Health Sciences University of Mongolia
Department of Medical Device Engineering

Hamburg University of Applied Sciences
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Medical health care problems and possible solutions for developing countries: Case study Mongolia

Master - thesis

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Propound by

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IV. List of acronyms

Acronym	Meaning	introduced
4DCT	Four Dimensional Computed Tomography	6.2
ADB	Asia Development Bank	5.1
AISI	American Iron and Steel Institute	7.2
BCM	Broadcom (SoC abbreviation)	8.4
CDP	Committee for Development Policy	4.1
CSSD	Central Sterile Service Department	7.6
CPU	Central Processing Unit	8.4
CT	Computed Tomography	VI
CT-Angio	Computed Tomography Angiography	6.2
DIN	Deutsches Institut für Normung (German, German Institute for standardization)	6.2
DNA	Deoxyribonucleic acid	6.2
DST	Drug Susceptibility Testing	6.2
EI	Education Index	4.2
EML	Essential Medicine List	4.3
EVI	Economic Vulnerability Index	4.1
EYOS	Expected Years of Schooling	4.2
FID	Free Induction Decay	8.1
FIND	Foundation for Innovative New Diagnostics	6.2
FFT	Fast Fourier Transformation	8.5
GDP	Gross Domestic Product	4.3
GNI	Gross National Income	4.1
GOST	Gosudarstvennyy Standart (Russian, State Standard)	7.1
GPIO	General Purpose Input /Output	8.4
GPS	Global Positioning System	7.5
GPU	Graphics Processing Unit	8.4
HA	Halbach-Array	8.5
HAI	Hospital Acquired Infections	4.5
HCC	Hepatocellular Carcinoma	6.1
HCV	Hepatitis C	6.2
HDI	Human Development Index	1.4
HDR	Human Development Report	4.5
Hep	Hepatitis	6.1
HIV	human immunodeficiency virus	4.3
HRCT	High Resolution Computed Tomography	6.2
HSUM	Health Sciences University of Mongolia	5.2
HTA	Health Technology Assessment	1.4
i.MX	Freescale (SoC abbreviation)	8.4
ICCIP	International Climate Change Information Programme	VI
ICD-10	International Statistical Classification of Diseases and Related Health Problems	6.1
ICU	Intensive Care Unit	1.3
ICMJE	International Committee of Medical Journal Editors	1.5
IEC	International Electrical Commission	7.2
II	Income Index	4.2
IIs	Intestinal Infections	6.1
IJERA	International Journal of Engineering Research and Applications	7.5
IT-network	Isolation Terra - network	7.2
kVA	Kilo Volt Ampere	7.4
LCD	Least Developed Country	4.1
LED	Light Emitting Diode	6.2
LEI	Life Expectancy Index	4.2
LHD	Low Human Development	4.2
LINAC	Linear Accelerator	5.1

Acronym	Meaning	introduced
MDG	Millennium Development Goal	1.4
MDR-TB	Multi Drug Resistant Tuberculosis	6.2
MeshHp	Mongolian Emergency Service Hospital Hygiene project	5.1
MHD	Medium Human Development	4.2
MLC	Multileaf Collimator	5.1
MNS	Mongolian National Standard	6.1
MOH	Ministry of Health	5.1
MonICU	Mongolian Intensive care unit	4.5
MOTT	Mycobacteria other than tuberculosis	6.1
MR	Magnetic Resonance	8.1
MRI	Magnetic Resonance Imaging	1.3
MRI-Angio	Magnetic Resonance Imaging Angiography	6.2
MSM	Qualcomm (SoC abbreviation)	8.4
MUST	Mongolian University of Science and Technology	5.2
MYOS	Mean Years of Schooling	4.2
NAT	Nucleic Acid Testing	6.2
NCC	National Cancer Center	5.1
NCCD	National Center for Communicable Diseases	5.1
NEMA	National Electrical Manufacturers Association	7.4
NIH	National Institutes of Health	7.5
NRTL	National Reference Tuberculosis Laboratory	5.1
PC	Personal Computer	8.4
PCR	Polymerase Chain Reaction	6.2
PEPFAR	United States President's Emergency Plan for AIDS Relief	6.2
PE	Protective Earth	7.1
PET	Positron Emission Tomography	VI
Pi	Python interpreter	8.4
RCBO	Residual Current Breaker with Over-current protection	7.3
RCD	Residual Current Device	7.3
RF pulse	Radiofrequency pulse	8.1
RIs	Respiratory Infections	6.1
RNA	Ribonucleic acid	6.2
RR-TB	Rifampicin Resistant Tuberculosis	6.2
RSNA	Radiology Society of Northern America	V
S	Samsung (SoC abbreviation)	8.4
Schuko	Schutzkontakt (German, protection pin)	7.1
SDRAM	Synchronous Dynamic Random Access Memory	8.4
SoC	System on Chip	8.4
SPD	Surge Protective Device	7.3
STI	Sexually Transmitted Infection	4.5
STD	Sexually Transmitted Disease	4.5
TB	Tuberculosis	4.5
TN-network	Terra Neutral - network	7.2
TT-network	Terra Terra-network	7.2
UK	United Kingdom	4.3
UN	United Nations	4.1
UPS	Uninterruptable Power Supply	7.1
US	Ultrasonography	6.1
USAID	United States Agency for International Development	6.2
UTC	Universal Time, Coordinated	4.4
VA	Volt Ampere	7.4
WHO	World Health Organization	1.4
XDR-TB	Extensive Drug Resistant Tuberculosis	6.2
ZN	Ziehl-Neelsen	6.2

V. About the Author

Sven Kannenberg is master student in the degree of Biomedical Engineering at the Hamburg University of Applied Sciences in Germany. He graduated from the same university as Bachelor of Science in Biomedical Engineering in 2012. During his time as a student he focussed on different projects and topics such as:

a. "Computer assisted evaluation of surgical maxillary expansion based on pre- and post-operative CT", 2008 - 2010, study project during Bachelor studies at Hamburg University of Applied Sciences, Germany.
b. "Quantitative evaluation concept of artifact reducing algorithms for medical CT data", 2011 - 2012, Bachelor-thesis at Kitami Institute of Technology, Japan, for Hamburg University of Applied Sciences.
c. "Robotic Arm programming in a complex drug delivery system", 2013-2014, study project during Master studies at Hamburg University of Applied Sciences.
d. "Biofeedback control of heart rate variability – effects of training and gender", 2013 - 2014, study project during Master studies at Hamburg University of Applied Sciences.

During his studies he was author and co-author of different publications. The following list shows the non-German publications:

1. Dong J, Hayakawa Y, Kannenberg S, Kober C. *Metal-induced streak artifact reduction using iterative reconstruction algorithms in x-ray computed tomography image of the dentoalveolar region.* Oral Surg Oral Med Oral Pathol Oral Radiol. 2013 Feb;115(2):e63-73. doi: 10.1016/j.oooo.2012.07.436. Epub 2012 Oct 1. (Pubmed ID: 23036800)

2. Dong J, Hayakawa Y, Kannenberg S, Kober C. *Statistical Iterative Reconstruction Applied for Streak Artifact Reduction in X-ray CT Image of Dento-Alveolar Region.* RSNA 2012, November 25th - 30th , McCormick Place, Chicago, Illinois

3. Dong J, Kondo A, Hayakawa Y, Kannenberg S, Kober C. *Sequential Statistical Reconstruction for Streak Artifact Reduction in X-ray CT Image.* RSNA 2011, November 27th - December 2nd , McCormick Place, Chicago, Illinois

4. Kannenberg S, Dong J, Kondo A, Abe K, Hayakawa Y, Kober C. *Basic Evaluation of artifact reducing algorithms for medical CT data.* In: Proceedings of Info-Hokkaido 2011; 2011 Oct 1; Kitami, Japan. Information Processing Society of Japan (IPSJ); 2011 pp. 213-214

5. Kober C, Kannenberg S, Frank B, Al-Hakim G, Parvin A, Landes C, Sader R. *Computer-assisted Pre- and Postoperative Evaluation of Surgically Assisted Rapid Maxillary Expansion.* Int J Comput Dent. 2011 Sep 30; 14(3); 233-41. (Pubmed ID: 22141233)

6. 董 建 (Dong J), 近藤 篤 (Kondo A), 阿部 恒介 (Abe K), 早川 吉彦 (Hayakawa Y), Kober C, Kannenberg S. *OS-EM*画像再構成法を用いて*X*線*CT*画像における金属アーチファクトの軽減 Forum on Information Technology 2011 (FIT2011), September 07 – 09, Hakodate University, Japan.

7. Kannenberg S, Frank B, Parvin A, Al-Hakim G, Preiss A, Landes C, Sader R, Kober C. *Computer assisted evaluation of surgical maxillary expansion based on pre- and post-operative CT*, In: Proceedings of the International Workshop on Modern Science and Technology, Kitami, September 2010, Kitami, Japan. –poster-

8. Kober C, Kannenberg S, Frank B, Al-Hakim G, Parvin A, Landes CA, Sader R. *Computer assisted maxillary pre- and post-operative deformation analysis upon surgical distractive transversal expansion.* Cars2010, June 2010, Geneva.

9. Kannenberg S, Frank B, Parvin A, Al-Hakim G, Landes C, Sader R, Kober C. *Evaluation of surgical maxillary expansion based on pre- and post-operative CT.* Bernd-Spiessl-Symposium 2009, Thursday, June 11th - Saturday 13th, 2009, University Hospital Basel, Switzerland. –poster–

During the six months for preparing this Master-thesis, Mr. Kannenberg spent five months in Mongolia, to perform personal research, included interviews with

Medical doctors	Technicians	University professors
Nurses	Biomedical Engineers	University workers
	Medical device users	University students

as well as observations of the general working problems and problem solving methods of people, who are involved in the use, maintenance or repair of medical devices.

His interviews included people from the following universities:

- Health Sciences University of Mongolia
- Mongolian University of Science and Technology
- Etugen private University

Furthermore he observed and/or worked in the following hospitals:

- SongDo private Hospital
- GrandMed private Hospital
- InterMed private Hospital
- National Central Hospital
- National Cancer Center
- National Center for Communicable Diseases
- District Polyclinic Bayangol

During his stay, he took part in the following meetings:

- National Forum on Infection Prevention and Control (June 17-18)

VI. About the supervisors

Prof. Dr. (mult.) Dr. h.c. (mult.) Walter Leal

Prof. Leal is the head of the research- and transfer-centre "Application of Life Sciences" at the Hamburg University of Applied Sciences and a Professor of Environment and Technology at Manchester Metropolitan University. His focus is on ecology, sustainability and international studies. He is also member of the Projects Complaints Mechanism of the European Bank for Reconstruction and Development and created the International Climate Change Information Programme (ICCIP) in 2009.

"Prof. Walter Leal Filho has a first class degree in Biology and a doctorate in environmental science (PhD), having also completed a post-doctorate programme on environmental communication. He also has a higher doctorate (Dr. rer. nat habil.) in environmental information (DSc), a DPhil in sustainable development and holds the titles of Doctor of Letters (DL), Doctor of Literature (DLitt) and Doctor of Education (DEd) commensurate with his scientific performance and outputs translated by over 300 publications among books, book chapters and scientific papers."

Walter Leal, http://cv.international-projects.eu/

M. Eng. Myagmarnaran Tserendorj

Mrs. Myagmarnaran is the head of the department of Medical Device Engineering at the Health Sciences University of Mongolia. She obtained her Master of Engineering in the degree of Medical Equipment at the Mongolian University of Science and Technology. She has worked at several national and private hospitals in Mongolia as a Biomedical Engineer.

Since 2012 she has been giving lectures in Radiology and Medical Equipment at the Health Science University of Mongolia. She owns certificates of Interventional Radiology and PET/CT (both from the Radiology Society of Northern America [RSNA]), X-ray quality assurance (from the Nuclear Agency of Mongolia) and a diploma of qualified engineering (from the Ministry of Health).

1. Thesis introduction

1.1. Abstract

1.1.1. Abstract English

Mongolia is one of several developing countries, which faces serious problems in the health care system. High technology medical devices and gold standard diagnostics and treatment are mostly not available in these countries and the mortality rates of several diseases could be significantly reduced when knowledge and equipment would be at the same level as developed countries. Therefore the analysis of problems in the health care system of developing countries is necessary to find appropriate solutions.

Like many other developing countries Mongolia does not have own medical technology manufacturers but only companies focused on medical device import from other countries. Therefore also repairing of medical devices is mainly performed by personnel, which were not involved in the manufacturing of the devices and often do not have a technical education from the company to ensure an adequate and quality controlled repairing and maintenance of medical devices. Safety related checks as well as functional checks are not according to any national or international standards and do not detect incorrect calibration.

But also the electrical infrastructure is a serious problem in Mongolia, as the electricity endangers patients, medical doctors, personnel and also the devices. Electrical outages and overvoltage are problems, which require immediate solutions as they are likely to damage sensitive modern medical devices. The importance of an infrastructure improvement is shown by the high amount of damages of technical devices and high need of service for computed tomography (CT) or Magnetic Resonance Imaging (MRI) devices. Multislice CT devices are said to have new damages at their detector units every one or two weeks due to the overvoltage and voltage spikes with up to 230,000 volt.

Strategies to improve the electrical infrastructure in hospitals as well as strategies to avoid applying the wrong voltage to medical devices (220 V instead of required 110 V) are shown in this thesis. Health care problems as cancer, communicable diseases and circulatory diseases are analyzed and the technology for diagnosis and treatment are shown. Here, not only the gold standard but also alternative methods are described with their advantages and disadvantages.

1.1.2. Abstract German

Die Mongolei ist eines von vielen Entwicklungsländern, das große Probleme mit ihrem Gesundheitssystem hat. Hochtechnologische medizinische Gerätschaften und Gold Standard Diagnostik und Behandlung sind in diesen Ländern meist nicht vorhanden und die Sterblichkeitsraten für viele Krankheiten könnten signifikant gesenkt werden, wenn sie in Wissen und Ausstattung vergleichbar mit Industrienationen wären. Daher ist die Analyse von Problemen in Gesundheitssystemen der Entwicklungsländer notwendig, um angebrachte Lösungen zu finden.

Wie auch viele andere Entwicklungsländer besitzt die Mongolei keine eigenen Medizintechnik Hersteller sondern nur Händler, die sich auf den Import von ausländischen Medizintechnik Produkten konzentrieren. Dadurch werden auch Reparaturen dieser Medizintechnik Geräte meist von Personen durchgeführt, die keinen Bezug zum Herstellungsprozess haben und in vielen Fällen keine spezielle Aus- bzw. Weiterbildung des Unternehmens bekommen haben, um eine angemessene und qualitätskontrollierte Reparatur und Wartung der Geräte zu garantieren. Sowohl Sicherheitstechnische- als auch Funktionstechnische- Kontrollen sind nicht über eine nationale oder internationale Norm sichergestellt und können keine fehlerhafte Kalibrierung erkennen.

Doch auch die Elektrische Infrastruktur ist ein großes Problem in der Mongolei, da die Elektrizität eine Gefahr für Patienten, Ärzte, Personal und Geräte darstellt. Stromausfälle und Überspannungen sind Probleme, die sofortige Lösungen nötig machen, da sie die Ursache von Schäden an empfindlichen modernen medizinischen Geräten sein können. Die Bedeutung einer Infrastruktur-Verbesserung kann anhand der vielen Schäden technischer Geräte und der Wartungsintensivität der Computertomographen (CTs) und Magnetresonanztomographen (MRT) bewertet werden. Multislice CT Geräte sollen alle ein bis zwei Wochen neue Schäden an einzelnen Detektoreinheiten haben, die auf Überspannung und Spannungsspitzen bis zu 230.000 Volt zurückzuführen sind.

Strategien um die elektrische Infrastruktur in Krankenhäusern zu verbessern und die Verwechselbarkeit von Stromanschlüssen für 110 Volt und 220 Volt Geräten zu gewährleisten werden in dieser Abschlussarbeit aufgezeigt. Gesundheitsprobleme wie Krebs, Infektionserkrankungen und Kreislauferkrankungen wurden analysiert und die Technologien für Diagnose und Behandlung werden vorgestellt. Hierbei wurde nicht nur auf den Gold Standard eingegangen, sondern auch auf alternative Methoden mit ihren Vor- und Nach-teilen.

1.1.3. Abstract Mongolian

Монгол улс нь эрүүл мэндийн тогтолцоонд нь ноцтой асуудал тулгарсан хөгжиж буй орнуудын нэг юм. Өндөр технологийн эмнэлэгийн тоног төхөөрөмжүүд болон топ стандартад хүрэх оношлогоо, эмчилгээ нь эдгээр улс оронуудад ихэвчлэн байхгүй байгаа бөгөөд эмнэлэгийн салбарт ажиллаж буй эмч ажилтнуудын мэдлэг, хэрэглэж буй тоног төхөөрөмжүүд нь өндөр хөгжилтэй орнуудтай ижил түвшинд хүрсэн үед хэд хэдэн өвчний нас баралт эрс багасгаж болох юм. Иймээс хөгжиж буй орнуудын эрүүл мэндийн тогтолцооны асуудалд дүн шинжилгээ хийж, зохих шийдлийг олох шаардлагатай байна.

Бусад хөгжиж буй олон орнуудын нэгэн адил Монгол улс нь өөрийн эмнэлэгийн тоног төхөөрмжийн үйлдвэрлэгчгүй бөгөөд зөвхөн компаниуд бусад улс орны эмнэлгийн тоног төхөөрөмжийг импортлон оруулахад анхаарлаа хандуулсаар байна. Иймээс эмнэлэгийн тоног төхөөрөмжийн засвар үйлчилгээг ихэвчлэн тухайн тоног төхөөрөмжийн үйлдвэрлэгчийн сургалтанд хамрагдаагүй ажилтан гүйцэтгэх бөгөөд, зарим нь чанарын хяналтат засвар үйлчилгээний талаархи техникийн мэдлэггүй байдаг. Тоног төхөөрөмжийг хэрэглэх үеийн аюулгүй ажиллааг шалгах, мөн түүнчлэн тоног төхөөрөмж зөв горимоороо ажиллаж байгаа эсэхийг шалгах шалгалтууд нь ямарч улс орны болон олон улсын стандартад нийцэхгүй байгаа бөгөөд тоног төхөөрөмжийн тохируулгын алдааг ч илрүүлэхгүй байна.

Мөн Монгол улсын цахилгын эрчим хүчний дэд бүтцэд ч ноцтой асуудлууд байгаа бөгөөд тухайлбал зарим эмнэлгийн цахилгаан хангамжийн шугам сүлжээ нь өвчтөн, эмч, ажилтнууд болон эмнэлэгийн тоног төхөөрөмжид хор хөнөөл учруулахуйц хэмжээнд байна. Цахилгаан тасалдах болон цахилгааны хүчдэл огцом ихсэх зэрэг нь орчин үеийн өндөр мэдрэмж бүхий эмнэлэгийн тоног төхөөрөмжүүдийг гэмтээх магадлалтай байдаг тул нэн даруй шийдвэрлэх асуудал юм. Орчин үеийн Компьютерийн томографи (CT) болон Соронзон резонанс дүрслэлийн (MRI) тоног төхөөрөмжүүдийн өндөр эрэлт хэрэгцээ, техник тоног төхөөрөмжүүдийн гэмтлийн үлэмж тоо хэмжээ зэрэг нь цахилгаан сүлжээний дэд бүтцийг сайжруулахын чухал ач холбогдлыг харуулж байна. Цахилгаан тасалдах болон цахилгааны хүчдэл огцом ихсэх тухайлбал хүчдэл 230,000 Вольт хүртэл нэмэгдсэнээс Олон зүсэлтэт дүрслэл бүхий компьютер томографын төхөөрөмжүүдийн мэдрэгч хэсэгт 7-14 хоног тутамд шинээр гэмтэл гардаг гэж яригддаг.

