centralized way, huge amounts of paints are bought from the contractors and stored in the paint shops. However, it could be remedied if the planned substances' amounts are smaller than the actual ones. In this case, substances are bought from the local suppliers (Jutfjord, 2015).

1. 3. 6. Decision Making Process

In Lithuania decision making process will be maintained by the Material Resource Department. The managers from this unit will form up the queues and prioritize the specific vehicles. Depot Service's technicians will be responsible for the inspection which will be conducted in terms of the two documents: the act of technical condition and the act of the repair needs (Survila, 2015).

About Sweden: from the partly repainting perspective, there is a specific inspection unit who monitors vehicles' condition and by the documents and priorities, register them into a queue. Total refinishes could be applied when the vehicle is going from one geographical region to another and the different camouflage is needed. In this case, armed forces directly communicate with the paint shops and plan the painting (Jutfjord, 2015). Talking about buying new vehicles, Swedish set the requirements for the supplier in tender with the FSD code (e.g. FSD 7403) (Grop, 2015).

2. EFFECTIVENESS ANALYSIS OF LITHUANIAN ARMED FORCES COATING WORKSHOP

2. 1. PHASES OF THE RESEARCH

The research is separated into three different phases which help to completely analyze the effectiveness of the Lithuanian armed forces' coating facility:

1. An analysis of the annual painting amounts per spray booth in Lithuania and Sweden. It will give the specific numbers and could show how effectively Lithuanian workshop works in comparison to the Swedish one. Moreover, it will be possible to theoretically add or reduce painting amounts to achieve total process' optimization. Theoretical optimization is useless if there are no practical values, so the most suitable way to increase or decrease painting amounts will be provided. This optimized value will be used in the next two steps as an alternative to the current paint shop's scope.

2. Economic analysis of Lithuanian owned paint shop and optimized one. Firstly, project payback tool will be used for it. However, military is a non-profit organization and the painting service's price will be taken from the private sector. Secondly, cost per painted vehicle will be compared in the existing workshop, the optimized workshop and the private sector.

3. Multi-criteria decision analysis of four alternatives: existing paint shop, the same workshop with different scope and techniques, and outsourcing from the private sector. The most difficult part here is the accurate determination of the values for different criteria and it will be reached by interviewing people in charge of the Lithuanian workshop.

2. 2. ANALYSIS AND OPTIMIZATION OF PAINTING AMOUNTS

The quantity of required paint shops in the organization such as the armed forces is a numerable action. Having in mind, that there are many allies who have painting systems in their military, it is even easier to achieve. The drawback of Lithuanian armed forces' coating facility is exactly the fact that there was no market analysis or other planning accomplished to find the most-suitable decision for its own specific case.

In this chapter author represents what are the proportional ratios on painting amounts in Lithuania and Sweden. Swedish could be an example for Lithuanians because they have much more experience in this sphere, through the years painting infrastructure is optimized already, and what is

even more important, they use the same painting techniques. According to the specialists, Swedish system works without queues (Jutfjord, 2015). On the other hand, paint shops' quantity could depend on the geographical factor as well because in Sweden's case transportation of vehicles across the state could be even more expensive than painting itself. However, even from this perspective, the Swedish painting amounts per spray booth have to be even lower than coating system which does not depend on the geographical factors. So, it still works as an optimal system.

Ratio between painting amounts in Lithuania and Sweden should look like:

$$S = \frac{A_{Lithuania}}{A_{Sweden}} \quad (1)$$

Here: S – ratio between painting amounts, A_{Sweden} – Swedish painting amounts (per spray booth, per year), $A_{Lithuania}$ - Lithuanian painting amounts (per spray booth, per year).

While the demand of painting vehicles in the Lithuanian military is almost obvious, the ratio between painting amounts and capabilities are not clear at all. Under these conditions Logistics of Lithuanian armed forces decided to create this new infrastructure with one spray booth in Kaunas. However, there could be three different final results in terms of painting amounts:

1. One spray booth **is not enough** (if S value is much bigger than 1) to fulfil the existing painting needs. It is not the worst case scenario, because it would be better to have fewer capabilities than the surplus. Moreover, this could be easily fixed by buying another painting chamber or even more chambers.
2. The guess of having one spray booth was correct and it is the **optimal decision** (if S value is equal or similar to 1). It is the lowest chance that it is true but still it could be achieved with a little tolerance.
3. Even one spray booth **is too much** (if S value is much smaller than 1) for the Logistics of Lithuanian armed forces. This would be the worst possible result of this research part, because finances are already wasted in this case. However, it could be also improved by increasing the scope of the paintable vehicles; e.g. providing painting services to the administrative vehicles in the military or any governmental organizations.

In general case, painting amounts per spray booth (A) depend on only two parameters:

$$A = f(P, L)$$

$$A = \frac{P}{L} \quad (2)$$

Here:

P is a number of paintable items and *L* is a lifecycle. It is based on simple logic: larger quantity of vehicles requires larger quantity of the spray booths. However, the vehicles are not equal in size or shape and they require different time for preparation and painting. So the surface area would be much more accurate parameter. It means that for every single spray booth it is possible to count vehicles surface's area only if the work for tactical issues is ignored. But even then, the result will not be extremely accurate, because one's surface is not equal to another's because it might be more difficult to paint roof than a side or to paint flat surface than curved. Despite the above mentioned conditions formula is:

$$P = \frac{T}{n*k} \tag{3}$$

Here: *P* – surface area per spray booth, *T* – total surface area, *n* – number of spray booths, *k* – ratio between work for maintenance (not tactical) purposes in comparison with total work (%)

L is a lifecycle of the refinishing surface. This parameter is based on the specific paints or used technique because every total or partial refinish needs to be renewed after the specific period of time. The logic is simple: the longer lifecycle is, the lesser painting capabilities are needed.

It would be impossible to calculate surface area without errors because of the curves, external parts, lights, and windows. Total surface of the vehicle could be separated into five different objects as it is shown in Figure 6: roof, right side, left side, front, and the rear. Having such parameters as the length (*l*), width (*w*), and height (*h*) is not difficult to calculate the preliminary surface area.

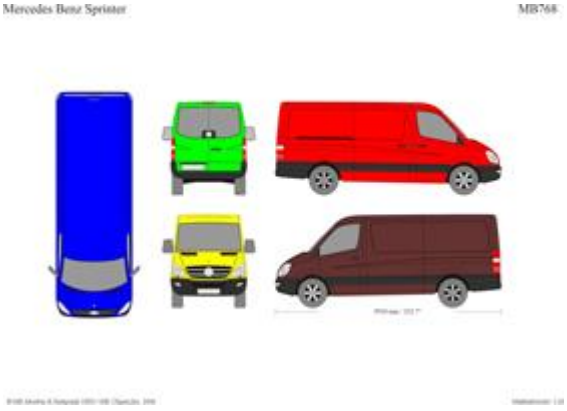

Figure 6. Vehicle surface's partition into separated objects (Unleashed Productions Inc.)

For the roof formula is:

$$Roof = l * w$$

For the both sides formula is:

$$Sides = 2 * l * h$$

For the rear and front formula is:

$$Front\ and\ rear = 2 * w * h$$

In this case, total surface is equal to:

$$Surface = Roof + Sides + Front\ and\ rear$$

$$Surface = l * w + 2h\ (l + w)$$

2. 2. 1. Swedish Painting Amounts

Calculating the total surface of Swedish armed forces' equipment is quite simple because the information on the quantities is not classified. The computations are provided in the Table 2. However, combat support, support, and civilian vehicles are not mentioned in this table because neither Lithuania nor Sweden provides their numbers but it is obvious that Sweden has proportionally larger number.

Table 2. Swedish vehicles surface's area (List of military equipment of Sweden)

Vehicle	***l* (m)**	***w* (m)**	***h* (m)**	**Surface area per item (m²)**	**Quantity**	**Surface area (m²)**
Ptgb 5	4,71	1,86	1,98	34,78	105	3651,67
RG-32MG Galten	4,97	2,06	2,05	39,06	260	10155,91
Terrangbil 11	4,4	1,9	2,3	37,34	6500	242710,00
Bv 206	6,9	1,87	2,4	55,00	4500	247495,50
BvS 10	7,6	2,34	2,2	61,52	48	2952,96
Patgb XA180	7,67	1,91	2,38	60,25	200	12050,10
MOWAG Piranha	7,45	2,66	1,98	59,85	33	1975,14
Patria AMV	7,7	2,8	2,3	69,86	113	7894,18
Patria Pasi	7,5	2,9	2,77	79,37	200	15873,20
Bv 206	6,9	1,87	2,4	55,00	50	2749,95
Pbv 401	6,45	2,86	1,86	53,08	147	7802,79
Strf 90	6,55	3,1	2,7	72,42	354	25634,91
Strv 121	9,67	3,7	2,79	110,38	12	1324,60
Strv 122	9,67	3,76	3,03	117,75	120	14129,40
Artillerisystem 08	14,1	3,0	3,3	155,16	4	620,64
					Total:	597020,95

It is already known that Swedish have 5 painting facilities with 8 painting / curing chambers in total. What is more, 85% of the work is partial and total repaints for maintenance while 15% are total repaints for tactical purposes. The relevant data here is only partial repaints and total refinishes

for maintenance because Lithuania does not camouflage vehicles. For Swedish case surface per item will be calculated with formula (3) where total surface area is 597020,95 (m^2), number of spray booths is 8 and the work for maintenance is 85% :

$$P_{Sweden} = 87797{,}2\ (m^2)$$

According to the specialists, average lifecycle in Sweden is 4 years. Using this value and the surface area per spray booth, painting amounts in Sweden per spray booth per year are obtained from formula (2):

$$A_{Sweden} = 21949{,}3\ (m^2/year)$$

2. 2. 2. Lithuanian Painting Amounts

Creating a table with Lithuanian data is much more complicated because military's capabilities are classified in Lithuania and without revealing state's secrets only information from the open sources could be provided that is clearly not totally corresponding to the reality but quite similar to it. What is more, Lithuania already signed a contract with Germany for self-propelled howitzers (in the table vehicles are written in *italic*) and IFV's (in the table vehicles are underlined) contest is still in progress. The most suitable option for Lithuanian armed forces is already known and it is supported by the Chief of Defence but it seems that Ministry of National Defence does not come up with the answer yet. However, all the applicants (Stryker, Boxer and Piranha) do not differ much between each other in size and the quantities are also the same. IFVs have to reach Lithuania till 2017 while howitzers till 2019.

Table 3. Lithuanian vehicles surface's area

Vehicle	*l* (m)	*w* (m)	*h* (m)	Surface area per item (m²)	Quantity	Surface area (m²)
M113	4,86	2,67	2,5	50,63	361	18276,06
M577 V2	4,86	2,67	2,7	53,64	26	1394,59
MT-LB	6,45	2,86	1,86	53,08	10	530,80
HMMWV	4,57	2,16	1,83	34,50	200	6900,60
Land Rover Defender	4,6	1,79	2,13	35,46	77	2730,07
Toyota Land Cruiser	4,95	1,97	1,88	35,77	12	429,25
SISU E13TP	9,5	2,5	2,7	88,55	50	4427,50
Bergepanzer 2	7,68	3,25	2,69	83,76	6	502,58
Bv 206	6,9	1,87	2,4	55,00	12	659,99
Mercedes-Benz Unimog	6	2,48	2,81	62,54	100	6253,76
M1064	5,32	3,02	2,5	57,77	42	2426,19
PzH 2000	11,7	3,6	3,1	136,98	21	2876,58
Stryker	6,95	2,72	2,64	69,96	84	5876,77
					Total:	53284,74

Table 3 was created from the data from the open sources: Wikipedia (Lithuanian army equipment), media (BNS, 2005) (BNS, 2002), military statistics' websites (US approves sale of 84 Stryker Infantry Carrier Vehicles to Lithuania, 2015) (Lithuania's defence information). Land Rover Defender number is counted from the multiple open sources: the sum of the project (BNS, Lietuvos rytas, 2006) was divided by the price per unit (Land Rover) with the 2006 currency rates (1 GBP for 5,14 LTL). Some of the data is not provided: MAN, GAZ 66, MB 1213, ZIL, Chevrolet trucks' quantities, other combat support, support and civilian vehicles but as it was mentioned before, they are not very significant, making the assumption that these quantities are proportionally lower in comparison with Sweden. In order to obtain more accurate results, military specialists could update the table with more detailed information.

Surface area per item is calculated with formula (3) where total surface area is 53284,74 (m^2) and there is only one spray booth and all of the work is focused on the maintenance:

$$P_{Lithuania} = 53284{,}74\ (m^2)$$

From the interview (Survila, 2015), lifecycle was set as 3 years. Using formula (2) painting amounts in Lithuania per spray booth per year:

$$A_{Lithuania} = 17761{,}58\ (m^2/year)$$

2. 2. 3. Ratio between Painting Amounts

As it was mentioned before, this ratio could not represent the situation totally because not all surface area of Lithuanian vehicles was taken into account (higher level commanders from Logistics could assess the situation by inserting more accurate numbers). Still, this expression could show if Lithuanian predictions are realistic and achievable. Using formula (1), the result is obtained below:

$$S_{existing} = 0,81$$

If *S* value is lower than 1, it means that Lithuanian scope is narrower than Swedish and the amounts are lower. As a result, there could be the downtimes of the paint shop. It is important that in the end of October the painting scope of the workshop was changed from the logistics' to the whole armed forces' vehicles. Otherwise, the paint shop would be extremely ineffective. On the other hand, recent ratio is not dramatically low but still not as good as it could be.

2. 2. 4. Optimal Painting Facility in Lithuania

Optimal painting facility should work with *S* value equal or very similar to 1. In Lithuanian case painting amounts have to be increased to achieve that. However, it would be difficult to add additional vehicles to the painting shop's scope when the scope already covers all the armed forces. However there is another option which could be extremely significant to the armed forces and it is camouflaging of the vehicles. According to Swedes, their total number of coatings could be divided into two parts: 85% for maintenance and 15% for tactical refinishes. If Lithuania, using the same technologies, would add this service to the paint shop's scope, *S* value could become much closer to 1. In this case, Swedish surface area per item and painting amounts per spray booth per year will be calculated with the value 1 on the ratio of the work for maintenance and tactical purposes by using the same formula (3):

$$P_{Sweden_{Optimized}} = 74627,62\ (m^2)$$

Now formula (2) will give different answer for the annual surface area per spray booth:

$$A_{Sweden_{Optimized}} = 18656,91\ (m^2/year)$$

In Lithuanian case all the values remain the same. So formula (1) will give the ratio of:

$$S_{Optimized} = 0,95$$

This number is much closer to 1 and it means that the exploitation effectiveness could be increased in this way. Camouflaging could increase efficient utilization of the paint shop and it does not mean that it requires any specific paints: just military-used colours. However, CARC protection and lower IR footprint could also be a goal for Lithuanian armed forces. In that case, number of painted vehicles, which is increased if the coatings are applied not only for maintenance, could be calculated as:

$$N_{optimized} = N_{existing} * \frac{S_{Optimized}}{S_{existing}}$$

Here $N_{optimized}$ is number of vehicles to be painted (includes both painting for maintenance purposes and for tactical purposes) and $N_{existing}$ is a number of vehicles painted only for maintenance purposes. Using this formula, where expectation equals to 240 vehicles per year, the total number of painted vehicles with optimized scope is:

$$Painted\ vehicles = 281{,}48\ (\frac{vehicles}{year})$$

2. 2. 5. Paint Shop with CARC Topcoat Refinishes

Lastly, the efficiency could change if the Lithuanian armed forces start to use CARC topcoat refinishes because it has longer lifecycle which is at least 4 years (Jutfjord, 2015). Having that in mind, it is possible to calculate the annual surface area per spray booth using formula (2) and assuming that number of paintable items is still the same:

$$A_{Lithuania_{CARC}} = 13321{,}19\ (m^2/year)$$

Afterwards, using formula (1) and last result, it is possible to get the efficiency ratio:

$$S_{CARC} = 0{,}71$$

In terms of efficiency, improving the lifecycle decreases the effectiveness because in the long-time perspective there will be more gaps in the queues because total refinishes would be able to sustain longer. On the other hand, it could also be an ability to increase the painting scope once more.

2. 3. ECONOMIC ANALYSIS

This part of the research is separated into 3 segments:

- **Economic data**. In this segment every piece of necessary data is described and the computations are provided.
- **Payback's period**. This segment shows the period of time in which paint shop's project pays off. There are two independent calculations: one for existing painting amounts and another one for optimized painting amounts (presented in the 2. 2. 4. paragraph).
- **Cost per painted vehicle**. It helps to compare four different options in terms of painting cost: 1. the military-owned paint shop with the existing painting scope; 2. same painting facility with the optimized amounts; 3. same facility using additional modern technologies, and 4. outsourcing the coating service from the private sector.