Эмнэлэг дэх цахилгаан хангамжийн сүлжээний дэд бүтцийг сайжруулах стратеги, мөн түүнчлэн эмнэлгийн цахилгаан хэрэгсэлд буруу хүчдэл (110В –ийн хүчдэл шаардагдах цахилгаан хэрэгслийг 220В-ийн цахилгаан сүлжээнд залгах) хэрэглэхээс зайлсхийх стратегуудийг энэ тезист үзүүлсэн болно. Мөн зүрх судасны өвчнүүд, халдварт өвчнүүд, хорт хавдар зэрэг эрүүл мэндийн асуудлуудыг судалж, оношлогоо болон эмчилгээний арга технологиудыг үзүүлсэн болно. Энд зөвхөн топ стандартийг дурьдсангүй мөн өөр арга барил тэдгээрийн давуу болон сул талууд нь тайлбарласан байгаа.

1.2. Motivation of this Thesis

As long as there have been medical doctors, there has also been medical research and technology. First basic approaches to medical research and technology have been documented in ancient times. The initial medical doctors used herbs, hot stones and other things given by nature. Although there has been a development of medicine before the industrial revolution, the end of the 18th century established a very close relationship between physics and newly invented technology for medicine.

One famous example for medical technology was discovered in 1895 by a physicist, who received the first Nobel Prize in Physics:

"In 1895 Wilhelm Röntgen made experiments with cathode rays - radiation emitted in a low pressure glass tube when a voltage is applied between two metal plates. He discovered weak light appearing on a screen a bit away although the glass-tube was shielded. Subsequent experiments showed that the radiation was previously unknown and penetrating."

The Official Website of the Nobel Prize - The Nobel Prize in Physics 1901 [1]
http://www.nobelprize.org

In the 20th century the discovery of electric energy caused a rapid development of medical technology, which can be seen in the inventions and discoveries of various Nobel Prize winners in the fields of Medicine, Chemistry and Physics, e.g. with Willem Einthoven's "Electrocardiogram" [2].

Furthermore the invention of drugs, e.g. Robert Koch's discovery of the pathogen of Tuberculosis or Sir Alexander Flemming's development of Penicillin, the development of mechanical ventilators and anaesthesia and the installation of the first Intensive Care Units (ICUs) in the 1950s were milestones in modern medicine. Research is done in many fields of health care, not only in pharmaceutics, but also in treatment methods, technologies and health care systems.

Modern research of medical technologies mainly lies in the hand of engineers, because the technologies include more and more mechanical but also electrical expertise. Sometimes collaborations between medical researchers and engineers produce new ideas and technologies, making medical technology a more and more High-end technology. Computer assisted tomography for example, which was invented by Allen M. Cormack and Godfrey N. Hounsfield [3], is an often used technology, and Magnetic Resonance Imaging invented by Paul C. Lauterbur and Sir Peter Mansfield [4] is probably one of the highest technology instruments for diagnosis in medicine.

But whenever a new technology was invented, the kinematics, electronics and mathematics of it became more and more sophisticated. Nowadays medical technology has certain requirements, which need to be fulfilled in order to use the devices. X-ray is working with high voltage between anode and cathode of the X-ray tube, Computed Tomography (CT) needs even higher voltages to create the high energy x-ray. Its detectors for multi-slice image acquisition became more and more sensitive. Magnetic Resonance Imaging (MRI) needs very specific cooling liquids to keep the device in working temperature and Positron Emission Tomography (PET) needs radio nuclides with a very short half-life.

As a result, only the industrialized high technology countries fulfil all the requirements for modern medical technology. More and more expenses need to be done by medical doctors or hospitals to buy and use modern medical technology. In relation to the new technology, appropriate new pharmaceutics and treatment methods are discovered or invented, recognizing the need and the possibilities of these new technologies.

Most medical diagnostics technology companies mainly produce their devices for the high-technology markets, such as Europe, the USA or Japan. Therefore they focus their research on improving the quality of images or the accurate treatment without limitations to the requirements. As a result, every new medical device consumes more energy, requires more complex drugs or supplies and of course costs more than the previous devices. The World Health Report 2013 says:

"In total, more than US$ 100 billion is spent globally on health research each year (71). About half of this is in the private sector, mainly in the pharmaceutical and biotechnology industries, and the products of this research are directed mainly at markets in high-income countries (71, 74)."[1]

"The World Health Report 2013 - Research for Universal Health Coverage" Page 45 [5].

The Human Development Report 2013 says that only 31.9% of the world's population is living in high or very high human development countries [6]. This means that about 68.1% of the world's population does not have widely access to modern medical technology and that most of the (worldwide) medical research is done for less than one third of the world's population. About 12.3% of all people in the world are living in countries, which are defined as "Least Developed Countries". The Human Development Report expects that it will increase up to 15.1% of world's population until 2030. At that time the population in high and very high human development countries will be only 29.5% of all people in the world [6].

In industrialized countries, a kind of gold standard has been established for nearly every illness, which gives the highest precision in detecting illnesses and the most effective methods to treat them. Especially the diagnosis of illnesses relies more and more on image acquisition, a field that has seen rapid development in recent years. To maximize the signal-to-noise-ratio of imaging modalities like CT, MRI or PET, more accurate detectors, higher magnetic fields and more complex substances are in use.

It can be concluded that not only the medical research, but also the international gold standards in medicine focuses on less than one third of the world's population, while the remaining two thirds suffer from medical problems, without access to adequate solutions. The World Health Organisation writes:

"Drug development is a case in point: only 21 of 1556 (1.3%) new drugs developed over the 30-year period from 1975 to 2004 were for diseases not found in high-income countries (75)".[2]

"The World Health Report 2013 - Research for Universal Health Coverage" Page 45 [5].

Mongolia is an interesting country, because it faces very unique problems in health care. On one hand the country is more than 4 times as big as the Federal Republic of Germany. The population in Mongolia on the other hand is only about 2.9 million people [7], which are spread very unequally throughout the country. While the capital district of Ulaanbaatar, with a size twice as big as the smallest non-city federal state of Germany "Saarland", contains more than 1 million citizens (population density of 261.87 people per square kilometre) , 9 of 21 districts have a population density of less than 1 person per square kilometre [7]. Creating a comparable health care standard for citizens in the urban areas and the nomads in the rural areas is a big challenge.

[1] (71) *Public health, innovation and intellectual property rights: report of the Commission on Intellectual Property Rights, Innovation and Public Health.* Geneva, World Health Organization, 2006
(74) Røttingen J-A et al. *Mapping of available health research and development data: what's there, what's missing, and what role is there for a global observatory?* Lancet, 2013, May 17. pii:S0140-6736(13)61046-6. doi: http://dx.doi.org/10.1016/S0140-6736(13)61046-6
[2] (75) Chirac P, Torreele E. Global framework on essential health R&D. Lancet, 2006,367:1560-1561. doi: http://dx.doi.org/10.1016/S0140-6736(06)68672-8 PMID:16698397

The afore mentioned facts makes the health care situation very difficult, because solutions for the capital cannot be applied on the rural areas in the same way. According to the Human Development Report 2013 only 67% of the Mongolian population has access to electricity [6], and water supply is not guaranteed. Even the capital of Mongolia sometimes faces problems due to energy shortages or the absence of hot water supply. Expensive modern medical technology is mainly available in private hospitals of Ulaanbaatar, which only a small part of the population can afford to pay for. Outside of Ulaanbaatar it is nearly impossible for medical doctors to earn enough money with an expensive device to compensate the enormous investment.

The modern medicine is developing in Mongolia, as can be seen at the high percentage of physicians in Mongolia (2.8 physicians per 1000 population, USA: 2.7 physicians, New Zealand: 2.4 physicians, Japan: 2.1 physicians) [6]. But also the traditional Mongolian medicine is still present in the Mongolian health care system as the number of 476 traditionally operating medicine doctors in 2012 shows [7].

All this makes Mongolia a special country, which needs individual solutions for different areas. The aim of this master-thesis is to detect the major health care problems in Mongolia and to find technical solutions for these problems. In order to do so, the medical infrastructure in Mongolia is analyzed, the medical problems are documented and the potential for technical solutions is investigated. The resulting cycle of investigation is shown in figure 1.

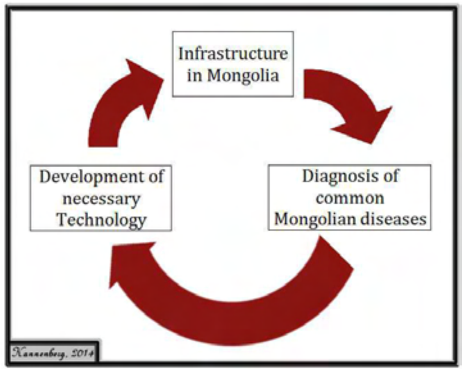

Figure 1: Cycle of investigation, which is visualizing the steps of this thesis

1.3. Purpose of this Thesis

During the last 14 years two major programs were established to make the world more equal:

In 2000 the Millennium Declaration was presented at the United Nations Millennium Summit. 189 nations signed this declaration, which is providing a framework for the development of the world. Eight Millennium Development Goals (MDGs) were established in total for environment, education and poverty, but also health [8]. They are listed in table 1.

Table 1: Millennium Development Goals (MDGs) according to the Millennium Declaration of the United Nations [8]

N°	Goal	N°	Goal
1	Eradicate extreme poverty & hunger	5	Improve maternal health
2	Achieve universal primary education	6	Combat HIV/AIDS, malaria & other diseases
3	Promote gender equality & empower women	7	Ensure environmental sustainability
4	Reduce child mortality	8	Develop a global partnership for development

Three of those eight goals have a direct connection to health care: the children's health (goal 4), the maternal health (goal 5) and the fight against the most common diseases (goal 6). But also other goals like the poverty and hunger reduction (goal 1) or the environmental sustainability (goal 7) will have an impact on health.

Every goal is associated with a number of targets, to define the exact aims and measurable indicators for making progress in these areas. While some targets could be reached up to now, others require a lot of progress in order to be successful. But reaching those international goals does not mean that the whole world has become better: As an example, the target 1 of goal N°1, to half the proportion of people living with less than 1.25$ a day, could be reached in 2010. It is important to note that the situation in many small countries might not have a big statistical influence, because China reduced its national poverty proportion from 60% to 12% [8]. The Human Development Report 2013 wrote that about 1.35 billion people were living in China in 2012 [6]. The MDG Report 2013 wrote that in absolute numbers 700 million people in the world taken out of poverty were enough to achieve this target [8]. Therefore it is to assume that China had a big influence in this statistic.

An indicator for that is the situation in "Eastern Asia", the group where China is categorized in. Table 2 gives an overview of the four countries included in the Eastern Asia group. Formula 1.1 shows that the proportion of the three other countries is only 5.3% from the total population of the group due to Chinas high population. When comparing the Mongolian population alone with the total population of the group (formula 1.2), it becomes obvious that the Mongolian numbers are not substantial enough to have an effect on the statistics of the Eastern Asia group in total. The fact that Eastern Asia fulfilled this target in 2002 [9] is the effect of the Chinese extreme poverty reduction.

Table 2:Population of countries included in the "Eastern Asia" group according to the Millennium Development Goals Reports and proportion of non-Chinese population in the group (data based on the Human development Report 2013)[6, 8]

Country	Population (millions)
Democratic People's Republic of Korea	24.6
Republic of Korea	48.6
Mongolia	2.8
Sum:	76.0
China	1353.6

Proportion of population calculation

$$\frac{76.0}{76.0 + 1353.6} \approx 0.053 = 5.3\,\% \quad (1.1)$$

Mongolian People (proportion calculation)

$$\frac{2.8}{76.0 + 1353.6} \approx 0.00196 = 0.196\% \quad (1.2)$$

Therefore, the global effect of the MDGs cannot be seen as success for every country. In fact, the national progress for each country is as important, as the global effect. A real success is when every nation which has signed the Millennium summit can show that on its own national level the target was achieved.

This thesis takes action in that field by investigating the current situation in Mongolia. Especially the fight against tuberculosis and some other diseases, as well as the children and maternal health are interesting topics in Mongolia, which are the MDGs directly connected to health.

The second program is the "Universal Health Coverage" program of the World Health Organization (WHO). As it is written in the World Health Report 2013:

"In 2005, all WHO Member States made the commitment to achieve universal health coverage. The commitment was a collective expression of the belief that all people should have access to the health services they need without risk of financial ruin or impoverishment."

"The World Health Report 2013 - Research for Universal Health Coverage" Page xi [5].

This universal health coverage is supposed to be achieved by national and international research on health systems, health problems, medical treatments, pharmaceuticals but also on topics, which are only indirectly involved into the health sector, e.g. environment and social systems [5]. *"Every nations should be producer of research as well as consumer of it"* [5], because national problems in health care systems need individual solutions, which can only be developed by people who are in direct contact with the system and its problems. As the World Health Organisation writes:

"Universal coverage is now an ambition for all nations at all stages of development. The timetable and priorities for action clearly differ between countries, but the higher aim of ensuring that all people can use the health services they need without risk of financial hardship is the same everywhere."

"The World Health Report 2013 - Research for Universal Health Coverage" Page 5 [5].

The health system should not be in focus of new research alone, but also the research methods needs to be validated. One of the main factors for medical treatment and research is cost-effectiveness. The Health Technology Assessment (HTA) is a process to evaluate and compare methods and recourses based on their cost-effectiveness in order to find the least expensive solutions for the respective health care issues. Unfortunately, most developing countries have a less efficient health care system than the high-income countries. This often results in more money being spent than necessary or available.

But universal health coverage also includes other kinds of research, especially in developing counties. In many areas of the world the access to appropriate health care does not only depend on financial aspects, but also on the availability of the necessities. Medical doctors have to have access not only to drugs and supplies, but also to medical technology with all its equipment. For instance an anaesthesia device is only useful, when the according drugs are available. And even then, in addition there must be oxygen and a stable source of electricity in order to use the device. If all these factors are given, the most important part is the knowledge of the medical doctor and the technician. Is the medical doctor properly trained to use that device? And does the technician has the means and knowledge to calibrate and maintain the device?

Because there are certain requirements associated with the usage of medical devices, research needs to be done in every country about the capabilities to fulfil these requirements. The question has to be: "Is it possible to use this technology in that country for improving the health care?" This is where this Master-thesis starts.

Mongolia is a developing country, whose Human Development Index (HDI) is above the average of all "Medium Human Development" countries according to the Human Development Report 2013 [6]. But it faces, as well as some "High Human Development" countries, serious problems in the national health care system. Although this thesis is a case study about Mongolia, many problems discussed and solutions given can be related to problems in other developing countries as well. In order to reach universal health coverage, the main questions in every country should be (table 3):

Table 3: Main questions for achieving universal health coverage in developing countries

	Question
1.	What are the main illnesses and diseases in that country?
2.	What is needed to diagnose and treat those illnesses?
3.	Is everything available, which is needed?
If not:	Are there alternative methods to diagnose and treat that illness?
If not:	What can be changed to make that method useable?

To achieve this aim, the thesis will focus on three main aspects:

1. Infrastructure: What kind of medical technology is available in Mongolia and what is its status? Are there companies in Mongolia, which take care of maintenance, repair or calibration of the devices? Are medical technology supplies available in Mongolia and how is their quality? And finally: Can new medical technology be introduced into the Mongolian health care system?

2. Health care problems: What are the most common diseases in Mongolia? What causes the highest mortality? Can the medical gold standard for diagnosis and treatment be utilised? Are there alternatives to take appropriate care of ill patients? And finally: Is there an adequate diagnosis and treatment method available for every major health care problem?

3. Technical solutions: Is it possible to perform changes in existing medical technology to make it fit with the possibilities and requirements of Mongolia? Can the MRI technology be adjusted to require less liquid nitrogen for cooling or can it be run completely without liquid nitrogen? Can technology improvement help Mongolia to fulfil requirements for medical devices?

1.4. Thesis structure

This thesis is divided into eleven chapters, following a red line of literature research over field investigations to experiments and possible solutions for problems discovered. Although this manuscript works with medical content, the "Uniform Requirements" of the International Committee of Medical Journal Editors (ICMJE) is not appropriate for structuring the document. Because this thesis also focuses on social, environmental and technical aspects, the structure of a literature review is chosen. It is replaced by the structure of technical documentation in the chapter on technical solutions.

Before the first chapter, some background information of the thesis will be given. After an outline and lists for tables, figures and acronyms used in this thesis, a short summary over the author and the two supervisors is given.

The first chapter gives an introduction of the thesis. Abstracts in English, German and Mongolian language and a paper in English language give a brief summary of the performed work for every interested and/or affected person and the motivation & purpose sub-chapters give some background information.

Chapter two and three take care of the official layout of this manuscript. In the declaration of authorship the author confirms his status as a student of the Hamburg University of Applied Sciences and declares conformity with international academic behaviour. In the Acknowledgment author shows his gratitude towards all people involved in this work and explains in which way they were involved.

Chapter four is giving an introduction to the topic. Beginning with a definition of developing countries, their actual development in general and especially in health care is shown. After that the focus is set on Mongolia in particular, providing some general background information and showing the current health care situation.

Chapter five is about the medical infrastructure in Mongolia. The quality and status of the usable medical equipment are shown as well as the company situation in Mongolia about sale, construction, repair and maintenance of medical equipment.

In chapter six a medical overview about common illnesses in Mongolia is given. The European "gold standard" for diagnosis and treating of these illnesses is investigated and compared with lower quality alternative diagnosis methods and treatments for the same illnesses. In the end of this chapter, a table is created, which shows whether all illnesses can be properly diagnosed or treated with the medical equipment available in Mongolia or not.

In chapter seven some technological solutions for improving the infrastructure of Mongolia are shown. Electricity, Grounding of the building, solutions for an ICU and ideas for improving the patient transportation are shown.

Chapter eight is about the technical aspects of medical technology. "Missing links" between an illness and its properly used medical equipment for diagnosis or treatment are shown and solutions are given on how specific medical technology can become more attractive for Mongolia. Other technology with relation to medicine is also mentioned.

In chapter nine to eleven the results of the study are presented and discussed. A conclusion in the end is completing the cycle of the red line, showing how the solutions could change the situation shown in the beginning of the thesis.

After these eleven chapters, the list of references is completing this manuscript.

2. Declaration of Authorship

I, Sven Henry Kannenberg, confirm that this Master-thesis and the work presented in it are my own achievement.

1. Where I have consulted the published work of others this is always clearly attributed;
2. Where I have quoted from the work of others the source is always given. With the exception of such quotations this dissertation is entirely my own work;
3. I have acknowledged all main sources of help;
4. If my research follows on from previous work or is part of a larger collaborative research project I have made clear exactly what was done by others and what I have contributed myself;
5. I have read and understood the penalties associated with Academic Misconduct.

This Master-thesis is being submitted for the degree of Master of Science in Biomedical Engineering to the Hamburg University of Applied Sciences, Germany. It has not been submitted before for any degree or examination at this or any other University.

Name: ____________ **Matriculation no:** ____________ **Date:** ____________

3. Acknowledgements

During my five months stay in Mongolia, I met many people involved in the Mongolian health care system. Some of them were students, others nurses or technical staff, but also ministry workers and hospital management professionals. All of them had in common, that their personal point of view could help me to get a more complete picture of the current situation. In health care it is always difficult to make a complete analysis as health care workers, medical doctors, public health scientists, technical staff and ministry workers tend to have completely different understandings and views on the threats and problems of the health care system. Therefore I am thankful for every person I was able to meet and talk with.

First of all I want to thank my both supervisors: Mr. Walter Leal for being interested and courageous when I introduced him to my idea for the thesis. Mrs. Myagmarnaran Tserendorj for introducing me to many people in Mongolia. Due to her work and experiences I was allowed to investigate in different public and private hospitals in Ulaanbaatar and to talk with University teachers from technical as well as medical universities.