2. 3. 1. Economic Data

2. 3. 1. 1. Service Cost in Private Sector

There are many small businesses in Lithuania that offer painting service for car owners. The spraying is the most common technique among these paint shops. However, none of them prepare

and paint by the specific requirements that would meet STANAG standard. On the other hand: if there was a demand, there would be offers as well (Survila, 2015).

Several Lithuanian private companies were interviewed on the coating price per little truck (MB Unimog size was given), technology's lifecycle and painting time (preparation included). The responders claimed that it is difficult to clearly identify the values because each different vehicle has its own parameters and the situation could be fully analyzed only with the specific software for every single vehicle (Pakalnis, 2015). Moreover, the lifecycle and application time are not equal in these companies. The results are presented in Table 4:

Table 4. Lithuanian private sector's services

Responder	**Cost (€)**	**Lifecycle (years)**	**Application time (h)**
Vladimiras Liber (Personal Enterprise "V.Liber" owner)	2750	N/A	220
Gediminas Vasiliauskas ("Vasiliauskai UAB")	3000	4	160
"UAB VTREMONTAS"	2500	5	160
Evaldas Pakalnis (director of "UAB Autoramiksas")	3500	N/A	160
Ričardas ("Ekvalis")	3600	6	180
Averages:	3070	5	176

The average price [*PS*] from 5 different companies is:

$$PS = 3070 \ (euro/vehicle)$$

2. 3. 1. 2. Long-term Assets

The coating workshop was taken over from the state enterprise "Turto bankas". Oddly the property's value included all the long-term equipment necessary for painting (e.g. spray booth or compressors). According to the purchase documents (Appendix 5), total long-term assets value [*LAV*] is:

$$LAV = Workshop\ value = 1733175{,}38 \ (euro)$$

Moreover, the facility and equipment is not ageless. After a period of time it depreciates. Annual depreciation [*PAD*] could be calculated using formula (4):

$$PAD = \frac{LAV}{DN} \quad (4)$$

According to the laws of Lithuania (No. X-1484, signed 2008-04-10), depreciation normative [*DN*] for this kind of facility is 15 years. Having this value, it is possible to calculate properties' annual depreciation, using formula (4):

$$PAD = 115545{,}03 \ (euro/year)$$

2. 3. 1. 3. Short-term Assets

General formula for short-term assets annual value is [*SAV*]:

$$SAV = (Substances' value\ (monthly) + Equipments'\ value(monthly)) * 12\ \left(\frac{months}{year}\right) * S_{(existing/optimized/CARC)} \quad (5)$$

This part is complicated because Lithuanian workshop has not painted any vehicles yet. Because of that, one of the private business company's data is taken (Pakalnis, Short-term assets and other expenses, 2015). "UAB Autoramiksas" is capable to paint 15 little truck's size vehicles monthly; it has slightly smaller capabilities than Lithuanian armed forces' first expectations. From this perspective, armed forces' short-term assets will be multiplied by 1,25 (ratio). "UAB Autoramiksas" provided two numbers related to the short-term expenses. One of them covers all the substances used for painting (paints, fillers, sealers, primers, etc.) and its value is 5500 euro. Another stands for the short-term equipment (special clothing, filters for spray booth, brushes, rollers, infrastructures networks' exploitation expenses) and it is 200 euro. Using formula (5), annual short-term assets' value is:

$$SAV = 85500\ \textit{(euro/year)}$$

2. 3. 1. 4. Public Utilities

The painting facility is attached to the infrastructures of Kaunas. Painting requires water for pre and post washes, electricity for all the equipment, heating system for the cold season because some of the coatings have to be applied under specific temperatures and gases are used for the spray booth. With the same exploitation ratio (1,25), "UAB Autoramiksas" utilities' expenses are used. General formula for all of the utilities (except heating) would be:

$$XXX = Consumption * Price * 12\ \left(\frac{months}{year}\right) * S_{(existing/optimized/CARC)} \quad (6)$$

Formula for heating is this:

$$AHP = Area * Required\ energy\ per\ area * Price \quad (7)$$

Water's consumption is 50 cubic meters monthly. Price per cubic meter in Kaunas with Value-added taxes is about 5 euro/m³. From here, annual water price [*AWP*] calculated with formula (6) is:

$$AWP = 3750\ (euro/year)$$

Monthly electricity's consumption is 1250 kWh. The workshop buys electricity from the "AB Lesto" which sells it for 0,129 euro/kWh. Therefore, annual electricity price [*AEP*] calculated with formula (6) is:

$$AEP = 2418{,}75\ (euro/year)$$

Workshop's total area is 1464,14 m². According to the documents, workshop requires 63,49 kWh/m² per year for heating. The same supplier as for water, provides heating service for 0,05 euro/kWh. So, annual heating price [*AHP*] calculated with formula (7) is:

AHP = 5087,15 (euro/year)

Gas consumption for spray booth in "UAB Autoramiksas" is 750 m³ per month. The gas' price is 0,42 euro/m³. Annual gas price [*AGP*] calculated with formula (6) is:

AGP = 4725 (euro/year)

Total price per annual utilities [*AUP*] is a sum of the above-mentioned and it is:

AUP = 15980,9 (euro/year)

2. 3. 1. 5. Expenses for Personnel

General formula for the expenses for personnel is:

$$EP = (Monthly\ salary + taxes) * 12 + \sum Allowances) * Personnel$$

Formula (1)

In the painting facility 3 corporals work directly with the coating. Soldiers who obtain this rank in Lithuanian armed forces get monthly salary of 639,45 euro and employers pay 198,23 euro taxes for every soldier. Moreover, every soldier gets allowances for food which is 5,4 euro per day. Soldiers might get allowances for the rent or for travelling to work and back, but these expenses could vary depending on many factors and they are relatively small comparing to the salaries and allowances for food. Using formula (8), total expenses would be:

EP = 36069,48 (euro/year)

2. 3. 2. Payback

Payback's period [*P*] is calculated by dividing project's investments from the possible profit in the private sector (where the cost of ownership and all the expenses related to painting are excluded from the income). General formula looks like this:

$$P = \frac{Project's\ investments}{Annual\ income - annual\ expenses} = \frac{LAV}{(Painted\ cars * Price\ per\ car) - PAD - S * (SAV + AUP) - EP} \quad (9)$$

2. 3. 2. 1. Existing Paint Shop

Making the assumption that the annual painting amounts' expectations are correct (240 vehicles), it is possible to count the payback's period of this project. Ratio between Swedish paint shop's scope which has 100% exploitation and Lithuanian paint shop's scope was 0,81. Private business company "UAB Autoramiksas" which provided short-term data and expenses has been working at full capacity as well. From the first part of the research, there is a hypothesis that in the long-time perspective the gaps in queues between paintings will appear due to insufficient scope. In order to

present more accurate results, short-term assets and public utilities will be combined with this ratio. Using formula (9) project‘s investments are equal to long-term assets (1733175,38 euro). Annual income is calculated by multiplying painted vehicles number (240 per year) to its price (3070 euro per vehicle) and the annual expenses are the sum of long-term assets depreciation (115545,03 euro per year), annual short-term assets value (85500 euro per year), annual cost per utilities (15980,9 euro per year) and expenses for personnel (36069,48 euro per year). Annual short-term assets and utilities cost is multiplied by the effectiveness ratio (0,81). Using this data, payback’s period is equal to:

$$P_{Existing} = 3{,}45 \text{ (year)}$$

While the long-term assets’ amortization is 15 years, it is possible to state that the existing paint shop’s payback’s period is relatively short.

2. 3. 2. 2. Optimized Paint Shop

If the painting for tactical purposes will be provided, the ratio between painting scope in Sweden and Lithuania might become 0,95. It means that annual painted vehicles number could be significantly increased (to 281,48 vehicles per year) and the numbers of gaps in queues will be eliminated. Using the same formula (9), payback’s term of optimized paint shop looks like:

$$P_{Optimized} = 2{,}81 \text{ (year)}$$

In this case not only the payback’s period could be reduced but armed forces’ vehicles could be painted in camouflaged colours or for additional price with layers which have lower IR footprint or CARC protection. Painting for tactical purposes definitely increases the efficiency of the military-owned paint shop. Using formula (9), paint shop’s with CARC and increased lifetime payback’s period is:

$$P_{Optimized+CARC} = 2{,}99 \text{ (year)}$$

2. 3. 3. Cost per Vehicle

Cost per vehicle is a very simple indicator which shows how the prices per vehicle change when having own painting workshop and when the service is outsourced from the private sector. It is important to mention that up to day the requirements on painting do not meet any military standard yet neither in Lithuanian workshop nor in any private business’ company. Civilian institutions have provided their prices and the average is already known (3070 euro per vehicle). Cost per vehicle [*CV*] is calculated for two alternatives independently that were analyzed in the payback’s part. Generally, cost is calculated by summing all the annual expenses and dividing them by the number of painted vehicles. Formula looks like this:

$$CV = \frac{Annual\ expenses}{Number\ of\ annualy\ painted\ cars} = \frac{PAD + S*(SAV + AUP) + EP}{Number\ of\ annualy\ painted\ cars} \quad (10)$$

2. 3. 3. 1. Existing Paint Shop

The assumptions will be the same as they were while payback was counted. Using the same data and formula (10), existing cost per vehicle is:

$$CV_{Existing} = 974{,}23\ (euro/vehicle)$$

The price is 3 times smaller than the price in private business. From the financial perspective, having own paint shop for armed forces is extremely important.

2. 3. 3. 2. Optimized Paint Shop

The paint shop with the optimized scope in the long-term perspective could paint more cars because of fewer gaps (theoretically 281,48 vehicles annually). In terms of that, ratio of exploitation is increased to 0,95. Using formula (10), answer is provided below:

$$CV_{Optimized} = 881{,}13\ (euro/vehicle)$$

The cost with existing painting amounts was significantly cheaper in comparison to private business. However, optimizing the painting amounts could reduce the price even more. Having in mind, that substances' price used for CARC protection and lower IR footprint is twice bigger than non-CARC and the effectiveness ratio is 0,71, it is possible to calculate cost per vehicle with formula (10) under these conditions as well (Jutfjord, 2015):

$$CV_{Optimized+\ CARC} = 1010{,}27\ (euro/vehicle)$$

This price shows that just for 4% higher cost than the existing one it is possible to increase the usability of the paint shop. Moreover, the CARC coatings have longer lifecycle and better protection qualities against most external factors (Jutfjord, 2015).

2. 3. 4. Discussion

The economic analysis was accomplished with the data from private sector and expectations. It might be that the final results will not reflect the real future statistics. It would be possible to redo this analysis after a year of full exploitation of the workshop and it could show up that some expectations or private sectors' costs were not corresponding to the true values. However, tolerances should not be as big to influence the final outcomes.

2. 4. MULTI-CRITERIA DECISION ANALYSIS

Multi-criteria decision analysis is a common tool for problems that could be statistically analyzed, separated and evaluated for different criteria independently. This methodology is useful when the decision making is very complex and the answer could not be intuitively seen. According to the

literature, MCDA could be separated into the steps that are presented in Figure 7 (Vicky Mabin, Michael Beattie, 2006).

Figure 7. MCDA steps

The first step is not expanded as a subchapter, because it could be described by one sentence. So objective here is the identification of the best-suitable painting system for Lithuanian armed forces. The problem will be analyzed without taking in mind that Lithuania has already bought the workshop. This assumption might show if the purchase was necessary or if there were any better options in the beginning of the project when the market analysis was not accomplished.

It is worth noting that the analysis is done without involving several conditions that could be extremely important for the Lithuanian armed forces at present and especially in the future:

- The existing workshop seeks to apply the coatings under STANAG standards. Nowadays, this service is available neither in private business nor in the military workshop. But even the possibility to improve the workshop's capabilities to the NATO requirements could be a huge advantage for some of the options when choosing the most-suitable alternative.
- Another important fact is that there could be classified equipment in the vehicles. APCs, IFVs, artillery or even armoured jeeps have such things as radio stations, command and control software, thermo visors or classified armament. Some of them could be unmountable from the vehicles, but not all. This might be a huge disadvantage for any private business' paint shop because someone must care of the protection of the equipment or sensitive information.

2. 4. 1. Identify Criteria

By analyzing priority functions of coating in the militaries author suggested 5 criteria to the assistant of commander of Logistics Cpt. Laimutis Vaičys and asked if he is able to add any more (Vaičys, 2015). The answer was negative and MCDA is based on these factors:

- **Visual appearance and colour**. This criterion characterizes the necessity for military transport to be painted in neutral colours. Having in mind that Lithuania is still preparing for the "green tactics", camouflage and concealment undoubtedly are components of success. Moreover, this criterion is split into two sub-criteria: painting vehicles in a single neutral colour or using multi-colour paintings (applying camouflage pattern).

- **Protection qualities**. The purpose of painting is not only visual appearance, protection against external factors could be even more important. In the private sector the most common protection is directed against corrosion. However, some of the protection's features are related to the military objectives only, such as the lower IR or UV footprints or the protection against substances' gathering on the surface. By its function, this criterion is divided into three sub-criteria: anti-corrosion protection, lower IR footprint and CARC protection.
- **Lifecycle**. This criterion comes not from the coating purpose but as a characteristic of painting quality. The longer is the lifecycle of the applied layers, the fewer number of coating capabilities is needed.
- **Cost**. This factor could be represented by the economic analysis' results. If being more accurate, paragraph 2.3.3 shows the possible painting prices per unit. Finances are also related to the lifecycle because if the vehicle has twice longer lifecycle of coating, the result could be satisfied even if the price is doubled as well.
- **Effectiveness** of the coating-workshop. In general, it is an index which shows the painting amounts and capabilities of the workshop. This factor was already analyzed in section 2.2, where the existing painting amounts were compared to the Swedish case and the optimized result was achieved. As it was mentioned before, it is inversely proportional to the durability.

The Figure 8 shows all the criteria and sub-criteria that will be included in the MCDA.

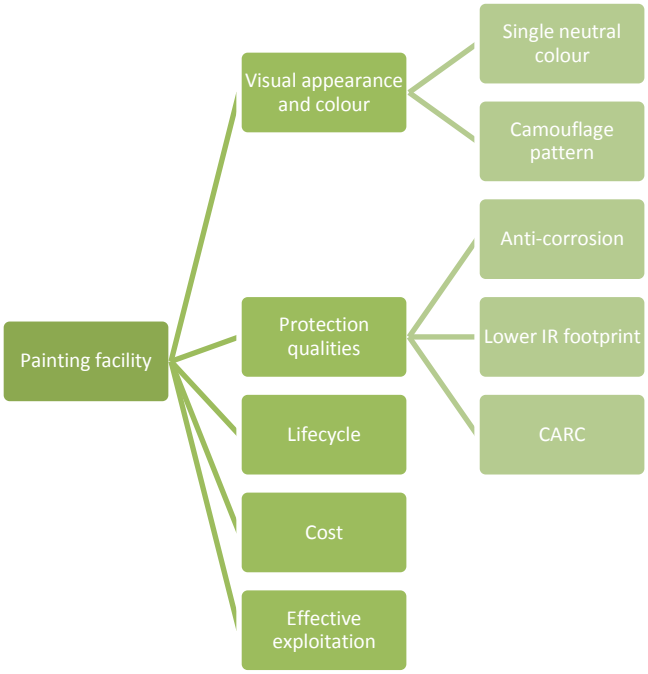

Figure 8. Criteria tree

2. 4. 2. Identify Alternatives

All of the alternatives which are analyzed were already mentioned in the thesis before:

- **Existing paint shop**. Nowadays the workshop is working as any private business company that just applies total and partial refinishes for maintenance and does that with neutral colour paints.
- **Existing paint shop with optimized painting scope**. The workshop could be easily used for tactical camouflaging (or just repainting from tactical perspective). Lithuania sends its soldiers to different joint-exercises and combat operations. Some of them require not only olive or military green colour. In terms of that, Lithuanian armed forces are able to prepare for their tasks as the professionals do, even with the specific colour coatings.
- **Existing paint shop with optimized painting scope and CARC refinishes**. Without buying any equipment, with the same application times and techniques, it is possible to protect the vehicles from thermo visors observation (with lower IR footprint) and have chemical agent resistance coatings as well. These refinishes require specific paints and undercoat layers which naturally have higher price. However, it increases the lifecycle of the coating as well and as a result, cost per vehicle differs minimally from the existing one.
- **Private sector**. While the coatings' characteristics are the same as in the private sector, it is also an option to prevent spending money on infrastructure and assets and to outsource the service from any company in the market.