I want to thank all workers at SongDo Hospital, GrandMed Hospital and National Central Hospital for their kind and helpful support. Also I would like to thank the technical head of radiotherapy at the National Cancer Center for showing me and a number of biomedical engineering students around in his department. I also want to thank J.Ganbat, installation and service engineer, who is said to be the best medical engineer in Mongolia. With him I was able to visit different hospitals in Ulaanbaatar to perform repairing of medical devices.

In the Health Sciences University of Mongolia (HSUM) I want to thank Batbaatar G., President of the HSUM, Oyuntsetseg S., Director of academic affairs, Enkhtuya V., Head of Division of International Relations and Dr. Urantuya, who took care of my visa documents in Mongolia.

During the time of the Mongolian "National Forum on Infection Prevention and Control" I was able to meet with members of the team from the Mongolian Emergency Service Hospital Hygiene Project (MeshHp) (Prof. Dr. Walter Popp, Prof. Ali Canbay, Dr. Birgit Ross, Dr. Michael Rossburg, Jan-Peter Sowa, Nouzha Maazouz) and Altantuya J. from the Asian Development Bank. Exchanging information was giving my investigation new impulses and was helping me with qualified statements.

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Finally I want to thank my friends, my girlfriend and her family as well as my own family to help me with the correction and motivation for the thesis. Of course I am also thankful for all the people, who helped me without being mentioned in this acknowledgements.

Sven Kannenberg

4. Topic introduction

4.1. Developing Countries: A definition

"Developing countries" is a term, which does not have a clear definition. On the one hand, an official list with currently 48 countries, which are named "least developed countries (code 481)" or LDCs in short [10] is given by the "Committee for Development Policy" (CDP) of the United Nations (UN) [11]. On the other hand, the committee wrote in its handbook:

"Income data were collected for 132 developing countries. Of these, 65 were retained for further review (50 already in the LDC category in 2006 and 15 low-income countries not previously classified as least developed)."
Handbook on the Least Developed Country Category:
Inclusion, Graduation and Special Support Measures, pages 38 & 39 [11]

On the internet page of the Committee, the income data of the 132 developing countries from 2006, 2009 and 2012 can be accessed. Within this data collection, countries like "Republic of Korea", "Israel", "Singapore" or "Turkey" are listed [14]. Obviously these countries' problems differ very much from those of low-income counties (Gross National Income (GNI) per capita[3] 2012: Singapore vs. Nepal - 36,677 US Dollar vs. 420 US Dollar). When comparing the list of developing countries according to the CDP with the Human Development Report 2013, the "Human Development Index" (HDI) ranges for all developing countries from 12 - 186 (where 186 is the last rank of the index, resulting in the lowest HDI value [6]. The HDI ranking is divided into equal groups (shown in table 4):

Table 4: Rank groups of the Human Development Index (HDI) [6] (*: rank 186 was given twice)

Name	Rank
Very High Human Development	1 - 47 (47 ranks)
High Human Development	48 - 94 (47 ranks)
Medium Human Development	95 - 141 (47 ranks)
Low Human Development	142 - 186* (46 ranks)

Developing countries like "Republic of Korea", "Israel" or "Singapore" are ranked in the "Very High Human Development" group (rank 12, 16 and 18) before countries like France (rank 20), Italy (rank 25) or the United Kingdom (rank 26) [6]. Therefore it is not easy to generalize developing countries. Also the least developed countries according to the CDP do not fit exactly into the grouping of the Human Development Report, as there are seven least developed countries, which are grouped into the "Medium Human Development" group (shown in table 5):

Table 5: "Least Developed Countries" with their Human Development Index (HDI) in the "Medium Human Development" group [6, 10]

Country	Rank
Kiribati	121
Vanuatu	124
Timor-Leste	134
Equatorial Guinea	136

Country	Rank
Cambodia	138
Lao Peoples' Democratic Republic	138
Bhutan	140

But also the "Low Human Development" group consists not only of LDCs. 38 LDCs are listed in this group, leaving space for eight other countries to be listed in that group (four low-income countries did not receive a HDI, listed in table 6).

[3] *"The CDP uses GNI per capita expressed in current United States dollars, calculated according to the World Bank Atlas method, which is defined in such a way as to reduce the effects of short-term fluctuations in inflation and real exchange rates on GNI."* **Handbook on the Least Developed Country Category: Inclusion, Graduation and Special Support Measures, page 39** [11]

Table 6: Non-Least Developed Countries with their HDI rank in the "Low Human Development" group and countries without HDI value [6, 10]

Country	Rank
Congo	142
Kenya	145
Pakistan	146
Cameroon	150
Nigeria	153
Papua New Guinea	156
Côte d'Ivoire	168
Zimbabwe	172

Countries without HDI	
Democratic People's Republic of Korea	-
Somalia	-
Tuvalu	-
South - Sudan	-

When comparing the review data of that eight non-LDCs with the criteria for the LDC list, four countries (Kenya, Pakistan, Cameroon and Côte d'Ivoire) do not fulfil the criteria of the Economic Vulnerability Index (EVI) [11], neither in 2006 nor in 2009 or 2012 [12, 13, 14]. Another criterion, requiring that the country needs to have less than 75 million people, excludes Nigeria (2006: ≈131.53 million people, 2009: ≈ 151.48 million people, 2012: ≈162.47 million people). Congo only meets two of the three criteria and is therefore excluded [12, 13, 14]. In that case only Papua New Guinea and Zimbabwe fit into the criteria to receive the LDC status. But the CDP writes in its handbook:

"Three countries—Ghana, Papua New Guinea and Zimbabwe—were considered by the CDP to be eligible for LDC status, but declined to be included in the list."
Handbook on the Least Developed Country Category:
Inclusion, Graduation and Special Support Measures, page 10 [11]

The situation for several other countries also remains unclear, as they are not named in the list of developing countries, although their HDI rank would lead to another suggestion, as they are ranked in the "Medium Human Development" group (table 7):

Table 7: Countries with their HDI rank in the "Medium Human Development" group, which are not listed as developing countries [6, 14]

Country	Rank
Turkmenistan	102
State of Palestine	110
Republic of Moldova	113
Uzbekistan	114

Country	Rank
Federated States of Micronesia	117
Kyrgyzstan	125
Tajikistan	125

In this thesis, the term "developing countries" will refer mainly to countries in the high, medium or low human development group of the Human Development Report. Ten countries named in the list of developing countries [14] are ranked in the "Very High Human Development" group of the HDI [6], which leads to the suggestion that general problems of developing countries do not affect them. Therefore they will be excluded from the focus of this thesis. 31 of 47 countries ranked in the "High Human Development" group are named in the list of developing countries as well (e.g. Mexico with rank 61, Brazil with rank 85 or Turkey with rank 90). Ukraine (HDI rank 78), which faces similar problems as developing countries, is not included in the UN list of developing countries [14]. Therefore, some of the problems mentioned in this thesis will also apply to a number of these countries.

4.2. Some facts about developing countries

One important aspect of developing countries is their high potential of development on the one hand, but also their real development on the other hand. Figure 2 can illustrate that in a very good way, when comparing the situation between the "Republic of Korea" and countries like Australia or Germany. While the other countries visualized on that figure started in 1980 with a HDI value of above 0.7 (Germany: 0.738, Austria: 0.747) the Republic of Korea had a HDI value of 0.64 in 1980 [6]. It had a high potential of development and had a much higher annual HDI growth than other countries in the "Very High Human Development" group.

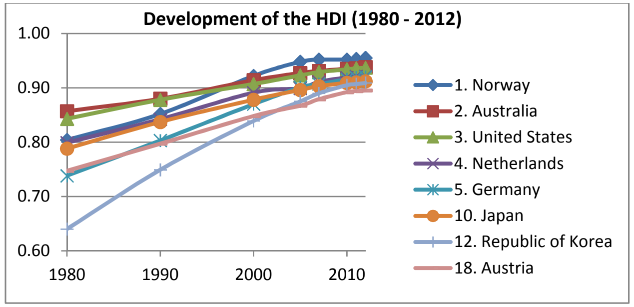

Figure 2: Diagram of the HDI values development for some "Very High Human Development" countries [6]

Other countries can also clearly be seen as developing countries, due to the fact that real development can be visualized by changes in their index values. In figure 3 the development of HDI values of three countries with "High Human Development" and three countries with "Medium Human Development" are shown. Turkey and China are two examples for a rapid growth of their HDI values (other countries like Iran, Malaysia, Tunisia and Thailand have a similar growth) [6]. That figure also shows another interesting aspect, connected with the former soviet controlled states: Four of the six countries were soviet controlled until 1990, and nearly all had a slight depression in their HDI values between 1990 and 2000 (Russian Federation: 0.730 to 0.713, Ukraine: 0.714 to 0.673, Republic of Moldova: 0.650 to 0.592 and Mongolia: 0.559 to 0.564, not visualized: Kyrgyzstan: 0.609 to 0.582 and Tajikistan: 0.615 to 0.529). Since the year 2000 especially Mongolia started a great development with the highest annual growth rate (1.51% every year) of the former soviet states mentioned above [6].

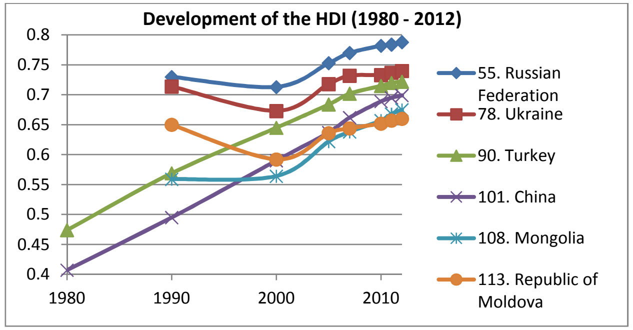

Figure 3: Diagram of the HDI values development for some high and medium human development countries [6]

In the area of low-income countries, which mainly are placed in the "Low Human Development" group, a positive tendency is also mentionable for most countries. In figure 4 the development of HDI values for four low-income countries is visualized. Two of them, "Nepal" and "Democratic Republic of Congo" are listed as LDCs [10], while India and Nigeria cannot be included due to the population threshold established by the CDP [11]. While the visualized values of three of the chosen countries show a steady growth during the time, the "Democratic Republic of Congo" faces a troublesome time due to war and terror.

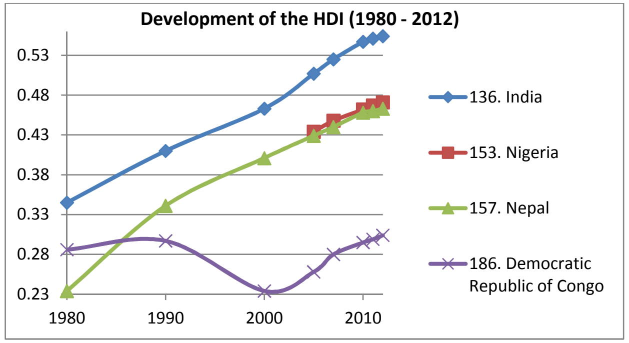

Figure 4: Diagram of the HDI values development for some "Low Human Development" countries [6]

But it needs to be mentioned that the HDI does not include every development of every country, when calculating the values. In detail, the technical notes to the Human Development Report 2013 document the calculation of the HDI values for each country. It is based on the four values "Life expectancy at birth", "Mean years of schooling", "Expected years of schooling" and "GNI per capita (PPP $)"[15]. The separation between mean years of schooling and expected years of schooling is due to the fact, that changes and improvements in the education system take a long time before they reach the majority of people in that country. Therefore, the change in the actual education situation (mean years of schooling) will be very slow.

Each of the four indicators is transformed into an index value between zero and one, by comparing it with standardized maximum and minimum values. These values are listed in table 8:

Table 8: Standardized maximum and minimum values and formula for HDI indicator calculations [15]

indicator	Observed maximum (M)	Minimum (m)	Formula for the index calculation
Life expectancy at birth (years)	83.6 (Japan, 2012)	20.0	
Mean years of schooling	13.3 (United States, 2010)	0	$i = \frac{actual\ value - m}{M - m}$ (4.1)
Expected years of schooling	18.0 [4]	0	with i = dimensional index, M = observed maximum, m = minimum
Combined education index	0.971 (New Zealand, 2010)	0	
GNI per capita (PPP $)	87,478 (Qatar, 2012)	100	

With these values and the formula 4.1 it is possible to calculate the indices. The indices for mean years of schooling (MYOS) and expected years of schooling (EYOS) will be combined to the education index by calculating the square-root of both values and use it as actual value in the formula. The income formula uses the natural logarithm for all values to take the concave shape of the income function into account [15]. The Human Development Index then is calculated by using the average mean of all three indices. The calculations are listed in table 9.

[4] Four countries (Australia, New Zealand, Ireland and Iceland) have an "expected years of schooling" value above 18.0. However, the value is capped at that value

Table 9: Calculation formulas for the Education Index (EI), the Income Index (II) and the HDI, with LEI = Life Expectancy Index [15]

Education Index:	Income Index:	Human Development Index:
$\frac{\sqrt{MYOS \cdot EYOS} - 0}{0.971 - 0}$ (4.2)	$\frac{\ln(actual\ value) - \ln(100)}{\ln(87{,}478) - \ln(100)}$ (4.3)	$\sqrt[3]{LEi \cdot Ei \cdot Ii}$ (4.4)

It is obvious that these four indicators do not include all parameters, which make a country a developed country. The possibility to read and write as an example is a basic right every person in the world should have. The MYOS and EYOS indicators should cover the education level of the population, but when comparing the adult literacy rate also given by the Human Development Report 2013, the Education Index becomes questionable (Myanmar, LHD country, has a MYOS of 3.9, Seychelles and United Arab Emirates, VHHD countries, have 9.4 and 8.9. Their adult literacy rate is 90.0% for United Arab Emirates, 91.8% for Seychelles and 92.3% for Myanmar) [6]. The full list is shown in table 10.

Table 10: Adult literacy rate of UN Member states[5] according to the Human Development Report 2013 [6]

Value	Low Human Development	Medium Human Development	High Human Development	Very High Human Development
99.0 - 100%		Tajikistan, Turkmenistan, Uzbekistan, Kyrgyzstan, Tonga	10 countries[6]	*29 countries[7]
96.0 - 98.9%		Samoa, Republic of Moldova, Maldives, Mongolia	8 countries[8]	Italy, Croatia, Chile, Cyprus, Argentina, Spain, Greece, Qatar, Singapore
92.7 - 95.9%		Philippines, State of Palestine, Suriname, China, Equatorial Guinea, Paraguay, Thailand, Viet Nam	Albania, Venezuela, Panama, Kuwait, Colombia, Malaysia, Mexico	Portugal , Brunei Darussalam
92.7%	Average "adult literacy rate" of the High Human Development group			
90.0 - 92.6%	Myanmar, Zimbabwe	Indonesia, Jordan, Plurinational State of Bolivia	Bahrain, Ecuador, Sri Lanka, Turkey, Brazil	Malta, Seychelles, United Arab Emirates
86.0 - 89.9%	Lesotho, Sao Tome and Principe, Kenya	Dominican Republic, Namibia, South Africa, Gabon, Swaziland	Peru, Lebanon, Libya, Mauritius, Oman, Jamaica, Saudi Arabia	
82.3 - 85.9%		Honduras, Botswana, El Salvador, Cape Verde, Syrian Arab Republic, Vanuatu	Islamic Republic of Iran	
82.3%	Average "adult literacy rate" of the Medium Human Development group			
75.0 - 82.3%		Iraq, Nicaragua, Cambodia, Guatemala	Tunisia	
70.0 - 74.9%	Comoros, Malawi, United Republic of Tanzania, Uganda, Zambia, Rwanda, Sudan, Cameroon, Angola	Lao People's Democratic Republic, Egypt	Algeria	
...				
60.8%	Average "adult literacy rate" for the Low Human Development group			
50.0 - 60.7%	Mauritania, Togo, Bangladesh, Côte d'Ivoire, Mozambique, Central African Republic	Timor-Leste, Morocco, Bhutan		
...				

[5] Only UN member states are listed, which had a literacy rate value given in the Human Development Report.
[6] The countries are: Azerbaijan, Cuba, Kazakhstan, Georgia, Ukraine, Armenia, Belarus, Russian Federation, Serbia, Antigua and Barbuda
[7] The countries are: Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Iceland, Ireland, Israel, Japan, Korea (Republic of), Liechtenstein, Luxembourg, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States (all 100% expected), Estonia, Latvia, Slovenia, Lithuania, Poland, Hungary.
[8] Trinidad and Tobago, Bulgaria, Montenegro, Uruguay, Bosnia and Herzegovina, Romania, The former Yugoslav Republic of Macedonia, Costa Rica

Another important factor for developing countries is the technology and innovation status. Communication technologies increase the global share of knowledge and provide additional potential in education. Figure 5 shows the amount of personal computers and internet users in the same 18 countries, which HDI values were compared with each other. The eight countries with the "Very High Human Development" status (on the left side) have in common that their amount of internet users is above 50% of the population. The other ten countries in contrast, which have a lower development status, have strikingly smaller amounts of internet users or personal computers [6].

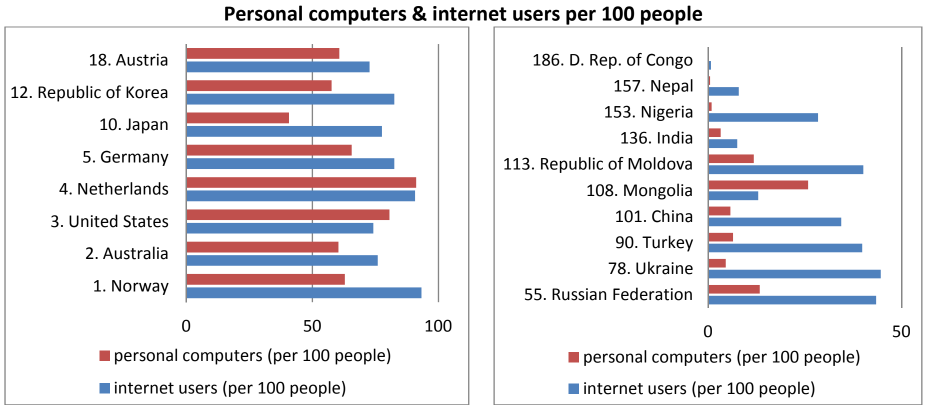

Figure 5: Amount of personal computers and internet users per 100 people in different countries [6]

It needs to be recognized that average values of a country do not represent the real values, because there are huge differences between urban and rural areas. The electrification rate for example is less than 50% of all population in 21.6 % of all countries (27 of 125 countries, 62 countries in the list did not had a value). On the opposite, 60% of all countries had an electrification rate of above 90% of all population (75 of 125 countries) [6].

Besides the Human Development Report, also the Millennium Development Goals (MDGs) are an important aspect of describing the situation of developing countries. With eight goals described to be fulfilled until 2015, the main problems in the developing world would become more fair and healthy for everyone. Several of the targets, which are indicators for reaching the eight goals, will have been fulfilled before 2015 or are in close range according to the Millennium Development Goals Report 2013 [8]. Especially targets like poverty reduction or increased access to improved water and sanitation are important to make the life fairer to all people.

As the success of the MDGs varies between the members of the United Nations (UN), the more difficult last phase of the project has started: Every country and land area needs to analyze its current situation. Countries, where high affords did not result in a significant change of the situation need to reconsider their activities to detect problems and to develop national solutions.

4.3. Medical situation in developing countries

There have been a number of publications on the topics of medicine in LDCs and developing countries. Most of the time, the term "developing country" refers to countries with lack of infrastructure, of medical education and of medical technology. In this thesis the term is used in a comparable way.