2. 4. 3. Determine Criteria's Values

This part is the core of the analysis because the criteria values have to correspond to the reality. Otherwise, the analysis' final result and outcomes could be erroneous. To prevent this, the survey (appendix 3) was sent to specialists of Logistics that were involved in the workshop's project and they were asked to identify the values for the criteria based on their own knowledge and opinion.

The survey asked the respondents about the importance of every single criterion (in scale from 0 to 5, where 0 stands for the least important criterion and 5 stands for the most important one). Moreover, every sub-criterion was evaluated almost in the same way; just the scale was from 1 to 5. It was done in this way, because sub-criterion value is related to the criterion and if the criterion is important (and got at least 1 in the scale), it means that sub-criteria are already partly important.

5 correspondents gave their answers (appendix 4) and identified the significance of every criterion and sub-criterion independently. To get the maximum value for every criterion, the survey result's average is multiplied by 10. To get the sub-criteria values, the maximum criterion's value is

multiplied by the sub-criteria survey's result and divided from 5 (the maximum possible value). The following table provides the values for every criteria and sub-criteria:

Table 5. Criteria's and sub-criteria's maximum values

Criteria	Sub-criteria	Maximum values
Visual appearance and colour		36
	Single colour	15,84
	Camouflaged pattern	27,36
Protection		44
	Anti-corrosion	33,44
	Lower IR footprint	29,92
	CARC	28,16
Lifecycle		40
Cost		34
Effective exploitation		36

2. 4. 4. Determine Alternatives' Values

This is the easy part, because the data was already mined or calculated in the first paragraphs of the research part. The following table provides them:

Table 6. Alternatives' values

Criteria / Alternatives	Single-colour	Camouflaged pattern	Anti-corrosion	Lower IR footprint	CARC	Lifecycle (years)	Cost (euro)	Effective exploitation
Existing paint shop	+	-	+	-	-	3	974,23	81%
Existing paint shop with optimized scope	+	+	+	-	-	3	881,13	95%
Existing paint shop with optimized scope and CARC topcoats	+	+	+	+	+	4	1010,27	71%
Private business	+	-	+	-	-	5	3070	100%

2. 4. 5. Calculations and Final Result

Calculation is the part where the best-suitable option appears. However, evaluation ways are different because some of the criteria do not express any numerical values; others represent the best result with the lowest score. Having that in mind this is how they are assessed:

- visual appearance and protection criteria results will be treated only as full points if the value is positive (+) and with 0 if the value is negative (-);

- the lower cost is, the better has to be the result, so using inversed proportions it will be calculated with formula below:

$$Value_{cost} = \frac{Lowest\ cost}{Alternative\ cost} * Criterion\ value$$

- lifecycle and effectiveness' ratio will get final values using this general formula:

$$Value_{L\ (or\ S)} = \frac{Alternatives' lifecycle\ (or\ effectiveness\ ratio)}{Highest\ lifecycle\ (or\ effectiveness' ratio)} * Criterion\ value$$

Using these formulas, the final calculations are given in the Table 7.

Table 7. Final MCDA' calculations

Criteria / Alternatives	Single-colour	Camouflaged pattern	Anti-corrosion	Lower IR footprint	CARC	Lifecycle	Cost	Effective exploitation	Total result
Existing paint shop	15,84	0	33,44	0	0	24	30,75	29,16	133,19
Existing paint shop with optimized scope	15,84	27,36	33,44	0	0	24	34	34,2	168,84
Existing paint shop with optimized scope and CARC topcoats	15,84	27,36	33,44	29,92	28,16	32	29,65	25,56	221,93
Private business	15,84	0	33,44	0	0	40	9,76	36	135,04

The final results show that according to the Logistics' specialists suggested values (based on Appendix 4), Lithuania has only one strong option (with 222 points in total) and it is the existing paint shop which could paint vehicles for the maintenance and tactical purposes and apply the CARC topcoats. Second but not the worst option is to have paint shop that coats for tactical purposes but without CARC (this option scored 169 points). The third-best option is outsourcing from the private sector (this option scored 135 points). The last and the least option is the existing paint shop with the current scope (with 133 points in total).

CONCLUSIONS

1. Despite the fact, that there was no market analysis or specific planning in Lithuanian armed forces before purchasing the coating workshop, ratio between capabilities and painting amounts in comparison with Sweden equals 81%. Consequently, the hypothesis that capabilities will outweigh the painting amounts could be rejected.
2. Using Chemical agent resistance coatings (CARC) which prevent any substances gathering on the surface could even decrease usage ratio to 71% because the lifecycle is increased and vehicles have to be repainted not as frequently.
3. From the economic point of view, having an own paint shop for the armed forces is beneficial because in the long-time perspective the cost per painted vehicle is three times smaller than outsourcing the service from the private business' companies. Moreover, the project's payback period is not longer than three and a half years while amortization period of the long-term assets is more than 4 times greater.
4. Cost per vehicle when CARC technology is used almost remains the same in comparison with existing coating price because while substances are more expensive, transport needs to be repainted less frequently.
5. Multi-criteria decision analysis has shown that the existing paint shop does not meet the requirements for the military-owned coating-workshop that had to be determined before the purchase of the workshop. Specialists stress the significance of the tactical protection qualities such as lower infrared footprint and chemical agents' resistance coatings which are not planned to be provided in the Lithuanian workshop.

SUGGESTIONS

1. The Lithuanian military workshop should increase its scope in order to optimize its usage: transport has to be painted not only for maintenance purposes but for tactical purposes also. It may increase the usage ratio of the workshop almost to its peak 95%. Moreover, it minimizes the painting cost per vehicle and payback's period.
2. If CARC technology was used, workshop must increase its scope once more by adding additional vehicles from governmental structures to its painting scope.
3. In order to meet specialists' suggested requirements for military workshop, paint shop has to expand its purpose to include tactical painting by providing lower IR footprint, camouflaging and CARC technology. If this was accomplished, vehicles would be more adaptable for military standards

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APPENDICES

Applying Recognition Factors

There are 7 factors which give ability to identify the specific objects in the surrounding (HQ, Department of Army, 2010, pp. 20-21):

- Reflectance is an energy which is reflected from the specific surface. There are 3 types of reflectance: visual, temperature, and radar-signal. Even the best camouflaged sniper could not avoid reflectance of the scope and nowadays there are sensors that could easily detect their position only because of this factor (Johnson, 2010).
- Shape is a form of the object. It might be difficult to deny that namely because of shape people recognize weapons, armoured personnel carriers, tanks and other vehicles. Straight lines and rectangular forms do not exist in the nature and in terms of that they could be seen by the sensors.
- Shadows are the revealing factor even if the objective is not seen at all. From the aerial observation even the well-camouflaged transport in the open area could be easily identified just because of the shadows.
- Movement attracts attention (Larsen, 2009, p. 334) so being undercover and moving fast are not always compatible. That is why it is recommended to freeze and move as slow as possible especially near the enemy lines.
- Noise is the most revealing factor during the night when the sight is not as significant as in the daylight. It is almost impossible to avoid making noise while moving but it is possible to cover it.
- Texture is significant for armament and transport because of shining. If there are any glossy surfaces (e.g. metal parts, headlights, and windows), they could provide shines even during the night when there is moonlight or a flare is shot (Camouflage of Vehicles: Shine).
- Patterns are the most relevant factor on the battlefield when the visual observation is in process and sight compares object to its background. Choosing the correct pattern might become the factor of success for the whole operation.

Sensor Systems

Having in mind recognition factors, in the 21st century there are different sensor systems that could easily detect troops, vehicles and other man-made objects in the surrounding. Without basic understanding about sensors, it might be difficult to discuss about painting as a counter measure. So, most of the systems are based on EM spectrum (as it is shown in Figure 9) and only sound sensors deal with the mechanical impact.