All of these developing countries have in common that they face financial problems in their health care systems [16]. Hodges, Mijumbi, Okello et al. for example showed in Anaesthesia in 2007 that the per capita expenditure on health in the UK (2853 $) is about ten times higher than the gross domestic product (GDP)[9] per capita[10] of Uganda (270 $) [17]. Because most of the time health insurances cannot compensate these problems, national health programs often do not have their desired effect and hospitals only have access to old and low quality medical equipment [18].

"Today, almost one fourth of hospital expenses are invested in the care of the most severely sick patients (4). In LDCs, however, the status quo of intensive care medicine differs enormously from Western countries. In most of these countries, less money is annually spent on the total health care sector than on intensive care medicine alone in the industrialized world (4, 5)." [11]

"A review and analysis of intensive care medicine in the least developed countries."
Crit Care Med 2006 Vol. 34, No. 4 page 1234 [19]

A typical problem of developing countries is the structure of the buildings of medical institutions. While the planning and maintenance of Intensive Care Units (ICUs) and emergency departments are highly professional in developed countries, the rooms for similar used institutions in developing countries do not match the specific needs in most cases. For example the power supply cannot be described as stable in many cases, due to intermittent voltage peaks (up to 500-600 V), which would damage sensitive medical equipment [19]. Voltage stabilizers can prevent the equipment from being damaged. Furthermore electricity shortages can cause trouble in ICUs and emergency departments, e.g. when the mechanical ventilation on critically ill patients does not work [18]. For example in Uganda 41% of all surveyed anaesthetists said that they sometimes have neither main electricity nor a generator available [17]. In fact, in most developing countries even more requirements would be needed to create a safe and effective medical station, such as water purification or central heating systems, as they are needed in most developed countries [19].

"Average technical and nursing equipment of most ICUs in LDCs range well below the standards of the first ICUs in Europe in the 1950s (41). Patient monitors, ventilators, defibrillators, and syringe pumps are rare and almost only available in hospitals that have received donations from Western countries (42, 43)." [12]

"A review and analysis of intensive care medicine in the least developed countries."
Crit Care Med 2006 Vol. 34, No. 4 page 1237 [19]

The status of medical equipment is often poor, most of the time it is old and sometimes it is second hand from other countries. The condition and age of functional medical devices most of the time remains uncertain, which makes is likely that most of the equipment would need to be replaced [17].

[9] **Gross Domestic Product (GDP)**: The sum of the value added by domestic and foreign enterprises, and citizens located in the country or the sum of the values of final products during a one-year period.
[10] **GDP per capita**: Gross domestic product (GDP) during a one year period, divided by mid-year population.
[11] (4) Jacobs P, Noseworthy TW: National estimates of intensive care utilization and costs: Canada and the United States. Crit Care Med 1990; 18:1282–1286
(5) "The World Health Report 2004. Changing History. "**[16]**
[12] (41) Benad G, Röse W: Die geschichtliche Entwicklung der Intensivmedizin in Deutschland. Zeitgenössische Betrachtungen: Folge 4: Strukturelle Entwicklungen der Intensivmedizin in der ehemaligen DDR. Anaesthesist 1999; 48:251–262
(42) Handa F: Anesthesia in a children's hospital in Nepal. Masui 2000; 49:1395–1397
(43) Binam F, Lemardeley P, Blatt A, et al: Anesthesia practices in Yaounde (Cameroon). Ann Fr Anesth Reanim 1999 18:647–656

The acquisition of medical equipment is not only limited because of financial shortages, but also because of a limited capacity for import, due to a lack of regional medical technology companies. Only a few people are trained in repairing medical devices locally, which makes it necessary to send the devices to other places for repair in case there is enough money to pay for it [17]. Besides, the use of medical equipment is limited for lack of supply materials, the incapability to calibrate the devices and the inadequate maintenance of the products [17, 18].

A related problem is the lack of capacities in other medical disciplines. Laboratories for tests and radiologic departments often do not possess the needed equipment to help critically ill patients. This lack of resources may also be a reason for high mortality rates in developing countries. A study in Mexico has shown that a simple battery-based ultrasonic device can improve the medical situation in rural areas [20]. As a result underestimated health problems of patients can be cured and the mortality of these health issues reduced. Also the accessibility of an expert often is a problem. In many cases no adequately trained physician is present in an ICU, which means that unprepared personal e.g. medical assistants or nurses need to do the physicians work [19].

This leads to two simultaneously working problems in developing countries. First, the low salary for the job, which often is not enough for surviving [7, 17, 18, 19], in combination with high workload can lead to burnout syndromes of the personnel. Second, highly-trained personnel is trying to get better working opportunities in the private sector or in other countries. Therefore, the qualified personnel is leaving the public health sector, a phenomenon described as "brain drain" [17, 21].

"Medical migration has resulted in many Ugandan doctors emigrating to wealthier countries such as the UK, resulting in a serious shortage of doctors."

Anaesthesia services in developing countries: defining the problems
Anaesthesia, 2007, 62, page 8 [17]

A report on the Canadian Medical Association Journal explained this situation. In the report it was mentioned that "close to 1500 South African physicians" are living and working in Canada [22]. An Australian study mentioned that Australian health care personnel refused to work in rural areas of Australia. Instead, an over-sea recruitment policy made medical doctors, nurses and other health care personnel from developing countries immigrate to Australia to fill the health care gap in the rural areas [21].

Furthermore, the drug situation is very important for developing countries. The World Health Organization (WHO) created a first "essential medicine list" (EML) in 1977 and is revising this list regularly [23]. The intention was to balance the availability of medicine in developing countries, because most of the available medical drugs were not useful whereas the necessary medicine was often not accessible. Most of the listed medical drugs are theoretically available in developing countries, but only a few of them are available in case of actual need of a patient. Not only shortages of vital medicine cause trouble in developing countries, but also low quality or forged drugs are sometimes sold to hospitals [19]. The WHO wrote in their 18th model list:

"The core list presents a list of minimum medicine needs for a basic health-care system, listing the most efficacious, safe and cost-effective medicines for priority conditions. Priority conditions are selected on the basis of current and estimated future public health relevance, and potential for safe and cost-effective treatment."

WHO Model List of Essential Medicines, 18th List, August 2013[24]

An analysis published 2003 in "The Lancet" showed that the national EMLs sometimes differ significantly from the recommended list of the WHO [23]. The range of medicines in that lists varied between 108 and 389, while the WHO recommended list contained 309 medicines at that time. Table 11 compares 17 countries that have been analyzed in that study.

Table 11: Comparison between the amount of medicines and dosage forms listed in 17 national Essential Medicine Lists. This table is extracted from the analysis published in 2003 [23]

Country or Organization	Medicines on EML	Dosage forms	Country or Organization	Medicines on EML	Dosage forms
WHO	309	547	Madagascar	253	389
Peru	341	423	Yemen	203	268
Eritrea	325	457	Kazakhstan	335	434
Karnataka state, India	389	411	Kosovo	204	253
Uganda	317	345	Zimbabwe	196	208
South Africa	337	422	Burkina Faso	220	239
Nepal	276	377	Philippines	244	364
Mongolia	229	374	Senegal	176	188
Palestine	304	312	Republic of Liberia	108	140

It needs to be mentioned that these conditions cannot be seen as a proof of bad health care in developing countries in general. In almost every country private hospitals especially in urban areas exists, which offer high standard medical care to patients, who can pay [25].

"In almost all LDCs, private medical institutions exist that are accessible for patients who have money (19). These hospitals frequently offer state-of-the-art medical care on a standard that is comparable to Western countries (20). Although some of these institutions also provide ICU services, most facilities specialize in surgical, internal, or diagnostic medicine (21)." [13]

"A review and analysis of intensive care medicine in the least developed countries."
Crit Care Med 2006 Vol. 34, No. 4 page 1235-1236 [19]

An article in the Bulletin of the World Health Organization in 2003 describes a situation, where some private medical institutions can provide a better quality of health care than the public institutions, without being more expensive [25]. With an efficient resource management, every worker in the hospital can perform the tasks he is trained for in an optimized way. Standardized drug prescriptions for different diseases and illnesses make the storage and replacement of drugs more time- and cost-effective. Some private medical institutions already started negotiations with local authorities to take over the responsibility of taking care of ill people and getting paid for every patient, because it would be less expensive for the government than maintaining their public medical institutions [25].

Big issues in developing countries are the health care aspects, which are mentioned in the Millennium Development Goals (MDGs). Children and maternal health are important goals, because the mortality rates during child birth remain high in many countries of the world and many children die because of malnutrition or inadequate protection, e.g. vaccines. Also the global fight against major diseases as HIV and Tuberculosis is important in order to protect the world population and especially the coming generations from these major threats. But also the fight against hunger and poverty and the protection of the environment have impact on human health, because they can protect from malnutrition, inadequate living situations and from environmental disasters.

[13] (19) Hanson K, Berman P: Private healthcare provision in developing countries: A preliminary analysis of levels and composition. Health Policy Plan 1998; 13:195–211
(20) "A new face for private providers in developing countries: What implications for public health?"**[25]**
(21) Streefland P: Public healthcare under pressure in sub-Saharan Africa. Health Policy 2005; 71:375–383

4.4. Mongolia: Some facts about the country

The Republic of Mongolia is a landlocked country in east-central Asia. It is 1564.1 thousand square kilometres in size, which is more than 4 times as big as the Federal Republic of Germany. Mongolia has a population of about 2.86 million citizens [7], which are living in 21 different districts (in Mongolia named "Aimags") of very different size, population and climate. The national language is Mongolian, a language spoken in Mongolia, northern China and parts of Afghanistan. The language can be divided in three separated groups: isolated Mongolian languages (e.g. in northern China, and parts of Afghanistan), western Mongolian languages (small tribes in western Mongolia) and the eastern Mongolian language (main group, including the national language of Mongolia).

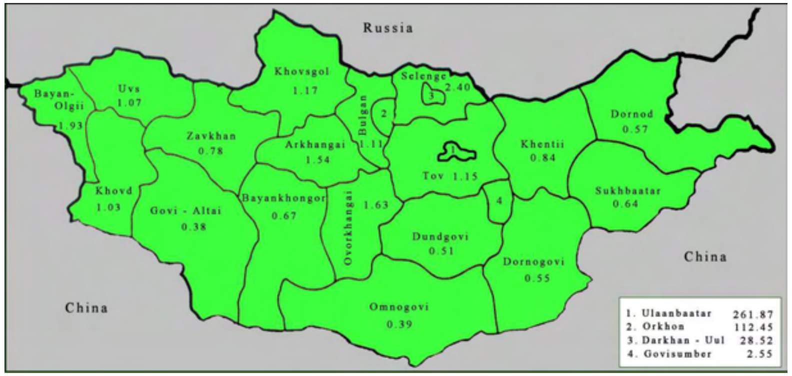

Figure 6: Map of Mongolia with its districts and their population density (people/km²) [7]

The time zone for all of Mongolia is UTC +8.00. The country has two neighbours, the Peoples Republic of China and the Russian Federation, whereas the border to the Russian Federation is 3543 km long and the border with the Peoples Republic of China is 4709.6 km long. In average the height of the country is 1580 meters above the sea level, but varies strongly from 532 meters above the sea level up to 4374 meters above sea level [7]. It is ranked as the 19th biggest country in the world (after Iran, which is about 20,000 km² smaller in land size but about 100,000 km² more water area). It is also the second largest landlocked country (after Kazakhstan, which is about 2724.9 thousand square kilometres in size).

As shown in figure 6, the situation in the respective Aimags is very different from each other. With 0.38 people per square kilometre the Aimag of Govi-Altai has the lowest population density of all Aimags in 2012 [7]. The four regions written in the white box are the smallest Districts of Mongolia but the ones with the highest population density on district level. But of course there are also enormous differences in density within each Aimag. As an example table 12 shows the population density for all nine sub-districts of Ulaanbaatar, the capital of Mongolia.

Table 12: The nine sub-districts (Duuregs) of Ulaanbaatar with their population density in 2010 [26]

Duureg	Density (pop./km²)	Duureg	Density (pop./km²)	Duureg	Density (pop./km²)
Bagakhangai	24.01	Bayanzürkh	223.05	Nalaikh	43.86
Baganuur	36.14	Chingeltei	1,640.53	Songino Khairkhan	214.52
Bayangol	6,058.47	Khan Uul	227.49	Sükhbaatar	613.32

In general it can be said that every district has its own capital area named Aimag Center, where the population density is higher than in the surrounding areas. In one Aimag, some if its Aimag areas only have a local population density down to 0.11 people per square kilometre, while the Aimag Center has a population density of 137.42 per km². Because it is one of the largest districts in Mongolia and more than 50% of the Aimags population are living in the Aimag Center, the average population density of that district is 0.65 (Mongolian Census 2010) [26].

Most areas in Mongolia can be described as rural areas without electricity or sanitation. The Mongolian statistical yearbook 2012 writes that about 51.7% of the Mongolian Population is living in rural areas. In many cases the people are living as nomads, living in tents and moving from area to area. Figure 7 and 8 visualize the population situation in the 21 Aimags and the capital. The percentage of urban population of every district is shown together with the districts total population proportion to the Mongolian population.

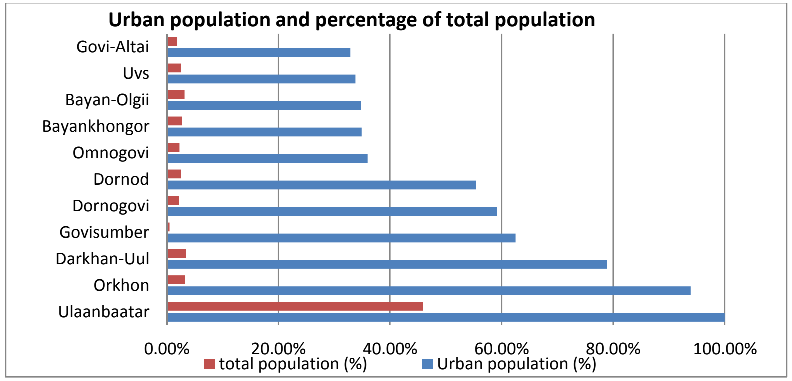

Figure 7: Percentage of urban population in each district, compared with the proportion of that district population with the total population (first eleven districts) [7]

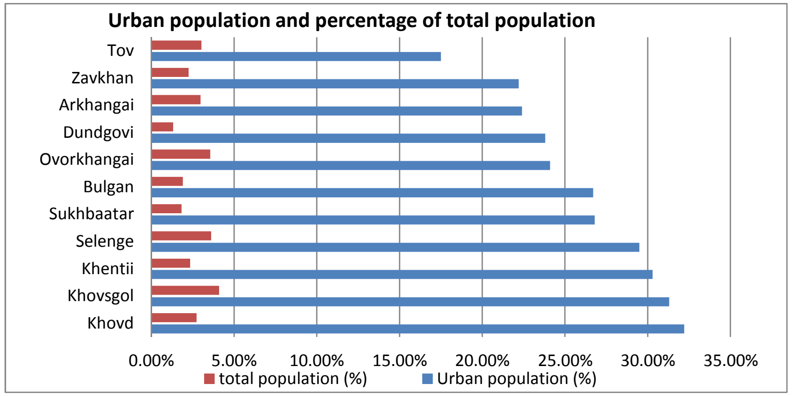

Figure 8: Percentage of urban population in each district, compared with the proportion of that district population with the total population (second eleven districts) [7]

Medical health care problems and possible solutions for developing countries:
Case study Mongolia

Every year people from the countryside decide to move into the cities, mainly Ulaanbaatar and the Aimag Centers, which leads to tent suburbs, where the people live at the border of the urban areas in the hope of finding a job and earning money. As a result, the unemployment rate rises in the low-educated population. Housing programs in Mongolia are trying to construct apartments and flats in different price categories, hoping that the working population moves into more comfortable apartments to make space for the poor population.

This situation is making it difficult to reach all targets of the Millennium Development Goals (MDGs) in Mongolia. The high amount of nomads and travellers leads to a high percentage of people without stable jobs for earning money. Also people who arrive in the capital in order to start a better life face difficulties because the capital cannot provide enough jobs for their increasing number. Many of these previous nomads do not have a higher education and do not have the opportunity to get a higher education anymore. As a result, the lower educated people suffer from a high unemployment rate [27], while the higher educated population have more job possibilities in combination with a higher payment. As the Mongolian National Progress Report 2013 [27] writes:

"However, the targets of reducing poverty by half, increasing employment, getting all children primary education, reversing the spread of tuberculosis, protecting the environment require additional effort."

Millennium Development Goals Fifth National Progress Report 2013,
Foreword of BATBAYAR Nyamjav, Minister for Economic Development. page 7[27]

Other targets of the Millennium Development Goals already have been achieved or are in range of getting achieved before 2015 according to the same report:

" The targets of reducing under-five child mortality, reversing the spread and prevention of HIV/AIDS, and developing new information communication technologies and building an 'information society' have already been achieved. Mongolia is on track to achieve the targets of cutting malnutrition, ensuring gender equality in wage employment, providing universal access to reproductive health services, and reducing the proportion of people without access to safe drinking water and basic sanitation."

Millennium Development Goals Fifth National Progress Report 2013,
Foreword of BATBAYAR Nyamjav, Minister for Economic Development. page 7[27]

Figure 9 and 10 show a map of the central area of Ulaanbaatar with focus on chosen Hospitals and Universities throughout the city. Figure 9 lists 13 public hospitals in Ulaanbaatar, which take care of different aspects of health. Figure 10 lists public and private hospitals as well as universities the author visited during his investigation in Mongolia.

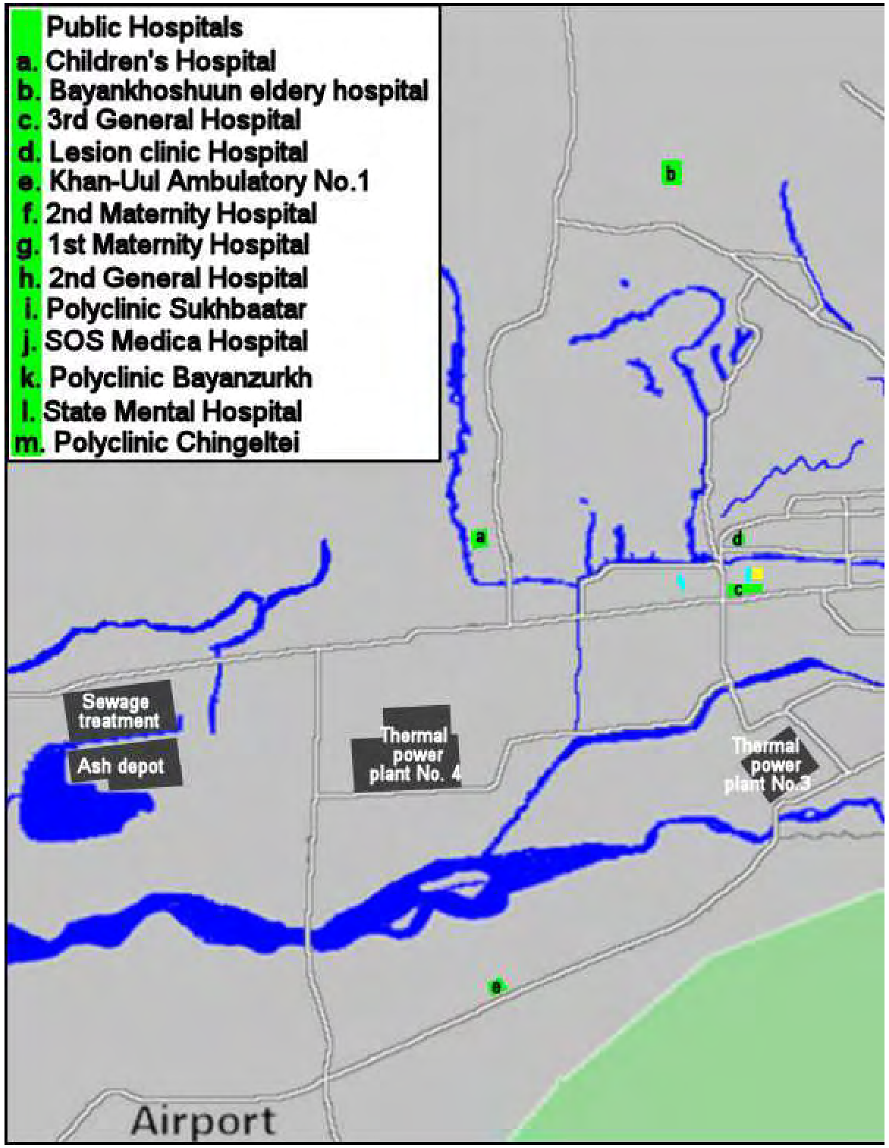

Figure 9: Map of Ulaanbaatar with the position of the main infrastructure (left part). Created by the repainting of an overlay of various tourist maps with Google Maps.