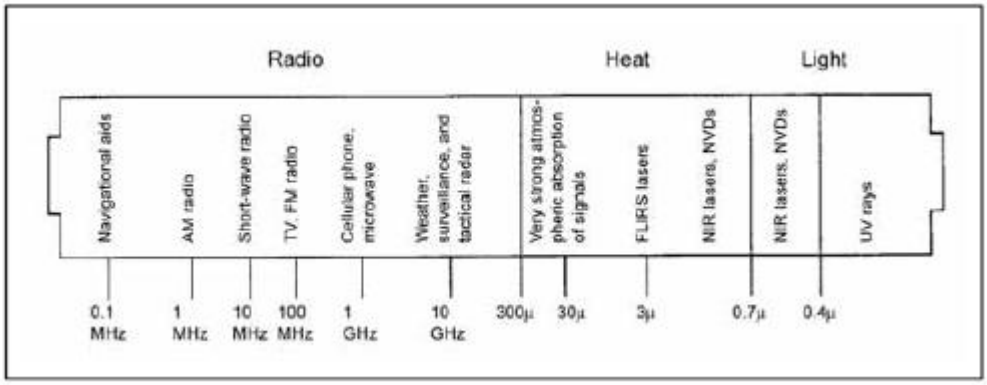


Figure 9. EM spectrum (HQ, Department of Army, 2010, p. 12)

It is always difficult to know exactly how enemy's sensors work and how efficient they are but it is better to not underestimate the enemy's capabilities and prepare to apply CCD methods for the newest worldwide technologies. ATTP excludes these types of modern sensor systems (HQ, Department of Army, 2010, pp. 12-15): visual, NIR, IR, UV, radar, acoustic, radio, multispectral and hyperspectral. However, only visual, thermal (NIR, IR, UV) and radar sensors are related to the painting techniques and they have to be briefly described.

Visual sensors

Every device that gives ability to see and record the surrounding's image goes to this group of sensors. Visual sensors are wide range devices from the cheap and primitive well-known ground surveillance tools such as monocular, scopes, and binoculars to modern ones: NVDs, cameras, and UAVs (HQ, Department of Army, 2010, pp. 12-13).While it is still the most common way of observation, the priority has to be given for those CCD techniques that counter the visibility because ground and aerial surveillance is done by the same recognition factors which were described above. (FM 5-20B).

Thermal sensors

Thermal sensors work very differently depending on their type: NIR sensors work in terms of energy reflection of the surface; IR sensors compare the object's heat to its background and highlight the warmer one (same principle is used in FLIRS); and UV sensors are mostly used in arctic warfare where the main terrain is covered by ice and snow which reflects waves with higher efficiency than clothing or vehicle surface does. Even when the sensors process with quite different techniques they have the same counter measures which are much more difficult technologically than those which are used against visual sensors (HQ, Department of Army, 2010, p. 13).

Radar sensors

Radar sensors are really similar to NIR and UV sensors from their operational perspective, but they use HF radio waves instead which could easily go through any soft patterns, natural objects and are

highly reflected from the metal surfaces. Moreover, the strength of reflected wave depends on the size of the object and that gives ability to identify the approximately type of the vehicles (e.g.: tank, armoured personnel carrier, civilian vehicle) (HQ, Department of Army, 2010, p. 14).

Counter Measures against Sensors

Even in the modern times when every single step could be tracked by extremely accurate computers, there are still many ways how to avoid the recognition in the battlefield. For better understanding there are some necessary definitions of general techniques used to stay concealed during the operation:

Hiding – being out of line of sight or having a barrier between enemy and object.
Blending – camouflaging oneself with the surrounding pattern.
Disguising – demonstrating false information about the object.
Disrupting – misleading enemy by using camouflage nets and sails.
Decoying – simulated actions that provokes enemy's attention (HQ, Department of Army, 2010, pp. 23-25).

Those techniques could be the key factor in the success of operation and it is a difficult task to achieve them all at once. In the following table, there are given many possible counter measures against different sensor systems. CCD techniques are divided for every single sensor system by its goal. There is no need to discuss all of them; however, some techniques are strongly related with the topic: paint, thermal paint, and textured materials. Those counter measures prove that there is a necessity of painting vehicles and armament in the supply chain of mentioned equipment till they are used in direct action operations.

Table 8. CCD techniques (HQ, Department of Army, 2010, p. 24)

CCD techniques	Sensor Systems		
	Optical	Thermal	Radar
Hiding	Earth cover Earth embankments Vegetation LCSS Screens Smoke	Earth cover Earth embankments Vegetation LCSS Screens Smoke	Chaff Earth cover Earth embankments Vegetation Nets RAM LCSS
Blending	Paint Foam Lights Vegetation LCSS Textured mats	Thermal paint Foam Air conditioning/heating Vegetation LCSS Textured mats Water Insulation	Vegetation LCSS RAM Reshaping Textured mats

Disguising	Reshaping Paint LCSS	Reshaping Paint	Corner reflectors
Disrupting	Camouflage sails FOS Pyrotechnics Smudge pots Balloons Strobe lights Tracer simulators Smoke	Flares Smoke	Chaff Corner reflectors
Decoying	Decoy target (pneumatic or rigid structures) Lights Smoke	Decoy target Flares Air conditioning/heating Smoke	Decoy target Corner reflectors Signal generators

Electrocoating

Electrocoating is not only undercoat application but topcoat also because paints and primer are also applied in this way. Without ED layer, painting is also possible and it was done like this till the electrocoating was developed. However, without ED layer, paints are not resistant to salt corrosion. This technique is not used to repaint a car in small private businesses; however, it is the most common way to paint vehicles' body in the manufacturing phase.

In the early 1960s when electrocoating was developed it was much better technique than just dip coating, in 1970s 10% of all vehicles were coated this way. Car was used as an anode in electroplating process; however the technique was not as successful as it has to be. Nowadays most of the vehicles are coated using a cathodic process which ensures better coverage, greater efficiency and improved resistance parameters. The success of this technique could be represented by the statistics: in 1990s 90% of vehicles were electrocoated and up to date it is the most common vehicle coating technique.

Electrocoating is not simple painting, it requires separating all the parts from the body and phosphating procedure in advance which gives greater anti-corrosion protection and provides better surface for the paint. It is really simple process where phosphoric acid is sprayed on the surface but when phosphating is used with electropaints, vehicle's lifecycle increases up to 10 years (NZ Institute of Chemistry, pp. 1-3).

Electrocoating is not as simple as phosphating. It requires huge electrocoat tank where cathodic process takes place. Tanks are fulfilled with the solvent and electropaints and the ED starts. At this stage, epoxy coating (primer) is also applied. After the primer, other layers are placed on top of it. There has to be cooling system installed into the tanks to keep the specific temperature (depends on the paints) (Epoxy Resin Committee, 2015, p. 2).

When the vehicle is pulled out from the tank, thin layer adheres to the vehicle's surface which has to be removed because it could cause film defects. For this purpose, body is sprayed and rinsed several times and lastly vehicle is put into drying chamber where the temperature has to be up to 180 ◦C and chemical reactions complete the electrocoating technique (NZ Institute of Chemistry, pp. 4-5).

Advantages: complete coating for raw materials, very quick application, fully automatic process, low coating cost and high efficiency (Lewarchik, 2015).
Disadvantages: mostly applied by the manufacturers, requires expensive technological equipment and competence of personnel.

Ecological-friendly Coatings

Most of volatile organic components are released to atmosphere from final vehicles' assembly plants and cleaning processes. Car manufacturers follow the modern trends and become more and more environmental-friendly. They start to use techniques that help to reduce VOC emission and solvent usage during the application and curing phases (M. Mohseni, H. Yari, B. Ramezanzadeh, p. 26). Some of them are described below:

UV curing is different from the original curing because specific length EM waves do the same work as the temperature does. This process is similar to the microwave oven functionality where even the lower layers could be heated without using curing chambers (P. Mills and J. Heathcote, 2012). IR curing is not very different from UV curing and works on the same principles. Moreover, same materials could be used for both UV and IR curing systems in the application phase. IR and UV systems help to use heat-sensitive materials as automotive components. However, wave is transferring different amounts of energy and that is the main difference between them (Horinka, 2003).

Water based paints have lower level of organic solvents than the mostly used ones. Moreover, these small amounts of solvent which are in the water based paints can dry up even to the complete evaporation. However, in this case VOCs are also released to atmosphere. Water based paints are quick developing technology and even nowadays it is possible to have same lifetime and drying time as their solvent-based equivalents; but the cost is still not the advantage of using them (Paint Quality Institute).

Powder coating is spraying on the pre-heated surface. The body is electrically grounded and particles of pigments and resins are sprayed on the surface (PAUWAY Co.). This technique is called painting of the future because with the same durability as the solvent based painting systems it is ten times cheaper. Also, it could be described as the best option for automotives that have to be resistant to chemical and environmental issues (M. Mohseni, H. Yari, B. Ramezanzadeh, p. 27). U.S. Army outsources this service from the contractors (PAUWAY Co.). However, in the civilian market it is still not widely used technique and only rims are painted in this way.

Advantages: healthier technologies to environment and personnel, requires less time, baking chambers become irrelevant.

Disadvantages: in most cases cost (except powder coating).

Coating Facility and Equipment

As it was mentioned before, coating is very versatile process and it leads to huge variety of equipment depending on the specific technique. For structural introduction to the basic equipment, it will be separated by its function: coating, curing and personnel protection.

It is not possible to compare specific techniques' equipment in terms of cost because electrocoat is used basically for manufacturers and there are no data about the approximate prices of its system while spraying or powder coating are so popular that even bigger e-shop sell their equipments for the private businesses. E.g. powder coating chamber could be bought from 10 000 USD or spraying from 5 000 USD. Price increases if the system has baking chamber at the same time (Global trade market Alibaba). However, Table 9 will help to see the equipment necessities for different techniques and introduce to the operational features.

Table 9. Painting equipment

Equipment	When is it used? How does it work?
Polishing machine	It is used in every coating phase for different reasons. During the preparation it helps to clean the surface. After applying primer and filler or the topcoat it helps to flatten roughness (A. S. Savich, V. P. Ivanov, V. K. Yaroshevich, 2009, pp. 174-175).
Electrocoat tanks	The most important installation in electrocoating which is fully automated. Tanks have to be larger than the vehicle's body and filled with paints and other indigridients. When the vehicle is immersed, between anode and cathode (cathode is vehicle) electrolysis starts. In several minutes, cathode is applied with several different coating layers one after another. Chillers are used to keep the specific temperature (it depends on paints) (NZ Institute of Chemistry, p. 3).
Painting chamber	Spraying has to be applied only when there are no dusts in the air, humidity and temperature levels have to fit the standards. It is difficult to achieve it without having a specific place for that. Painting chamber provides best conditions and ventilation during the application.
Spraying guns	Work not only for spraying technique, but for powder coating as well and even for electrocoating when the phosphating layer is applied and film has to be rinsed after taking our vehicle from the electrocoat tank (NZ Institute of Chemistry, pp. 2, 4). Spraying guns will not change brushes in some cases; however, it is the most efficient way to coat vehicles after electrocoating. Moreover, spraying guns are easy to operate and it is not difficult to learn it. They work in terms of air compression which is spread with small amounts of coating liquid (HQ, Department of the Army, 2008, p. 109).

Brushes / rollers	Used for topcoats (e.g. spot painting or CARC), primer application or touch up, rollers could be used for large surfaces as well. It is much easier to paint difficult places with round brush while rollers apply coating quicker if the surface is flat (HQ, Department of the Army, 2008, p. 42).
Patula / putty knife	Used for fillers application (HQ, Department of the Army, 2008, p. 29).
Spraying robots	Robots are painters that have the highest accuracy rate in spots painting. When they are programmed, human participation is not needed (HQ, Department of the Army, 2008, p. 89).
Wrapping paper / masking tape	When the vehicle is being sprayed, some of its parts have to be covered with paper or tape to prevent unnecessary applications. Wrapping paper is mostly used on large surfaces, while tape is irregular form objectives and smaller parts (HQ, Department of the Army, 2008, p. 114).

Drying is not as miscellaneous as the coating and the equipment does not differ so much. From financial perspective, curing chambers or IR systems for automotive could be bought from 5 000 USD (Global trade market Alibaba). Mainly, systems are selected based on the conditions: if there will be cured heat-sensitive parts or not. More deeply maintenance questions are described in Table 10.

Table 10. Curing equipment

Equipment	When is it used? How does it work?
Baking / curing chamber	It is used in the last electrocoating phase and after every single layer application when other techniques are used if the specific layer requires higher temperatures. The operating principle is similar to microwave oven, where radiation increases the temperature up to 180 ◦C (NZ Institute of Chemistry, p. 1).
UV / IR curing system	Used for hardening the coating layers. Radiation is drying the surface without the necessity of raising the temperature. Under UV or IR lamps it is possible to dry them in several minutes. Because of that these techniques are developing fast nowadays. (M. Mohseni, H. Yari, B. Ramezanzadeh, pp. 26-27) (Horinka, 2003).

Personnel protection is not the least significant measures in non-automatic coating techniques. However, their cost is so small that in comparison with system equipment they could be not counted in. Table 11 presents the basic equipment parts and explains when they are used.

Table 11. Personnel protection equipment

Equipment	When is it used? How does it work?
Respirators	When the vehicles are sprayed indoors and there are no ventilation, respirators have to be worn to protect airways from particles which could be even too small to see (HQ, Department of the Army, 2008, p. 4).
Glasses	Anytime there is an option to get some chemicals (thinners, cleaners, etc.) into the eyes, chemical splash-proof goggles have to be worn. They prevent from physical contact with an eye which could cause serious injuries or even death. Moreover, using hand tools or spraying with air pressure could lead to flying debris. In this case, shock-proof goggles have to be worn (HQ, Department of the Army, 2008, pp. 4,6).
Plastic face shield	Alternative to glasses if protecting eyes from chemicals, however, it might be difficult to wear respirator (HQ, Department of the Army, 2008, p. 5).
Protective clothing	They are used when CARC is applied by brushing and rolling to fully cover workers body from possible allergic reaction to chemicals (HQ, Department of the Army, 2008, p. 9).

First part of the survey:

Lietuvos kariuomenės dažymo koncepcija

Kadangi LK Depų tarnybai priklausančiai dažyklai keliami aiškūs tikslai nebuvo suformuluoti prieš ją įsigyjant, būtų įdomu sužinoti asmeninę nuomonę, kokia ta dažykla turėtų būti Lietuvos kariuomenėje, kokiems faktoriams turėtų būti teikiamos prioritetinės vertės ir koks rezultatas tenkintų geriausiai ginkluotųjų pajėgų poreikius.

*Privaloma

Kaip svarbu dažyti kariuomenės transporto priemonių paviršius neutraliomis spalvomis? *

	0	1	2	3	4	5	
Visiškai nesvarbu	○	○	○	○	○	○	Svarbiausias kriterijus

Kaip vertintumėte keletu spalvų (maskuojančiu raštu) nudažytos transporto priemonės galimybę vizualiai neišsiskirti vietovėje? *

	1	2	3	4	5	
Prastai	○	○	○	○	○	Puikiai

Kaip vertintumėte viena maskuojančia spalva nudažytos transporto priemonės galimybę vizualiai neišsiskirti vietovėje? *

	1	2	3	4	5	
Prastai	○	○	○	○	○	Puikiai

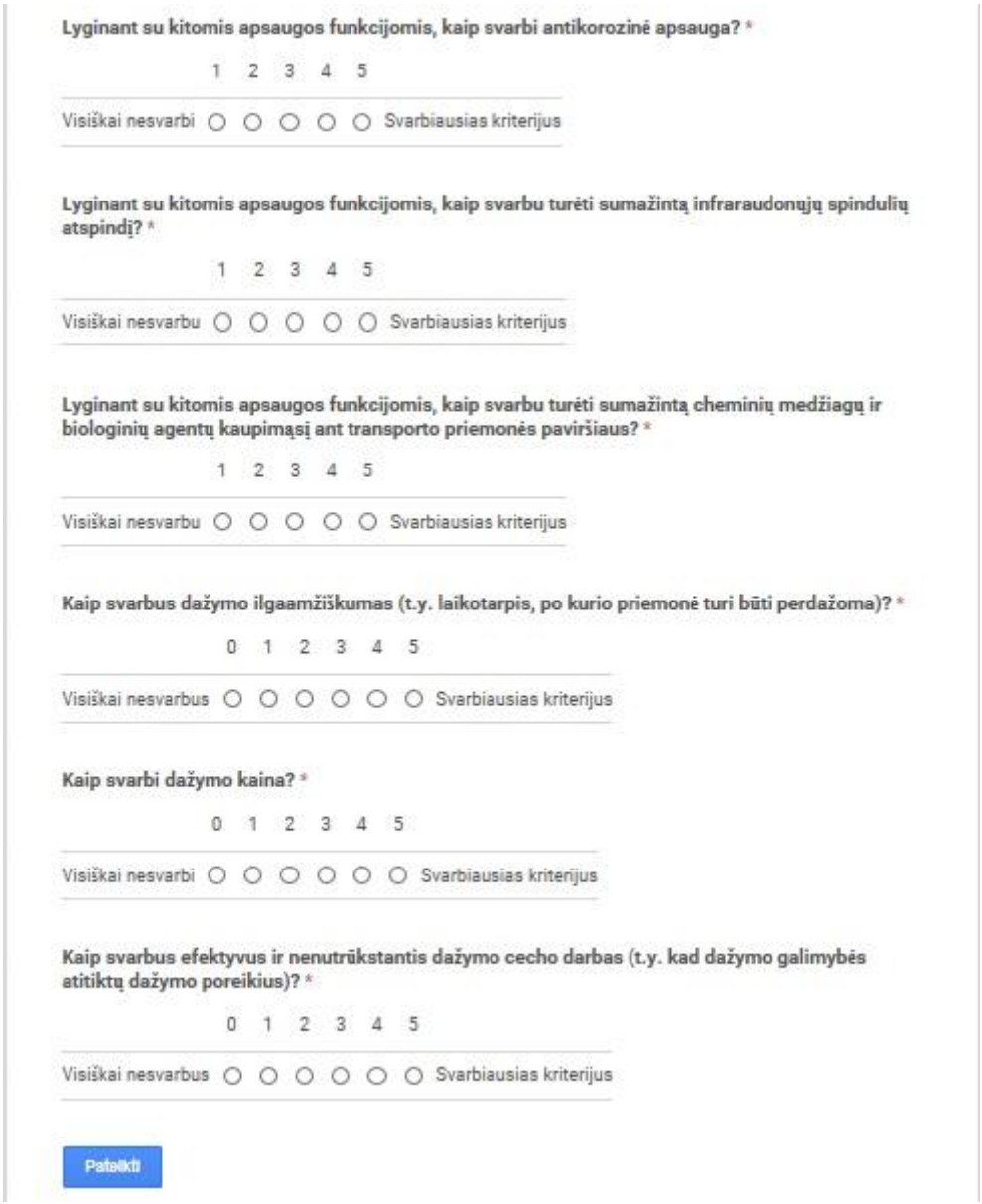
Kaip svarbi dažant transporto priemonių apsauga (nuo korozijos, išorės veiksnių, sumažintas IR atspindys, nuo konsistencijų kaupimosi ant paviršių)? *