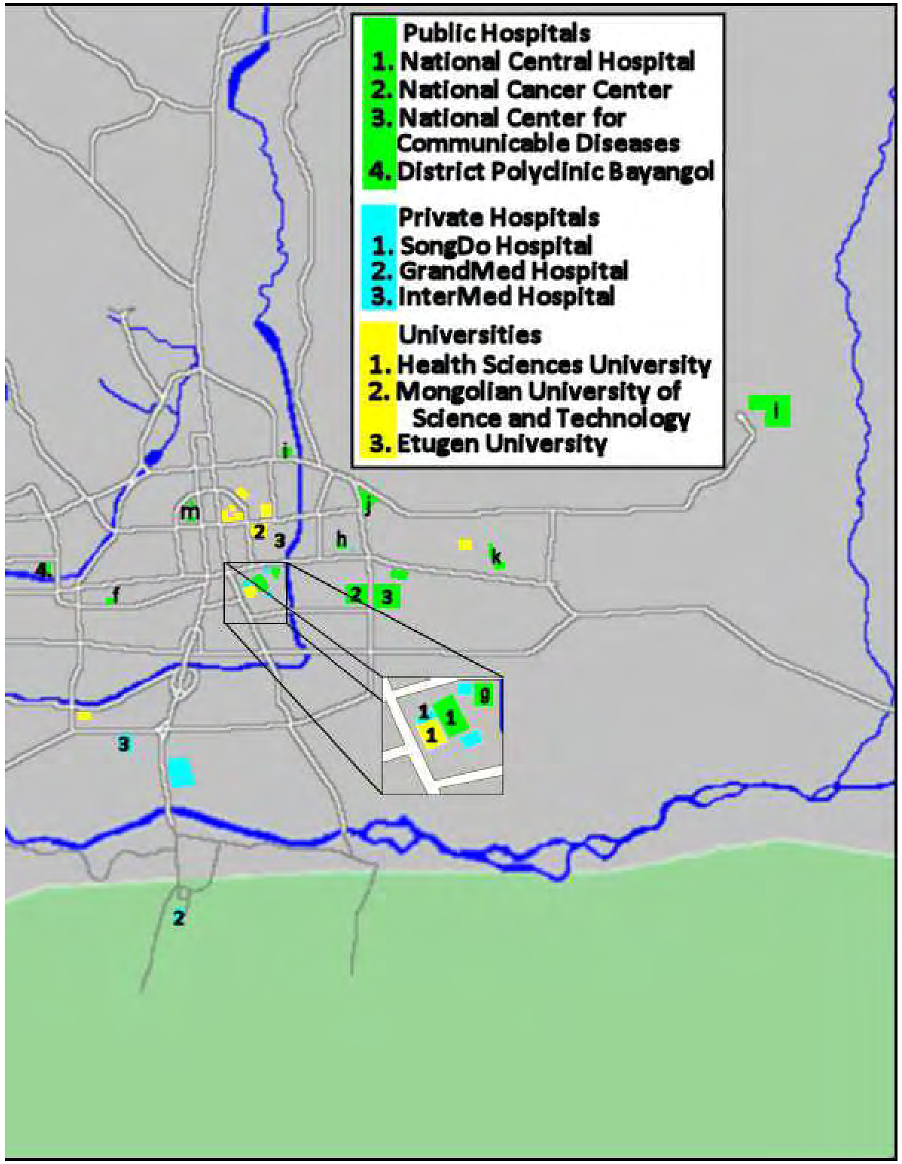

Figure 10: Map of Ulaanbaatar with the position of the main infrastructure (right part). Created by the repainting of an overlay of various tourist maps with Google Maps.

4.5. Mongolia: Medical situation

As a developing country Mongolia faces serious problems in the healthcare sector. As the national hospitals, which everyone who pays a health insurance can visit for free, get older, the medical diagnosis and treatment of expensive private hospitals become more attractive. Some people decide against the health insurance, because it will not help with the costs in private hospitals. As a result there is no stable healthcare system to cover the costs for high quality medical equipment in public hospitals. Private healthcare institutions seem to be attractive because of their high technology equipment, but the costs can be enormous for the patient. In the end, the money spent by the patient goes to the owner of the hospital and also does not support the healthcare system.

Especially intensive care medicine is still a problem, because the costs for that high quality medicine cannot be taken for every citizen [19]. Reports from 2006 and 2007 have shown that intensive care units (ICUs) in developing countries are limited due to a lack of medical equipment, drugs and supply materials, but also due to inadequate training and education of staff or a lack of personnel [18,19].

Since the end of Soviet control in Mongolia in 1990, many health care changes occurred in the country [28]. Due to a national immunization program, which started 1991, incidents of tuberculosis, polio, hepatitis B, diphtheria, pertussis, tetanus and measles could be dramatically reduced. In 2001 the vaccination rate for children was about 98% [29], which remained the same in 2012 [6]. Other vaccinations e.g. for rubella, mumps and influenza are still in the process of being added nation-wide. Four cases of diphtheria were reported in 2000, the same year where the WHO certified that Mongolia is free of polio [29]. In 2012 no cases of Measles, diphtheria, tetanus, pertussis or polio were reported [30]. Hepatitis A and B remain a problem in Mongolia even though the number of incidences of acute hepatitis B could be reduced. Liver cirrhosis and hepatocellular carcinoma mainly are related to chronic hepatitis. Hepatocellular carcinoma is the most common malignancy in Mongolia (followed by gastroesophageal, cervical, and lung cancers) [29]. A study about blood donors in Mongolia revealed in 2005 that 7.44% of all tested blood donors had markers of a hepatitis B infection [31]. Also markers for hepatitis C infections were found in this study. In 2011 more than 14,000 hepatitis infections had been reported in Mongolia, in 2012 it reduced to about 6,900 infections [30].

In Mongolia, which is a "medium developed country" according to the HDR 2013 [6], many hospitals remain in national hand, which makes is more difficult to have a financial support from national budget or health insurances [18]. Like in many other "Medium Developed Countries", the private medical institutions in Mongolia can offer medical treatment in a western countries standard [25]. Unfortunately these institutions only treat patients, who have enough money, which makes "gold standard" inaccessible to most of the Mongolian citizens [19]. In addition, these private hospitals only covers lucrative parts of health care, while special disciplines in medicine only can be covered by the big national hospitals in the Mongolian capital.

A major issue of infectious diseases in Mongolia is tuberculosis (TB). According to the Mongolian statistical yearbook of 1999, tuberculosis occurred in average about 3000 cases every year from 1995 to 1999. The number of TB cases before 1995 is uncertain, because there was no accurate observation before the national TB program was established in 1994. Another TB related rising problem is the single drug resistance of TB, which was spreading in Mongolia in 2003 [29]. In the years from 2009 to 2012, the infection rate with tuberculosis remained stable at about 4000 cases per year [30]. Even the high effort to reach the Millennium Development Goals (MDGs) and international projects to fight TB could not reduce the infection rates.

As a country with a long nomadic tradition, Mongolia has a lot of animals. Due to a vaccination program the prevalence of brucellosis bacteria in these Animals could be reduced. Nowadays most incidents in humans occur mainly from contact with infected animals through injuries, during slaughtering and rarely also from drinking contaminated milk. In 2001 the WHO started meetings with Mongolian institutions to increase the control of brucellosis [29]. Due to this the number of infections could be reduced to less than one third of the infections from 1999 [30].

Sexually Transmitted Infections (STIs), also known as Sexually Transmitted Diseases (STDs), detected in Mongolia were mainly syphilis (1,093 cases in 1999) and gonorrhoea (2,207 cases in 1999), but also others have been detected, mainly with an increasing rate [32]. As of 2001, only two HIV infections have been detected in a yearly HIV screen of about 20,000 patients in Mongolia, one acquired HIV in another country, and the second is thought to have acquired HIV through contact with an African person visiting Mongolia. Nevertheless, public health leaders remained concerned that its incidence would soon increase due to the increasing rates of STDs and increased tourism. And in fact, in 2011 17 HIV cases were reported in Mongolia and 27 in 2012[30]. Other infectious diseases of importance include echinococcus, plague, tularaemia, anthrax, foot-and-mouth, and rabies. Especially outside the urban areas of Mongolia a small number of infections with *Yersinia pestis* can be detected every year [29].

During the long winter season respiratory illnesses including pneumonia are common infections, especially among children. In the past these kinds of diseases were the cause of the high infant mortality rate. During the short summer season in contrast the country struggles with infectious diarrhoea as a health problem. Shigellosis and Salmonella infections are the most prominent infections, due to the fact that a lack of equipment and supplies does not allow identifying other common pathogens [29]. The exact numbers of infections are given in table 13.

Table 13: Morbidity of infections in Mongolia according to the Mongolian statistical Yearbooks 1999 and 2012 [7, 32]

Disease	1990	1995	1999	2009	2011	2012
Tuberculosis	1,664	2,543	3,221	4,218	3,985	3,944
Viral hepatitis	14,278	7,877	5,249	6,865	14,672	6,856
Brucellosis	-	850	1,482	302	384	458
Syphilis	705	718	1,093	4,912	4,268	4,954
Gonorrhoea	2,234	3,308	2,207	6,350	5,159	5,351
Salmonella	866	360	243	122	118	112
Shigellosis	1,930	1,589	1,383	3,099	2,120	2,051
Measles	296	558	10	9	0	0
Mumps	240	255	426	1,990	1,016	9,060

In 2008 Duenser MW, Bataar O, Tsenddorj G et al. published a comparison between an Austrian Intensive Care Unit (ICU) and a Mongolian ICU. On the Mongolian side the ICU of the National Central Hospital (formally named Central State University Hospital) in Ulaanbaatar was chosen, because it is supported by Swiss and Austrian medical aid organizations since 2004. This includes modernization and new construction, donation of medical equipment, donation of supply materials and regular staff training by these organizations. Therefore the Mongolian ICU (MonICU) is supposed to be better equipped and has a better trained staff than other Mongolian ICUs, which leads to the assumption that the medical situation in general is even worse in Mongolia as it is shown in that study [33].

"MonICU is equipped with patient monitors for all the beds and mechanical ventilators for 50% of them, but the unit faces serious problems caused by the variable and inconsistent supply of drugs and disposables. Support is deficient from backup disciplines such as radiology (computed tomography and magnetic resonance tomography are available only to patients who can cover the high costs), laboratory medicine (small and inconsistent spectrum of laboratory tests), blood bank (shortage of blood products), cardiology (no intravenous thrombolytics available or percutaneous coronary interventions possible) and endoscopy (no interventional procedures possible)."

"Differences in critical care practice between an industrialized and a developing country", Wien Klin Wochenschr (2008) [33]

Their study revealed that chronic diseases were significantly less in Mongolia (0.9 ± 0.8 vs. 2.7 ± 1.5, P < 0.001) compared with the Austrian ICU except for liver cirrhosis and immune defects. Chronic tuberculosis was diagnosed in 2.5% of all Mongolian patients in that study. Important is also the fact that 10.8% of the Mongolian ICU patients had never been medically examined before. The patients received significantly fewer therapeutic interventions than the Austrian patients (mechanical ventilation 35% vs. 65%, P<0.001, renal replacement therapy 5.9% vs. 18.7%, P<0.001 or tracheotomy 1.5% vs. 6.6%, P=0.011) and had a higher mortality (19.7 vs. 6.2%, P < 0.001) [33].

In fact the comparison between industrialized countries and developing countries are very controversial because different standards (e.g. water and air quality) and different localizations (e.g. subtropical area, tropical area) lead to different illnesses, which need to be treated [18, 19, 29].

The comparative study from Duenser MW, Bataar O, Tsenddorj G et al. also showed that the life-sustaining therapy was less frequently withdrawn for incurable patients (27.5% vs. 68.8%, P=0.014) [33]. The authors of that study give two possible reasons for that, in consensus with their own experiences:

"On the one hand, it may be due to the Mongolian people's belief that every disease can be healed with modern, apparatus-based intensive care medicine; on the other hand, it could be due to the doctors' frequent anxiety about having possibly administered insufficient diagnostic or therapeutic measures."

"Differences in critical care practice between an industrialized and a developing country", Wien Klin Wochenschr (2008) [33]

Because of a significantly higher mortality rate in Mongolia outside of ICUs the authors suggest a low acceptance of the ICU and its service among physicians of other medical disciplines in Mongolia. As an outlook they explained that the training of the personnel as well as the acceptance of the ICU as an institution for immediate care for critical patients should be increased [33]. Another reason for the high mortality rate outside of the ICU is the small amount of patient beds. The National Central Hospital, which is the biggest hospital in Mongolia with a ground size of about 12,000 m^2 and up to 6 floors, only has one intensive care unit with 8 patient beds. Outside of the big cities, ICU stations are rarely known and mostly not provided.

In 2011 an Australian-Mongolian team published their results on hospital-acquired infections (HAIs) in which the overall prevalence of HAI was described as comparable with other developing countries (5.4%) [34]. Cancer is a steadily growing health care problem in Mongolia. As there is only one Hospital in Mongolia, which is specialized in the treatment of cancer, the National Cancer Center of Mongolia, an adequate treatment for all cancer patients is effectively impossible. Not only is the number of cancer patients too high to be covered by a single institution (3,591 in 2012) [30], but also do most patients not have the means to travel the long distances to the capital. A list with the main mortality reasons in Mongolia can be seen in Annex I.

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5. Health care infrastructure in Mongolia

5.1. Medical technology available in Mongolia

The medical technology available in Mongolia varies highly in dependence of the location. Private hospitals most of the time have more modern equipment than the public hospitals. On the one hand it is due to the fact that private hospitals earn money from their patients, which they can use to invest in new medical equipment. On the other hand it is due to the fact, that private hospitals are a relatively new phenomenon in Mongolia. Therefore, the public hospitals normally are located in older buildings and are using their older equipment.

At the time of the thesis, five Magnetic Resonance Imaging (MRI) devices are installed in Mongolia, all located in the capital Ulaanbaatar. Some of them are low-field MRI systems, using a permanent magnet. All MRI devices in private hospitals belong to the high-field MRI systems (all 1.5 Tesla), which create their magnetic field with a magnetic coil made of superconducting material. Table 14 shows the list of MRI systems in Mongolia.

Table 14: List of MRI devices in Mongolia (June 2014)

MRI device	Magnetic field	Hospital name	Public / private
Siemens Magnetom C!	0.35 T	National Central Hospital	Public
Siemens Magnetom Symphony	1.5 T	SongDo Hospital	Private
Siemens Magnetom Essenza	1.5 T	GrandMed Hospital	Private
Siemens Magnetom Avanto	1.5 T	InterMed Hospital	Private
Phillips Intera	1.5 T	National Trauma Orthopaedic Research Center	Public

Computed Tomography (CT) devices are more common in Mongolia with many variations in age and quality. Their functionality (as well as the functionality of the MRI devices) is mainly ensured by service contracts with the manufacturers. In case of problems, these manufacturers provide telephone- and remote- support or send service technicians. As there are no service companies from international medical equipment manufacturers, the service technicians are coming from other countries. This sometimes results in long out-of-service periods, before the service technician fixed the device and puts it back into operation.

Other medical equipment in Mongolia is mainly old and in many cases out-of-service e.g. the mechanical ventilators in the intensive care station, which were manufactured in 1988. Medical engineers often need to be creative when repairing these devices, because the manufacturers do not provide replacement parts anymore. As no engineer is trained to repair these devices properly, the accurate functionality of most devices cannot be guaranteed. Also calibration and maintenance is not done according to international standards.

Sometimes containers with medical devices are sent to Mongolia. Those devices most of the time were in use by its former owners and were donated to Mongolia. Sometimes the cable connection of the devices are cut, which makes it difficult to set that devices back into operation.

The National Cancer Center (NCC) is installing a new linear accelerator (LINAC) for cancer treatment. It is the first and only LINAC system with a Multileaf collimator (MLC), which is a construction of many movable tungsten leaves to allow an individual shaping of the beam coming from the LINAC [35]. It is therefore possible to reduce the dose applied to the patient. In addition, organs and tissue with high absorption rates of radiation can be protected.

A 1995 installed cobalt 60 teletherapy device from China was removed from the hospital because of serious trouble with the dosage control. Another cobalt 60 teletherapy machine from Czech is in use (figure 11a). Besides the external cancer treatment, also a machine for internal cancer treatment is available at the NCC. A brachytherapy high dose rate afterloader (figure 11b) is a device, where a radiotherapy source, e.g. cobalt 60, is moved through an applicator tube into the patient's body to move the source as near as possible to the cancerous area. After the predefined treatment time, the source is moved back into the safe chamber, before the doctor is allowed to enter the treatment room and to remove the applicator tube.

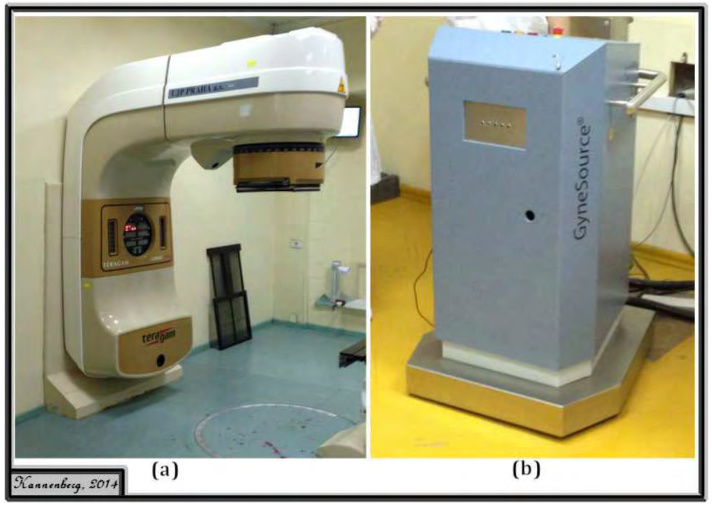

Figure 11: Cobalt 60 cancer treatment devices at the National Cancer Center. a) Teletherapy, b) Brachytherapy afterloader

Laboratory machines vary from laboratory to laboratory, mostly due to the small budged, which is available. The "National Reference Tuberculosis Laboratory" (NRTL) of Mongolia is located in a separated building belonging to the National Center for Communicable Diseases (NCCD) is equipped with diagnosis devices according to the World Health Organization (WHO) standards. A GeneXpert system, which is delivered 12 times to Mongolia until now [36] is a new all-in-one laboratory device to produce fast and reliable test results. It is the recommended device for tuberculosis diagnosis and resistance tests, according to the WHO policy [37]. This policy allowed a price reduction of the device by 75% for 116 low- and middle- income countries [38].