	0	1	2	3	4	5	
Visiškai nesvarbi	○	○	○	○	○	○	Svarbiausias kriterijus

Lyginant su kitomis apsaugos funkcijomis, kaip svarbi antikorozinė apsauga? *

	1	2	3	4	5	
Visiškai nesvarbi	○	○	○	○	○	Svarbiausias kriterijus

Second part of the survey (the last question in the first part of the survey and the first question in the second one are the same):



Lyginant su kitomis apsaugos funkcijomis, kaip svarbi antikorozinė apsauga? *

	1	2	3	4	5	
Visiškai nesvarbi	○	○	○	○	○	Svarbiausias kriterijus

Lyginant su kitomis apsaugos funkcijomis, kaip svarbu turėti sumažintą infraraudonųjų spindulių atspindį? *

	1	2	3	4	5	
Visiškai nesvarbu	○	○	○	○	○	Svarbiausias kriterijus

Lyginant su kitomis apsaugos funkcijomis, kaip svarbu turėti sumažintą cheminių medžiagų ir biologinių agentų kaupimąsį ant transporto priemonės paviršiaus? *

	1	2	3	4	5	
Visiškai nesvarbu	○	○	○	○	○	Svarbiausias kriterijus

Kaip svarbus dažymo ilgaamžiškumas (t.y. laikotarpis, po kurio priemonė turi būti perdažoma)? *

	0	1	2	3	4	5	
Visiškai nesvarbus	○	○	○	○	○	○	Svarbiausias kriterijus

Kaip svarbi dažymo kaina? *

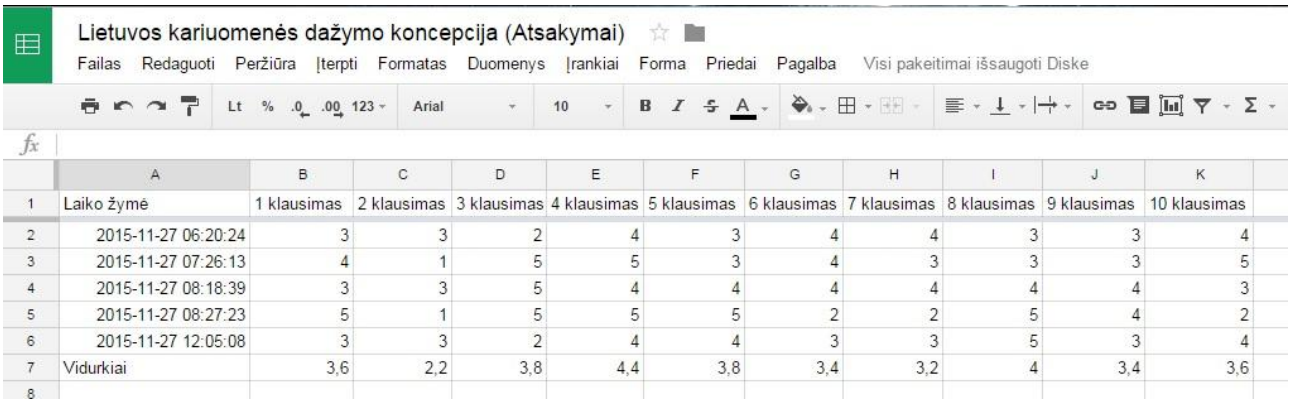
	0	1	2	3	4	5	
Visiškai nesvarbi	○	○	○	○	○	○	Svarbiausias kriterijus

Kaip svarbus efektyvus ir nenutrūkstantis dažymo cecho darbas (t.y. kad dažymo galimybės atitiktų dažymo poreikius)? *

	0	1	2	3	4	5	
Visiškai nesvarbus	○	○	○	○	○	○	Svarbiausias kriterijus

Pateikti

Appendix 4. Survey's results



Lietuvos kariuomenės dažymo koncepcija (Atsakymai)

Failas Redaguoti Peržiūra Įterpti Formatas Duomenys Įrankiai Forma Priedai Pagalba Visi pakeitimai išsaugoti Diske

Arial 10

	A	B	C	D	E	F	G	H	I	J	K
1	Laiko žymė	1 klausimas	2 klausimas	3 klausimas	4 klausimas	5 klausimas	6 klausimas	7 klausimas	8 klausimas	9 klausimas	10 klausimas
2	2015-11-27 06:20:24	3	3	2	4	3	4	4	3	3	4
3	2015-11-27 07:26:13	4	1	5	5	3	4	3	3	3	5
4	2015-11-27 08:18:39	3	3	5	4	4	4	4	4	4	3
5	2015-11-27 08:27:23	5	1	5	5	5	2	2	5	4	2
6	2015-11-27 12:05:08	3	3	2	4	4	3	3	5	3	4
7	Vidurkiai	3,6	2,2	3,8	4,4	3,8	3,4	3,2	4	3,4	3,6
8											

Perduodamo turto vertė:

Turtas	Įsigijimo vertė (EUR)	Sukauptas nusidėvėjimas (EUR)	Likutinė vertė iki rekonstrukcijos (EUR)	Rekonstrukcijos vertė (EUR)	Turto vertė po rekonstrukcijos (EUR)
Pastatas - Technikos depo dirbtuvės	529012,11 (1826573,00 LT)	331137,83 (1143352,69 LT)	197874,28 (683220,31 LT)	1535301.10	1733175,38
Aikštelė	-	-	-	241326.85	241326.85
Rampa	-	-	-	11593.94	11593.94
Dujų tinklai	-	-	-	48276.89	48276.89
Vandentiekio tinklai	-	-	-	26333.87	26333.87
Nuotekų šalinimo tinklai	-	-	-	39913.04	39913.04

Perduodamo turto būklė perdavimo metu šalims yra žinoma.

Perdavimo metu dujų skaitiklio FM9 FMR DN50 940 Nr. R000010503 rodmuo V_b=0,00000002 m3;

Aktas yra sudarytas 2 (dviem) vienodą juridinę galią turinčiais egzemplioriais, po vieną egzempliorių abiem šalims.

PRIDEDAMA:

1. Nekilnojamojo turto registro centrinio duomenų banko išrašo kopija, 17 lapų;
2. Technikos depo dirbtuvių Juozapavičiaus pr. 11 Kaune rekonstravimas statybinės dokumentacijos perdavimo – priėmimo aktas, 1 lapas;

Perdavė:

VĮ Turto banko
Projektų skyriaus viršininkas
l. e. Nekilnojamojo turto departamento direktoriaus pareigas

LaimasDaniūnas,

Priėmė:

Komisijos pirmininkas kpt. Linas Kuzminskas

Komisijos nariai: mjr. Rolandas Ivaškevičius

Liudvikas Charževskis

Ingrida Mikalauskienė