Ulaanbaatar is starting to create laboratory networks, to use laboratory devices more effective. This will also lead to a specialization of the laboratories and a higher knowledge and experience with working on those machines. Microscopes for staining of bacteria in microbiology labs are sometimes old; sometimes there is no microscope in the laboratory at all [39]. The medical situation in urban and rural areas in Mongolia is getting support from the prime minister, the Ministry of Health (MoH), the Asia Development Bank (ADB) and the Mongolian Emergency Service Hospital Hygiene Project (MeshHp). Although sometimes the coordination between these investors is missing [40], most efforts result in a real success for the Mongolian health care system. As a support for all hospitals at the same time is nearly impossible, the differences between hospitals, which have received support, and hospitals, which did not receive support until now is high. Figure 12a for example shows a self-made glass cabin in a blood bank.

"There is also a self constructed glass cabin as 'sterile working room' in the blood bank, without any ventilation."

"Health 5 Trip in April 2014 - Report" by Prof. Dr. W. Popp (MeshHp) [40]

As a comparison, many hospital laboratories have working benches, which are more professional (figure 12b). But this does not mean that all of these benches can work safely. Some of them are not connected to a ventilation system and therefore do not allow a protective and sterile environment for working [39, 40]. Other Equipment is getting stepwise more modern (figure 12c), due to the fact that the Mongolian government tries to improve the health care system to make it become "state of the art".

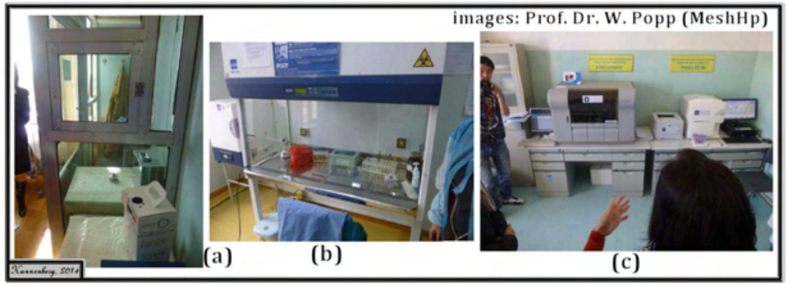

Figure 12: Laboratory equipment in Mongolia. a) Self-made "sterilized" cabin for working (without any ventilation). b) Modern working bench, c) modern equipment for the laboratories [40].

5.2. Medical technology requirements available in Mongolia

Technology requirements are a big topic in developing countries, also in Mongolia. Many different kinds of infrastructure are necessary to optimize the efficiency and safety of medical devices. The most important infrastructures needed are listed in table 15:

Table 15: List of most important infrastructures for the use of medical equipment

Infrastructure of		Infrastructure of	
1.	Water	3.	Knowledge / Education
2.	Electricity	4.	Medicine / supply material

While the infrastructures one and two can be described as the most basic infrastructures, the third one is the most important one. Knowledge of the medical device connected with some general knowledge can protect from making mistakes and can help adapting situations to fulfil all needs. While the training with medical devices for staff and medical doctors is done at the Health Sciences University of Mongolia (HSUM) (besides other private medical universities), the technical aspect of medical devices is taught by the Mongolian University of Science and Technology (MUST). Therefore, most people, who get involved with medical devices in Mongolia, only have one of these previous education possibilities. This results in some very basic mistakes of handling the available medical devices, e.g. connecting a 110 volt medical equipment without transformer with a 220 volt electricity network.

The supply of medicine and supply materials for medical devices is another important aspect, as it is impossible or at least inefficient to use medical drug applicators without the drugs, which were intended to be applied by the device. A wide range of medicines from Europe, America and Asia are available in Mongolia. Although these two infrastructures are important for the use of medical devices, they will be no further discussed in this thesis, because their improvement would need management and financial solutions instead of technical ones.

Water and electricity supply are the most basic infrastructures in the modern world. Stable access to hot and cold water should be available for at least everyone, who is living in urban areas. The water should meet certain requirements on water quality, in order to ensure a safe use. Especially in the health sector, it is important to have access to sanitized and improved water supply. Microbiologic labs as well as other laboratories often require sterilized water or distilled water. Several standards in Mongolia are about water quality in general, drinking water or industrial used water. The list of Mongolian standards 2011 classified by subject lists four and a half pages full of standards, which refer to water quality and water quality measurements [41].

Nevertheless, the water infrastructure cannot provide water in every region of Mongolia. The report of the Health 5 trip report from Prof. Dr. Popp gives an example of a hospital in an Aimag area, where no fluent water was available during their visit [40]. But even in the capital area, the hot water supply is not guaranteed for hospitals, office buildings or residential houses. The Hot water supply in the capital is centralized by a cogeneration power plant, which provides electricity and hot water at the same time. Due to the cold winter, where the soil is frozen deeper than one meter, the hot water tubes often get damaged and need to be replaced during the summer time. This results in planned water outages of areas, where the water tubes need to be replaced. But also during the normal time it can happen that the hot water is only a few degrees Celsius warmer than the cold one. Therefore, the basic infrastructure of water supply is a big problem in Mongolia.

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The other basic infrastructure, which is important for medical devices, is the electricity. Most medical devices need energy supply for running. An absence of electricity in Hospitals leads to big problems, especially where life-supporting devices are in use. It is therefore necessary for hospitals to rely on a stable and safe electricity infrastructure. The electricity infrastructure should include protection measures to ensure that no harm can be done to patients, staff or third person in a hospital.

Mongolia has a 220 Volt [42] electricity network with a frequency of 50 Hertz [43]. Especially older buildings have a low protection against electric shock. Their electricity network is based on two cables, the phase and the zero cables. No additional ground cable is in use in these buildings, which would remove possible electric potentials from metallic parts. Also power sockets do not have a connection with a protective earth (PE). In newer houses, standards force the use of PE cables [44].

Major problems in the Mongolian electricity infrastructure are the fluctuations inside the system. In average, once a week an electricity outage happens, mostly just in single districts of the capital. These outages can be between seconds and hours, sometimes a cascade of several short outages happen during a single day. Also voltage spikes occur irregular in the electricity infrastructure. Sometimes the television turns on up to four or five times during a day or also in the night, because of overvoltage in the system. Voltage spikes with up to 230 kilo Volt (230,000 V) have been measured in the electricity system. This very unstable situation is dangerous, especially in older buildings without protection measures and without PE cables. The high voltage can damage the isolation of the phase and the zero cables and therefore increases the probability that metallic objects or construction parts get in contact with the cables. This would lead to an electric potential on the metallic part, which is a safety treat.

In addition, the voltage spikes are very likely to damage devices, which are connected to the electricity infrastructure. This can lead to damaged electronic parts like electrodes, capacitors or transformers. In rare cases single electronic parts can burn or explode, as it happened with an old mechanical ventilator. Photos of the burning are shown in figure 13a, 13b and 13c.

Figure 13: Photos of an energy compound of a mechanical ventilator. a) Electric platine from the bottom. The copper connections are burned. b) The electrode (middle) is burned, the capacitor next to the electrode is damaged and not functional anymore. c) The metal case of the electric platine. The force of the burning/explosion of the electrode can be seen.

Another infrastructure related to the support of medical devices, as maintenance, calibration or repairing will be described in detail in chapter 5.3. Medical technology companies in Mongolia.

5.3. Medical technology companies in Mongolia: An overview

Medical technology companies in Mongolia are very rare. In fact, technology manufacturing is a rare business in Mongolia in general. Instead of producing technology themselves, nearly everything is imported from other countries. Some companies focussed on the import and sale of medical devices to medical doctors and hospitals (the two major ones are described in table 16).

Table 16: The two biggest import companies for medical devices in Mongolia.

Biggest medical device import company	Biggest medical device import company
Medimpex International LLC [45] A MCS Group company Partners: Siemens, Olympus, Dräger, Agilent Technologies, OFA Bamberg, MDF instruments, Standard Diagnostic, Riester, Trismed, Firstar, B Braun, SuperOrtho	Setunari LLC [46] Import company with German roots Partners: Roche, Philips, Aesculap, Horiba, Stago, Rotem, Hettich, Ferroma, Liebherr, Skadi, Marquet

Both companies offer the import as well as maintenance for products, they imported for their customers. Also extra options of buying medical equipment from other countries are possible, as installation of the device and training of the staff. But most of the time, these options are not chosen because of the possibility to save money. In fact, in many cases this opinion causes many problems e.g. non functional medical devices, not installed or not properly installed equipment and an inadequate use of the devices. All these problems lead to an extinguishment of the guarantee and therefore to additional costs in case of damaged devices. Because of not properly made installation the devices are more likely to get damaged in addition to the damages, which can occur related to the unstable electricity system mentioned in chapter 5.2.

For medical devices not imported by one of these import companies, only local companies offer to repair damaged medical devices. There is a one-man company named "Installation & Service of Medical Equipments LLC", which is founded by an installation & service engineer, who was educated in Ukraine and Russia during the time of Soviet Union in the major of anti air missile systems. Many people name him the best engineer in Mongolia, because in most cases he can find the cause of the problem and fix it, bringing the device back into operation. He is travelling throughout Mongolia to fix devices in hospitals, health care centres and local doctors offices.

Another group, which is taking care of medical devices, is the Medical Engineering Division of the National Central Hospital, the biggest hospital in Mongolia, which also was university hospital for some time. Still education on specialities in medical education is held in this complex. Movable medical equipment from all of Mongolia is brought to this division to be fixed.

But one big problem of fixing medical equipment remains: Quality assurance of medical devices rely on a correct functioning of the devices. Functional tests not only need to check whether the devices turns on properly or not, but it also need to check the accuracy and the need for a renewed calibration of medical devices. Medical devices with wrong calibration can be even more dangerous than a lack of medical devices, because the patient and the medical doctor rely on appropriate working medical equipment. In case the device is not doing what it should do, the possible hazard can range from ineffective treatment over wrong diagnoses up to serious injuries to the patient.

Germany forces the operator of medical devices to perform measurement-related checks as well as safety-related checks regularly for each medical device to ensure the correct and accurate operation of the equipment, as it is described in table 17.

Table 17: List of important checks for the measurement-related check and the safety-related check

Measurement-related checks	Safety-related checks
1. Visual inspection 2. Function test - measurement cables 3. Function test - measurement options 4. Calibration tests - comparison 5. Calibration tests - tolerances 6. Display functionality 7. Accuracy control devices 8. Accuracy knobs 9. Software error log control Documentation: Every test a new protocol Date, name & signature (inspector) Serial number & type (device) Date of the next inspection Serial numbers & types (used devices for the inspection)	1. Visual inspection 2. Potential check - measurement cable 3. Potential check - metal parts 4. Residual currents - tolerances 5. Mechanical accuracy check 6. Mechanical safety check Documentation: Every test a new protocol Date, name & signature (inspector) Serial number & type (device) Date of the next inspection Serial numbers & types (used devices for the inspection)

In general, both checks are performed together by the same person. The person needs to be specially trained to perform the checks properly and reliable. The company, which the inspector is working for, needs to be certified by an authority and must own special norms for different inspections of all classes of devices.

A plan is made in Mongolia to create a national centre for medical device maintenance, which should include not only the repairing of medical devices but also the training and education of biomedical engineers and other staff, which is taking care of medical equipment. Quality- management, -control and -assessment should become important parts for this new centre. With this national centre, it could be possible to set up new standards for maintenance of medical equipment. Nowadays, there are no current standards in Mongolia, which control a regular check-up of medical devices and also no standards about how these check-ups should be made. It should become more important for the Mongolian health care system to be able to rely on medical technology available on Mongolia, than to invest into new medical equipment, which is not reliable due to missing quality control and inadequate maintenance.

5.4. Technology companies in Mongolia

The situation of technology companies in Mongolia varies with the definition of the term "technology company". While technology manufacturers are not very common in Mongolia, technology providing companies are very common in Mongolia. Electronic stores all over the Mongolian capital offer technical products from refrigerators to personal computers.

Telecommunication technology is important in Mongolia, what can be seen by the big number of companies (table 18), which are offering solutions for telephone, cell phone or internet. Also internet for cell phones is provided using radio wave data connections. The market is in balance, as different companies focus on different areas (e.g. G-Mobile focuses on providing rural areas with cell phone and internet connectivity.)

Table 18: List of the mayor telecommunication companies

Name	Mayor business	Name	Mayor business
Mobicom	Cell phones, Internet	Skytel	Cell phones, Internet
Unitel	Cell phones, Internet	Mongolia Telecom	Cable telephone network
G-Mobile	Cell phones, Internet		

But not only the support of telephone and internet connection is an increasing market in Mongolia, also the manufacturing of telecommunication devices starts to grow. In 2014 four companies located in Mongolia announced, to create inexpensive smart phones for Mongolian people. These companies follow different ideas to reach their personal goals. One company announced that they want to buy used phones to import them to Mongolia. In Mongolia, they will be checked and updated before they can be sold with a 30% price reduction compared with the market prices of new smart phones. Two other companies announced, they would import smart phones and update them with Mongolian software to provide Mongolian language software for Mongolian customers [47]. The fourth company, IT Zone, released its "Mogul Sonor" in 2014[48]. This Android 4.2 based smart phone is assembled from imported parts.

IT Zone company not only produces smart phones, but has their main focus on televisions and computers, which are assembled in Mongolia, and tested before bringing them into market. For this purpose the company created Mongolia's first fully-automated assembling factory [49] for their new "Mogul" brand (figure 14). Due to agreements IT Zone can sell their computers with Windows 7 as operating system and Mongolian language pack [50]. During an interview B. Enkhbagana explained that only high quality components are assembled into the Mogul computers: Memory from Kingston, Main boards from Foxconn, optical drives from Sony [51].

Mogul™
Дэлхийд өрсөлдөх Монгол брэнд

Figure 14: Logo of the first Mongolian brand "Mogul".

In the area of sustainable development the first steps were made in 2004, when an idea was born to create wind energy farms in Mongolia. After a long phase of investigation and measurements 18 local companies with about 500 workers participated in the construction of the first wind farm in Mongolia. 31 wind turbines created by General Electric were built up about 70 km away from the capital in the mountains. With 120 meters of height each, they produce about 50 Megawatt of Electricity in total [52].

The plan for the future is not only to provide 20% of Mongolia's complete energy consumption with renewable energy until 2020. According to Bloomberg, Clean Energy Asia LLS, a joint venture of the Newcom investment group and a Japanese investor, is planning more wind farms in Mongolia with a possible total energy production of more than 7,000 Megawatt [53].

Also small solar cell farms with up to 100 kilowatt power generation can be seen in the surrounding areas of the Mongolian capital, where no buildings are producing shadows, which could reduce the possible outcome of the solar cells.

In general it can be said, that Mongolian technology companies focus on the import of technical products or components to assemble products, which are sold under a Mongolian brand. The construction of technical components is not provided by the Mongolian economy. Of course a Mongolian company would have to compete with big producers of technology components in the world, which have much knowledge and experience with the manufacturing of technology.

But this kind of manufacturing could be a big and lucrative market for Mongolia, because Mongolia is mining for materials like copper, gold, silver and coal. Nowadays these metals and minerals are sold for little money to companies, which are producing technology components and products. These components and products then are sold back for higher money to Mongolia. A component manufacturer in Mongolia would lead to the situation, that 100% Mongolian products could be created, from the mining to the complete product. It would be an improvement for the Mongolian economy, because the money could be kept within the Mongolian economy instead of supporting other countries' economies.

5.5. Conclusion

This chapter focused on the health care infrastructure of Mongolia. It was shown that technology in general is imported from other countries instead of producing technology inside the country. That causes a number of problems in Mongolia, because Mongolia is dependent of technology from outside, which makes it difficult to set national standards. Without technology standards the quality of technology products cannot be ensured. Quality control varies and is not reliable, because every inspector can focus on his/her main interests.

A second big problem of importing medical devices is the installation and operation. Medical devices from different countries are conform to the standards of their company's countries. They might have different requirements in the needs for installation and operation. The user manuals might not include accurate translations into Mongolian language. Also instruction of the use of the devices by foreign company workers could lead to misunderstanding and wrong usage of medical devices. Professional installation of the device becomes more expensive and more complicated, because foreign workers need to come and inspect the room or construction site, before the installation can be performed. In addition foreign technology can have different requirements on the electricity network, e.g. USA devices with 110 volts between phase- and zero- cable and 60 hertz instead of 220 volts between phase- and zero-cable and 50 hertz as it is in Mongolia. This results in additional costs for transformers or possible damages due to mistakenly connecting the 110 volt device to the 220 volt network.

Another problem is a more general problem of Mongolia. By importing technology from other countries, the Mongolian country is spending money to support foreign economies. Due to this, much money is missing in the Mongolian economy, which leads to less governmental income of taxes and therefore missing money, which would be needed in the Mongolian health care and social systems. Technology manufacturers inside of Mongolia would provide new jobs and could lead to a situation, where Mongolian money stays in its own economy instead of being spent to foreign countries.

This chapter shows that the development and quality of the advanced infrastructure development for medical technology suffers from problems occurring in the more basic infrastructures. Dirty water and unstable electricity are likely to damage expensive medical devices as well as other technology products in developing countries. Projects, which support urban and rural areas in Mongolia with new medical devices, might be a waste of money, when the basic infrastructure cannot be ensured before setting the devices into operation. Older medical devices were developed during a time, where the infrastructures of their manufacturing countries had a lower level. Therefore the old devices are more robust against voltage spikes or dirt in the devices. This might be the reason, why these devices have fewer problems with the Mongolian infrastructure than more modern devices. In order to install state-of-the-art equipment for Laboratories, for diagnosis or treatment the basic infrastructure should be improved. Only a reliable basic infrastructure ensures an efficient and correct working device.

Along with the investment into new medical devices, an investment into the education and training of staff is necessary to ensure a correct and appropriate use of the medical devices. Medical devices are only useful in case the operator and the user know details about the machines specifications, advantages and disadvantages. It must be known to the user what the device can do and what the device cannot do. Together with the correct installing and a good infrastructure, medical devices can be operated for many years without much further investments. Regular checks of the devices increase the safety and can reduce costs, because small problems can be fixed before they develop to bigger problems. In addition, reliable equipment strengthens the faith into modern medicine.

In 2011 there were no Mongolian standards regarding the stability of water and electricity infrastructures. Also no standards were available about the construction of hospitals and the operation and use of medical devices [41]. This results in highly unequal situations not only between different areas of Mongolia but also within.

A health care project in Mongolia should focus on setting Mongolia wide standards to make the situation in all hospitals more equal. A stable water supply with improved water and separated wastewater system and a stable and reliable electricity system are basic requirements for modern medical technology. Also coordination of the support with medical devices can improve the general situation of Mongolia's health care system. Prof. Popp mentioned in his Health 5 trip report, that different hospitals received modern sterilizer systems from the World Health Organization (WHO) for their waste management [40]. He also suggested that these modern systems should not be used for the waste management but instead for sterilizing medical devices, which are reused. The more old and more inaccurate sterilizers, which are in use for sterilizing medical devices, should be replaced by the new WHO sterilizers, while the old systems can be used for sterilizing the waste instead [40].

Improvements of all kinds of infrastructures are helpful for the development of the country as well as the development of the health care sector. Technology manufacturers and technology service companies with different locations in Mongolia would provide a better and more individual supply and support of medical and not medical devices. Improved water and electricity infrastructure improves not only medical facilities but strengthens the quality of life for all Mongolian citizens and reduces health care problems, which are related to low quality of living.

The medical facility infrastructure suffers from old buildings, which do not cover international standards and do not allow any efficient hospital organization. The lack of knowledge about the appropriate construction design of hospital building lead to problems during the construction and additional costs. Prof. Popp described in his report the construction progress of the new Bayangol District Hospital, where an operation theatre is made in a room, which was initially planned as the kitchen [40]. Also other rooms and stations, which have additional requirements, were shifted to other locations in the building, which results in changes in the electricity plan, water tube connection and the air flow system.

Especially in the Mongolian capital Ulaanbaatar the street infrastructure is an important aspect for the health care. Due to regular traffic jams, the patient transportation to hospitals is slow and inefficient. Programs like the Mongolian Emergency Service Hospital Hygiene Project (MeshHp) are improving the situation by providing special training to the ambulance drivers and paramedics to increase the first aid inside the ambulance car, while the patient is on the way to the hospital. But these projects are limited because there are no standards for ambulance cars and their equipment. Also the staff situation does not allow every ambulance car to have a paramedic in the back to observe the patient. Even when a paramedic is observing the patient, the possibilities are limited to the equipment available in the ambulance car. Therefore the traffic situation should be improved to allow ambulance cars a faster transportation of patients to the hospitals. Also other possibilities like a guiding system for ambulance cars are an improvement of the patient transport infrastructure.

6. Medical situation in Mongolia

6.1. Medical diseases in Mongolia

6.1.1. Overview

In 2013 the Ministry of Health (MoH) published a document named "Health Indicators 2012" [54]. This document shows that Mongolia faces several problems with infections and non-communicable diseases. Circulatory system diseases are the cause of about 35% of all deaths in Mongolia, followed by cancer, which causes about 21% of the Mongolian mortality[14]. A complete list with the most important death causes can be found in Annex I.

But not only is the mortality important for the health care. Also the morbidity[15] of diseases is an important indicator of the health of the Mongolian population. Especially communicable diseases are a problem in the world, because of its potential to spread fast. While infectious diseases as Typhoid- and Paratyphoid- Fever or Measles are no problems due to a wide spread vaccination in Mongolia, other infections like Mumps, Hepatitis and Tuberculosis (TB) still are a serious thread in the Mongolian health care system [7, 54]. Three main types of infections are the most common communicable diseases: Intestinal infections (IIs), respiratory infections (RIs) and sexually transmitted infections (STIs). Table 19 shows the ten infections with the highest morbidity in Mongolia in 2012.

Table 19: Top 10 morbidity of communicable diseases in Mongolia 2012 [54]

#	Name	Type	Cases	%	#	Name	Type	Cases	%
1	Mumps	RIs	9,060	20.92	7	Varicella	RIs	2,806	6.48
2	Viral Hepatitis A	IIs	5,892	13.61	8	Shigellosis	IIs	2,051	4.47
3	Gonorrhoea	STIs	5,351	12.36	9	Hepatitis B, C etc.	IIs	964	2.23
4	Syphilis	STIs	4,954	11.44	10	Oth. bact. food-borne intox.	IIs	719	1.66
5	Trichomoniasis	STIs	4,158	9.60					
6	Tuberculosis	RIs	3,944	9.11		Top 10		39,899	91.88

The table shows that these ten most common communicable diseases make about 92% of all communicable diseases in Mongolia in the year 2012. In the statistics of the health indicators 2012 five other intestinal infections are mentioned, which have 603 cases in total [54]. They are listed in table 20 together with the other intestinal infections from 2011 and 2012.

Table 20: Number of cases of intestinal infections per 10,000 population [54]

	2011		2012	
	Abs. numbers	Per 10,000 population	Abs. numbers	Per 10,000 population
Typhoid and paratyphoid fever	2	0.0	0	0.0
Salmonella infections	118	0.4	112	0.4
Shigellosis	2,120	7.6	2,051	7.4
Other bacterial food borne intoxications	278	1.0	719	2.6
Diarrhoea infections	75	0.3	86	0.3
Viral hepatitis A	13,612	49.0	5,892	21.2
Hand-foot-mouth disease	1,042	3.7	405	1.5

[14] Mortality: The death rate of a population
[15] Morbidity: The rate of incidence of a disease.

The respiratory infections in Mongolia vary much between the years. Most of the time tuberculosis leads the list of respiratory infections in Mongolia, because the absolute number of cases remains on the same level during the years [7, 32, 54]. In 2012 an outbreak of mumps in some Aimags of Mongolia lead to the situation that the absolute numbers of Mumps cases are about 9-times higher than the year before. According to the statistics, no case of Measles was noted in Mongolia in 2011 and 2012. Other respiratory infections like scarlet fever or meningococcal infections are very rare. Table 21 shows the complete list of respiratory infections in 2011 and 2012.

Table 21: Number of registered cases of respiratory infections per 10,000 population [54]

	2011		2012	
	Abs. numbers	Per 10,000 population	Abs. numbers	Per 10,000 population
Tuberculosis	3,985	14.3	3,944	13.9
Scarlet fever	68	0.2	89	0.2
Meningococcal infections	20	0.1	28	0.1
Varicella	3,097	11.1	2,806	10.1
Measles	0	0.0	0	0.0
Rubella	16	0.1	215	0.8
Mumps	1,016	3.7	9,060	32.6
Erysipelas	169	0.6	201	0.7

Sexually transmitted infections are an increasing problem in Mongolia. During the years the absolute numbers of infections were rising steadily year by year. As it was described in chapter 4.5, there were only two cases of HIV in Mongolia in 2001, one acquired in another country and the other one by an African visitor in Mongolia. Since then the number of cases were increasing year by year. In 2012 27 cases of HIV were detected in Mongolia. The fear is that HIV could spread faster in Mongolia, because other STI's e.g. Syphilis or Gonorrhoea became serious problems in Mongolia. The complete list of sexually transmitted infections in the years 2011 and 2012 can be seen in table 22.

Table 22: Number of cases of STI's per 10,000 population [54]

	2011		2012	
	Abs. numbers	Per 10,000 population	Abs. numbers	Per 10,000 population
Syphilis	4,268	15.3	4,954	17.8
Gonorrhoea	5,159	18.6	5,351	19.2
Trichomoniasis	4,000	14.1	4,158	15.0
HIV/ AIDS	17	0.1	27	0.1

Although there are high amounts of cases of communicable diseases in Mongolia (43,425 cases in total in 2012) they are highly outnumbered by the non-communicable diseases in Mongolia. In 2012 there were 311,956 new cases of respiratory system disease detected, most of them are assumed to be caused by air pollution in Mongolia [55]. With 1.194,871 cases in 2012 this category covers most of the Mongolian health care problems. A growing threat in Mongolia is cancerous diseases, especially as there is only one public hospital in Mongolia, which can treat cancer with appropriate devices and medicine. Table 23 shows the 2012 cases of non-communicable diseases in Mongolia.

Table 23: Number of cases of non-communicable diseases in Mongolia in 2012 [54]

Diseases of	2012	
	Absolute cases	Per 10,000 population
Respiratory System	311,956	1099.44
Digestive System	291,632	1027.81
Circulatory System	231,825	817.03
Genitourinary System	216,804	764.09
Injuries, poisoning, etc.	142,654	502.76

Cancer is a big problem in Mongolia, especially liver cancer, due to the high amount of hepatitis in Mongolia. But the intestinal tract is not the only area of cancer, as there are small numbers of breast-, lip- and oesophagus cancer. Also some cases of Leukaemia have been detected in 2012 [54]. 75% of all sort of cancer is covered by the five most common cancer diseases. They are listed in table 24.

Table 24: Top 5 list of Cancer cases in Mongolia in 2012 [54]

cancer	Abs. cases	%
Liver	1,712	37.68 %
Stomach	665	14.63 %
Trachea, bronchus and lung	368	8.10%

cancer	Abs. cases	%
Cervix	348	7.66%
Oesophagus	330	7.26%
Top 5	3,423	75.33%
All cancer	4,544	100,00%

Viral hepatitis and tuberculosis still cause deaths in Mongolia every year besides disease as diarrhoea or diabetes mellitus. Also syphilis caused eight deaths in Mongolia in 2012. But all of these diseases cause relatively less deaths compared with e.g. car accidents (593 deaths in 2012) or acute myocardial infarctions (875 deaths). An overview is given in table 25.

Table 25: Mortality of some chosen diseases in Mongolia in 2012 [54]

Disease	Abs. deaths
Acute respiratory infections	358
Tuberculosis	274
Diabetes mellitus	133

Disease	Abs. deaths
Diarrhoea diseases	29
Viral hepatitis	14
Syphilis	8

Nevertheless, Tuberculosis remains to be a serious thread for the Mongolian health care system. Since Mongolia signed the United Nations Millennium Summit, much afford was taken to reduce the infections and deaths of tuberculosis (TB). While the death rate could be significantly lowered during the time by providing appropriate medicine to the patients, the infection rate of TB could not be lowered.

6.1.2. Tuberculosis

Tuberculosis (TB) is named as one of the most dangerous infectious disease in the world. According to WHOs Global Tuberculosis Report 2013, about 1.3 million people died in 2012 because of Tuberculosis, 320,000 of them had HIV in addition [56] This makes it the second leading cause of death from an infectious disease worldwide [56]. It can be caused by various strains of mycobacteria, whereas M. tuberculosis is the most common. The lungs are most likely to be infected by this pathogen, but also other parts of the body can be affected. Other TB bacteria are M. africanum, which is mostly common in parts of Africa, M. canetti and M.microti, which are rare bacteria. Another mycobacterium, M.bovis, is causing the so called "bovine TB", which is a growing problem in Animals. Especially due to unpasteurized milk of infected animals the bovine TB can spread also in human bodies [57]. Other Mycobacteria can cause tuberculosis signs but are not infectious (Mycobacteria other than tuberculosis, MOTT).

M.tuberculosis is an aerobic gram-positive bacillus, which divides every 16 to 20 hours. It has a protection shell, which protects it from weak disinfectants and the dry atmosphere. Therefore, it can survive several hours in the fresh air. Living in an aerosol [56] it can be inhaled by people, who will become infected, when the bacteria reaches the lung. In general only five to ten percent of all infected people get ill during their lifetime. The reason is that only an insufficient working immune system or genetically caused vulnerabilities can cause the bacteria to spread. Therefore diseases, which affect the immune system, e.g. HIV, increase the risk that the infection results in a disease. Also genetically caused problems, e.g. vitamin D inefficiency, increase the risk of developing a disease. Smoking of cigarettes is said to a higher risk of TB than non-smokers [58]. In case the TB becomes active, it will damage the lung. In this case, the bacillus can be exhaled by the person, which means that it is an infectious form of TB. This form is also named "open tuberculosis". At this stage, the bacteria can also spread with the blood and damage other organs. Other ways of infection are by consuming infected milk or meat (both raw), open wounds, blood or organ transmission or sexually in case of infected primary sexual organs.

Although the treatment of TB could reduce the amount of deaths by 45% compared with 1990 [56], it is still a serious problem in developing countries, mostly because of inadequate treatment possibilities, because the Antibiotics are expensive and the treatment takes a long time. This makes the regular treatment in most cases difficult or nearly impossible. Also the laboratories, drugs or technology is not always available to diagnose and treat tuberculosis.

"The number of TB deaths is unacceptably large given that most are preventable if people can access health care for a diagnosis and the right treatment is provided. Short-course regimens of first-line drugs that can cure around 90% of cases have been available for decades."

Global Tuberculosis Report 2013 [56], page 1

Forms of TB can be set in two categories: Pulmonary and extra-pulmonary. Infections by inhaling TB bacilli lead to an infection of the lungs, which is named pulmonary TB (ICD-10 A15 and A16). When the TB becomes active, it damages the lung and gains access to the trachea. Infected people then become infectious because TB bacilli can be exhaled. In addition the patient may cough up small amounts of blood. In a further progress, the arteries of the lung can get damaged, which allows the bacilli to spread in the patient's body, what will result in an extra-pulmonary TB in addition to the pulmonary [56].

Extra-pulmonary TB (ICD-10 A17 and A18) can have different causes. Transmission through blood due to open wounds, infected needles or the consumption of infected food or milk allow TB bacilli to enter the body and infect other organs. But late stages of the pulmonary form lead to a spreading of bacilli in the body as well. Typical infection areas are the pleura, the central nervous system, lymphatic and genitourinary systems as well as bones and joints. In general this form can become more difficult to treat, because it can lead to a multi-organ infection with various symptoms. In this stadium, the TB is also named Military TB (ICD-10 A19).

National standards and recommendations from the World Health Organization (WHO) give suggestions about adequate diagnosis and treatment of TB. Mongolia has a few national standards about tuberculosis as well, which are listed in table 26. Further statistics are available in Annex II and Annex III.

Table 26: List of Mongolian Standards related to Tuberculosis [41]

11. Health care technology	
11.020 Medical sciences and health care facilities in general	
MNS 5348-12 : 2003	Tuberculosis A15-A19 (pulmonary) - Definition
MNS 5348-13 : 2003	Tuberculosis A15-A19 (extra-pulmonary) - Definition
MNS 5349-12 : 2003	Diagnostics & management of the Tuberculosis A15-A19 (pulmonary)
MNS 5349-13 : 2003	Diagnostics & management of the Tuberculosis A15-A19 (extra-pulmonary)
11.100 Laboratory medicine	
MNS 5456-6 : 2005	Technical instruction of laboratory diagnostics for tuberculosis
11.100.10 In Vitro diagnostic test systems	
MNS 5730-1:2007	Chromatographic immuno assay for the detection of Mycobacterium tuberculosis IgG, IgA and IgM.
11.120.10 Medicaments	
MNS 4129 : 1992	Bacteriophage for diagnosticate of pseudo tuberculosis
11.220 Veterinary medicine	
MNS 3576 : 1963	Laboratory methods for diagnose of avian Tuberculosis
MNS 4395 : 1996	Methods for detecting of the agent of Para tuberculosis (John's disease)
MNS 5720 : 2007	Protein antigen of ELISA for diagnosis bovine tuberculosis. Technical requirement
MNS 6080 : 2010	Veterinary. Immunofluorescent IgG (immunoglobulin) for diagnosis bovine tuberculosis. Technical requirement
67.100 Milk and milk products	
67.100.01 Milk and milk products in general	
MNS 4371 : 1996	Method for detect agent of tuberculosis in the milk

6.1.3. Hepatitis

Hepatitis is a disease of the liver, which can have several different reasons such as toxics (alcohol) or infections (virus). Virus infections are a common problem because of different hepatitis viruses (A-E), which have different forms of transmission e.g. faecal in contaminated water and dirty food (Viral Hep A and E) or by body fluids (Viral Hep B, C and D). All forms of viral hepatitis damage the liver, whereas Hep A is only known to produce active hepatitis, which will be cured after a few weeks or months. Other hepatitis viruses are likely to produce chronic hepatitis, which will cause liver cirrhosis and/or liver cancer (together more than ten percentage of the Mongolian mortality in 2012) [54].

National standards have been established in 2003 about hepatitis and the diagnosis of hepatitis, which means that new developments and international studies are not taken into account when defining these standards. A List of hepatitis related standards is shown in table 27.

Medical health care problems and possible solutions for developing countries:
Case study Mongolia

Table 27: Mongolian national standards related to viral hepatitis [41]

Standard	Name	Standard	Name
MNS 5348-7	Acute viral Hepatitis A	MNS 5349-7	Diagnostics & management of Hepatitis A
MNS 5348-8	Acute viral Hepatitis B	MNS 5349-8	Diagnostics & management of Hepatitis B
MNS 5348-9	Acute viral Hepatitis C	MNS 5349-9	Diagnostics & management of Hepatitis C
MNS 5348-10	Acute viral Hepatitis D	MNS 5349-10	Diagnostics & management of Hepatitis D
MNS 5348-11	Acute viral Hepatitis E	MNS 5349-11	Diagnostics & management of Hepatitis E
Standard	Name		
MNS 5456-5	Technical instruction of laboratory diagnostics for viral hepatitis A,B,C,D,E		
MNS 5730-2	Hexagon-HCV Test for the Detection of Antibodies to Human Hepatitis C Antibodies		
MNS 4715	Hepatitis B vaccine 1 ml		

Especially the high prevalence of viral hepatitis B and C [59] are a big problem in Mongolia, together with the high amount of liver cirrhosis and alcohol related liver diseases. It leads to the high rate of liver cancer in the Mongolian population.

6.1.4. Cancer diagnosis and treatment

Cancer is a serious threat in Mongolia as there is only one hospital in the country, which is providing treatment as surgery, radiotherapy or chemotherapy for the cancer patients. In 2008 a Mongolian study about Hepatocellular carcinoma (HCC) estimated that the National Cancer Center (NCC) can only treat about 800 patients with radiotherapy during the year [59], which was about 50% of all new cancer cases in that year. Taking into account that one radiotherapy device was removed from the hospital and the new LINAC system is not in operation until now, it is to assume that less than 800 cancer patients can receive radiotherapy treatment during the year. Comparing this number with the cancer mortality in 2012 (about 3,600 cases) it can be assumed that less than 20% of all cancer patients have access to radiotherapy treatment.

As there is no screening for cancer in Mongolia, most cancer is detected in the late stages, where a surgery cannot be applied to remove the cancer completely. Besides the lack of possible treatment there is also a lack of cancer diagnosis possibilities. The HCC study described the diagnosis situation, using an ultrasonography (US) system as follows:

"The number of US machines is very low, especially in local areas, and the quality of US and examiners is unsatisfactory. For the proper diagnosis of HCC, high imaging diagnostic capacities including computed tomograms (CT) and magnetic resonance imaging (MRI) are essential. Unfortunately, only the NCC and state hospitals in Mongolia have several machines and these are of low quality."

Current Situation of Hepatocellular Carcinoma in Mongolia [59].
Oncology page 150

6.1.5. Other diseases

Typical health care problems in Mongolia are respiratory, circulatory and digestive system diseases (cerebrovasular disease, ischemic heart disease, pneumonia, liver cirrhosis). Often they can be related to high bacteria and virus prevalence's or environmental factors (air pollution).

6.2. Gold standard technology for diagnosis and treatment of these diseases

6.2.1. Overview

National standards for diagnosis and treatment of diseases often base on international standards or guidelines. The World Health Organization (WHO) provides the international community with guidelines and recommendations on the diagnosis and treatment of different diseases. It also takes care of evaluating new technologies and methods, which are designed for treatment or diagnosis of these diseases.

In Germany national standards regulate the operations in diagnostic laboratories. All standards are written in German as well as in English language and therefore a good source for national standards in developing countries. The standards get reviewed and changed regularly to fit the international standards and changes in guidelines. For example the DIN 58943, which focuses on the laboratory diagnosis of tuberculosis bacilli, was updated in the year 2011, part 7 and part 40 are already marked as inaccurate again [60]. The full list of all parts of the standard (status 2011) is shown in table 28.

Table 28: List of parts of the German standard for tuberculosis diagnosis (2011) [60]

Standard	Name
DIN 58943-3	Detection of mycobacteria by culture methods
DIN 58943-4	Primary samples for the diagnosis of tuberculosis and mycobacteria - Qualitative and quantitative requirements, extraction, transport and storage
DIN 58943-4 Supplement 1	Prevention of contaminations of clinical specimens with mycobacteria during processing in the laboratory
DIN 58943-5	Molecular biological identification and differentiation of tubercle bacilli
DIN 58943-7	Modified Löwenstein-Jensen medium for the growth of mycobacteria
DIN 58943-8	Methods for the determination of susceptibility of tubercle bacilli to chemotherapeutic agents
DIN 58943-9	Phenotypic differentiation of tubercle bacilli
DIN 58943-32	Detection of mycobacteria by microscopic methods
DIN 58943-40	Evaluation criteria for fast culture procedures for the detection of mycobacteria

Gold standards in medicine describe the state-of-the-art method or technology in developed countries to treat various illnesses and diseases of their patients. It should be the aim of developing countries to reach these state-of-the-art standards to ensure a qualitative and appropriate medical treatment of their patients. As these technologies and methods have certain requirements and are expensive, a stepwise change towards these gold standards should be organized. In some cases it is also possible to keep alternative technology, in case it is accurate and appropriate enough to ensure a high quality of health care. It needs to be recognized that changing guidelines also change the recommendations about medical technology used for diagnosis and treatment and therefore also the definition, what technology can be seen as alternative methods and technologies.

In some cases new technologies create possibilities, which cannot be compared with the possibilities from other technologies. In that case, no alternative technology is available. This makes it necessary to investigate into the implementation of these modern technologies.

6.2.2. Tuberculosis diagnosis

International gold standard for tuberculosis diagnosis is a combination of different aspects. A case history is important to investigate how the patient obtained the infection and what people he met and where he was after his infection, because other people can be infected as well. The second important aspect is the microscopy of the patient's sputum. In case tuberculosis bacteria can be found in the sputum, the patient is infectious and all people mentioned in the case history could be infected. Imaging techniques are the third aspect. Lung damages due to tuberculosis can be seen on the x-ray image, while extra pulmonary TB requires other imaging systems. The most important aspect, which unfortunately takes the longest time, is the culturing of the bacteria, to have a final proof of M. tuberculosis. These cultures are also important for performing resistance tests, in order to choose the best combination of antibiotics to fight the TB. Multidrug-resistant TB (MDR-TB) is a growing problem in the world, because treating the patients is more expensive and takes longer. Eliminating MDR-TB in an adequate way is important to reduce the spreading of extensively drug-resistant TB (XDR-TB).

Microscopy is an initial method of analyzing the patient's health condition. Germany has standards about preparing specimen for the further analysis for TB [61]. These prepared specimens are also used for microscopy, which is described in detail in another German standard [62]. Various sources can be used to obtain specimen for the analysis. They are listed in table 29.

Table 29: "Extraction of and requirements for the specimen" according to German standards [61]

Sputum	Protected brush and bronchoscopically extracted biopsies	Sperm and prostatic secretion
Urine	Body fluids from primary sterile compartments	Bone marrow
Swabs	Fasting gastric contents and stomach washings	Tissue, biopsies
Blood	Bronchial and tracheal secretions	Wound materials
stool	Bronchoalveolar lavage liquid	Menstrual blood

Two techniques are described for microscopy in the standard, the bright light microscopy using the Ziehl-Neelsen stain and the fluorescence microscopy using the phenol-auramin stain. These techniques have different requirements on the microscopic device. The fluorescence microscopy is the gold standard for microscopy, because it is more sensitive in detecting acid-fast bacilli (e.g. mycobacteria) and faster. Only in case of uncertain results (e.g. other stained bacteria), a second microscopy with the Ziehl-Neelsen stain is performed, because it is more specific.

"In 2009, WHO recommended the use of the more sensitive fluorescent light-emitting diode (LED) microscopy as a replacement for traditional Ziehl–Neelsen (ZN) microscopy."

Global Tuberculosis Report 2013 [56], page 61

The World Health Organization (WHO) negotiated together with the Foundation for Innovative New Diagnostics (FIND) and the Bill & Melina Gates Foundation about a price reduction of a recommended microscopic device, which can perform both techniques (most microscopes are designed for either bright light or fluorescence microscopy). As a result, Carl Zeiss offers their Primo Star iLED microscopic system (figure 15a) for a reduced price for low- and middle- income countries in the world, to strengthen their national TB program [63].

Imaging is important for the diagnosis of TB as well. Pulmonary TB can be often seen with x-ray images, but in many cases it is difficult to distinguish between tuberculosis and other lung diseases. Therefore CT images can be necessary for an accurate detection. Imaging of extra pulmonary TB is more difficult, because of the different locations of the possible infection. Intracranial TB (e.g. tuberculosis meningitis), spinal TB (infection of the backbone) or urogenital TB (male or female genital TB) can be visualized best by MRI systems or with contrast high resolution CT (contrast-HRCT) [64, 65].

International standard for the diagnosis of TB is the detection of the bacteria by culturing on solid or liquid media for a detailed analysis of the type of bacteria and its resistances against antibiotics. It is a time consumptive method, because the incubation of the media takes up to six weeks before TB can be surely detected. DNA technology methods like polymerase-chain-reaction (PCR) can increase the amount of bacteria DNA for analysis, but has the disadvantage that it cannot differ between living and dead bacteria DNA. Therefore also dead bacteria will be detected in PCR methods. Natural growth in solid or liquid media in contrast only works with living bacteria.

"In countries with more developed laboratory capacity, cases of TB are also diagnosed via culture methods (the current reference standard)."

Global Tuberculosis Report 2013 [56], page 1

New methods for the culturing of bacteria are developed to increase the speed, safety and quality control are integrated systems. These systems allow a natural growth of bacteria with optimal conditions and therefore increasing the growth of the bacteria in their reagent tubes. The aim is to increase the speed of detecting TB colonies in an automated system without big workload for laboratory workers.

The WHO recommends the "BD Bactec MGit 320" and "960" systems (figure 15b), which are fully-automated liquid media culture growth systems [56]. With fluorescence detection technology, several specimen probes can be cultured, incubated and observed at the same time [66]. WHO and FIND negotiated with the manufacturer to obtain prize reductions for several countries affected by high TB and MDR-TB burden [67]. Unfortunately Mongolia is not listed in the list of countries, which can get the device for a reduced prize.

Molecular technologies for fast detection of TB bacilli and their resistances are getting a higher importance in the diagnosis of MDR-TB. Whenever a tuberculosis bacilli has a resistance against a single antibiotic (rifampicin resistant TB: RR-TB), two antibiotics (rifampicin and isoniazid: MDR-TB) or more than two antibiotics (XDR-TB), the resistances need to be detected fast to change the drugs for treatment in an appropriate way. In case an antibiotic combination is given to the patient, where one of two drugs is not working due to a resistance, the bacilli is very likely to develop a resistance against the second drug as well. Therefore a fast and quality assured resistance testing is essential for fighting the further spreading of antibiotic resistances.

"Molecular technologies are increasingly being used in drug resistance surveys to simplify logistics and reduce laboratory workload. GenoType® MTBDRplus (Hain Lifescience, Germany) was used in the national survey completed in 2012 in Nigeria and Xpert® MTB/RIF (Cepheid, USA) is being used in the surveys underway in Pakistan and Papua New Guinea."

Global Tuberculosis Report 2013 [56], page 46

Line probe assays are DNA based techniques to detect known mutations in bacteria, which causes resistances. By reproducing the bacteria DNA with PCR the DNA codes, which cause the resistances, can be detected. The Line probe assays show the result of the analysis after a few hours. Line probe assays for first line drugs (the commonly used drugs for treating TB) are endorsed by WHO in 2008. These "GenoType MTBDRplus" line probe assays (figure 15c) together with the adequate devices to use them are available for reduced prices due to negotiations between the WHO and FIND with the manufacturer [68]. Line probe assays for the second line drugs (antibiotics only used for MDR-TB and XDR-TB cases) are developed as well and are in a stage of analysis before they can be endorsed by the WHO.

Another modern technology system is the fully-automated microbiological analysis system "GeneXpert MTB/RIF" (figure 15d & 15e), the first all-in-one device of its kind [69]. The unprepared sample is placed into a cartridge, which is then inserted into the device. Without further work necessary, the device is performing a PCR and analyzes the system. It is endorsed by the WHO and part of an international TB program, where laboratories all around the world should get access to this new technology. It is able to test for TB bacilli and possible rifampicin resistance. The results can be provided by the device after about 90 minutes, which is a huge difference compared with the four to six weeks for normal culture growth methods. But it cannot replace the culture methods as they are the only standard reference method to perform drug susceptibility testing (DST) on the bacilli.

"The recommendations were that Xpert MTB/RIF should be used as the initial diagnostic test in individuals at risk of having MDR-TB or HIV-associated TB (strong recommendation), and that Xpert MTB/RIF could be used as a follow-on test to microscopy in settings where MDR and/or HIV is of lesser concern, especially in smear-negative specimens (this was a conditional recommendation, recognizing major resource implications)."

Global Tuberculosis Report 2013 [56], page 60

"GeneXpert MTB/RIF" is available for reduced prices in many low- and middle-income countries due to negotiations between WHO, FIND, the Bill & Melinda Gates Foundation and the manufacturer [70]. It is assumed to be able to replace the microscopy analysis in the future, as it is planned in South Africa [56].

"The current price per cartridge is US$ 9.98, following a novel financing agreement reached in August 2012 between the manufacturer and the United States Agency for International Development (USAID), the United States President's Emergency Plan for AIDS Relief (PEPFAR), UNITAID and the Bill & Melinda Gates Foundation. South Africa alone accounts for 43% of the modules and 60% of the cartridges procured globally, and is aiming to position Xpert MTB/RIF as a replacement for microscopy for the diagnosis of TB."

Global Tuberculosis Report 2013 [56], page 61

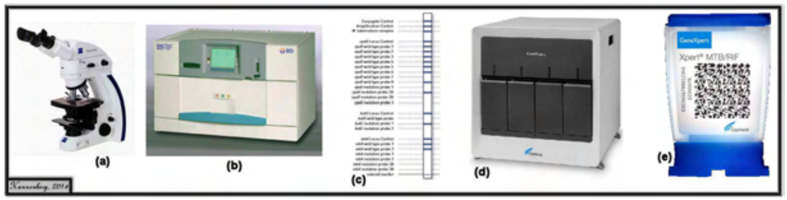


Figure 15: Gold standard devices for tuberculosis diagnosis endorsed by WHO. a) Carl Zeiss Primo Star iLED microscope for bright light and fluorescence microscopy b) BD Bactec MGIT 320 liquid culture growth incubator and observer c) Scheme of the GenoType MTBDRplus line probe assay d) GeneXpert IV device for the analysis of different specimen e) Xpert MTB/RIF cartridge for the analysis of tuberculoses specimen.

6.2.3. Viral Hepatitis diagnosis

The diagnosis of viral hepatitis relies on the laboratory diagnostic of virus materials or antibodies created by the immune system. The gold standard for the hepatitis diagnosis is the Nucleic acid testing (NAT) by using PCR methods to increase the amount of DNA or RNA fragments in the sample. Because it is an expensive method, it is not often used [71] Immunoassays are a good alternative as gold standard for the detection of viral hepatitis. A screening for viral hepatitis B and C would be important in Mongolia (associated with Liver cancer or liver cirrhosis) because of the high prevalence of both viral infections in the Mongolian community. A screening should be performed according to the WHO guidelines [72]:

"Recommendations on screening for HCV infection
1. Screening to identify persons with HCV infection: It is recommended that HCV serology testing be offered to individuals who are part of a population with high HCV prevalence or who have a history of HCV risk exposure/ behaviour. (Strong recommendation, moderate quality of evidence)
2. When to confirm the diagnosis of chronic HCV infection: It is suggested that nucleic acid testing (NAT) for the detection of HCV ribonucleic acid (RNA) be performed directly following a positive HCV serological test to establish the diagnosis of chronic HCV infection, in addition to NAT for HCV RNA as part of the assessment for starting treatment for HCV infection. (Conditional recommendation, very low quality of evidence)"

Guidelines for the screening, care and treatment of persons with hepatitis C infection [72], page 14

6.2.4. Cancer diagnosis and treatment

Diagnosis and treatment of cancer relies significantly on modern medical technologies. Although ultrasonography (US) can be used for the initial detection of some kinds of cancer, the following examinations need to be performed with CT or MRI imaging, to receive an accurate 3D impression of the cancer. This is needed to decide whether there is a possibility to surgically remove the cancer or not. Also in care of radiation therapy the exact shape of the cancer is needed to prepare a treatment plan.

The treatment of cancer tries to focus the damaging energy from radiation or protons in the cancerous area while protecting the surrounding area, especially nearby organs, as much as possible. Multileaf collimator (MLC) linear accelerators (LINACs) offer the possibility to shape their beams in a special way that from the position of the radiation source only the cancerous area is affected [35]. Several different position of the radiation source during one treatment plan and appropriate shapes of the radiation beam allow an effective treatment of the cancer while leaving other areas of the patient's body relatively unaffected.

An extension of the possibilities can be reached with the Cyberknife, a robotic arm systems, which allows movement in several orientations. A Cyberknife system allows the treatment plan creator to use radiation beams from a nearly unlimited amount of positions [73]. Therefore the surrounding tissue and organs are less affected by the radiation, which is much healthier for the patient. By placing gold seeds inside the body and performing regular x-ray images, the robotic arm knows its own position, the patient's position and the position of the cancer. It is therefore even possible to react on position changes of the cancer due to movement (breathing) of the patient.

6.2.5. Other diseases

Different other medical problems require an adequate diagnosis to reduce the number of deaths related to these serious problems. Cerebrovascular diseases are caused by arterial damages of the brain and lead to stroke or other dangerous diseases. Ultrasonography (US) or x-ray cannot visualize these dangerous situations as x-ray is not sensitive enough to detect something within the skull and US waves cannot enter the closed skull to visualize inside. Therefore only CT and MRI systems allow an accurate diagnosis of cerebrovascular diseases [74].

Ischemic heart diseases are another serious circulatory system problem, which needs to be diagnosed using imaging methods. Gold standard diagnosis of these diseases is the visualization of coronary arteries with angiography methods (CT-Angio, MRI-Angio). Newer developments are the possibility of 4D CT images, which allow observing the heart-beat with a series of 3D pictures [75].

Pneumonia is a special problem in Mongolia, as it can have different causes (bacteria, virus, fungi, air pollution, etc.). Therefore it is necessary to perform microbiologic tests as well as virus detection methods in addition to the visualization of the pneumonia. The presence of a tuberculosis infection needs to be observed in addition to other possible infections. Microscopy of the sputum (fluorescence microscopy) and rapid molecular systems and culture growing technologies are needed to distinguish between different infections. Specialized molecular systems are only partly useful as they can only search for the presence of a certain bacilli. Imaging can be done with x-ray and CT in case of difficulties in the analysis of x-ray images [76].

Liver cirrhosis is a serious disease in Mongolia, because it can be caused by viral hepatitis, by increased alcoholism or by environmental aspects. Accurate virus detection is necessary as well as the imaging of the liver itself. CT systems and especially MRI systems, which are designed for the visualization of soft tissues like inner organs, can give accurate information about the current status of the liver [77].

6.3. Alternative technology for diagnosis and treatment of these diseases

6.3.1. Overview

It was shown that gold standard technologies rely in most cases on high-end technologies, which are very expensive and difficult to get for developing countries. The WHO and FIND are improving the situation for Tuberculosis by negotiating for reduced prices for high-end technologies for low- and middle-income countries.

Nevertheless, there are possibilities in some cases to use less expensive alternative medical equipment, which can also generate reliable outcome for diagnosis and treatment. Disadvantages can be the additional workload because of manual systems, a manual quality control, less safety standards and a higher education, knowledge and experience of the users. Especially the field of imaging relies in many cases on computed tomography (CT), Magnetic Resonance Imaging (MRI) or technology of nuclear medicine (not mentioned in this thesis).

6.3.2. Tuberculosis diagnosis

Tuberculosis is a disease mainly occurring in the developing countries of the world. It can be assumed that many of these countries face financial problems in their health care systems, which results in a lack of gold-standard technology. Alternative technology for an appropriate diagnosis of tuberculosis is available in some cases but contains disadvantages compared with the recommended technology. Their main advantages are the lower costs (also in maintenance) and their great availability.

In microscopy the fluorescence microscopy is recommended because it is more sensitive in detecting bacteria and can analyse more percentage of the specimen in a shorter time period. The bright light microscopy is also endorsed by the WHO, but needs some special considerations about the Ziehl-Neelsen stain, because toxic waste is generated, what is a problem not only because of the waste management but also because of safety of the laboratory personnel. It is less sensitive and therefore takes more time to analyse a single specimen.

"The most common method for diagnosing TB worldwide is sputum smear microscopy (developed more than 100 years ago), in which bacteria are observed in sputum samples examined under a microscope."

Global Tuberculosis Report 2013 [56], page 1

In imaging there are some possibilities for making diagnoses with x-ray and ultrasound, whereas the ultrasound system needs to have certain requirements on sensitivity and resolution to be able to detect damages due to tuberculosis. The possibility to create slice-based 3D images with CT and MRI systems allow to detect tuberculosis related meningitis, which is nearly impossible to visualize in alternative imaging methods. X-ray only can visualize the bone and not the brain and ultrasound does not allow a picture because the skull is a closed protection where the ultrasonic waves cannot enter.

Culturing methods are available in many ways from simple incubator systems with solid media Petri-plates up to fully automated systems. Therefore, the more simple systems are an alternative to the gold standard technology. It needs to be considered that these kind of culturing need an extensive quality control and assessment, because working with specimen and agar plates can not only lead to safety threats for the personnel but also cause a contamination of the agar plate prior to the preparation of the specimen, which should be analyzed. Therefore it is possible that bacilli can be found after the incubation, which were not in the specimen.

6.3.3. Viral Hepatitis diagnosis

Detecting the virus in the patient's body is essential for the diagnosis of Viral Hepatitis, as the chronic form of the infection can lead to liver cancer and liver cirrhosis without showing other signs and symptoms before. Expensive PCR methods are not available in many cases, which lead to alternative methods for the detection. Blood panel tests allow a screening of a patient for viral hepatitis, by detecting virus fragments or body produced antibodies in the blood.

As is was described in the gold standards, the screening for hepatitis is an important aspect especially in Mongolia, due to the high prevalence of viral hepatitis A, B and C in the population. While viral hepatitis A does not cause chronic hepatitis, viral hepatitis B and C are the main reasons for chronic hepatitis in the world.

6.3.4. Cancer diagnosis and treatment

While the treatment of cancer offers possibilities in many ways e.g. radiotherapy or brachytherapy, the previous imaging of the cancer is difficult with the absence of CT or MRI technologies. Ultrasonography (US) can visualize the presence of cancer but it is not appropriate to detect the exact shape of the cancer, which is necessary to prepare an accurate therapy plan for the patient.

Cobalt 60 treatment from the outside (radiotherapy) or the inside (brachytherapy) are possible treatments at the National Cancer Center in Mongolia. These methods can be seen as alternative treatment methods, because they can result in appropriate outcome but are more difficult to handle and can cause damages outside of the cancerous area.

X-ray and US are in many cases not accurate enough to allow a reliable visualization of the cancer. The size and shape of the cancer are requirements for the decision whether the cancer can be removed surgically or need to be treated with radiation therapy. Therefore reliable information about the size and shape of the cancer are essential in the field of cancer treatment.

6.3.5. Other diseases

Diagnoses relying on imaging solutions (e.g. cerebrovascular diseases, ischemic heart diseases or Liver cirrhosis) are not accurately to perform without CT or MRI technology. Ultrasonography with Doppler mode allows to observe the blood flow, which can give hints about existing problems in the human body. Infections are diagnosed similar to tuberculosis with alternative methods like solid media culture growth and bright light microscopy, using the fitting staining methods for the bacteria.

6.4. Comparison between needed technology and available technology

Table 30 shows the connection between described technology and its availability in Mongolia.

Table 30: Comparison between needed and available technology in Mongolia. G: Gold standard technology. A: Alternative technology.

		Microscopy			Micro-biology			Culture			Virus			Diagnosis				Cancer			
		Bright light microscopy	Fluorescence microscopy	Primo Star iLED [1]	Line probe assays	Geno Type MTBDRplus [2]	GeneXpert MTB/RIF [3]	Solid media growth	Liquid media growth	BACTEC MGIT 320 [4]	Virus panel tests	Immunoassays	NAT (PCR)	Ultrasound	X-ray	CT	MRI	Brachytherapy	Teletherapy	Multileaf collimator	Cyberknife
Tuberculosis (TB)	Pulmonary TB	A	G	G	A	G	G	A	G	G					G	G					
	Lymphatic TB	A	G	G	A	G	G	A	G	G						G					
	Intestinal TB	A	G	G	A	G	G	A	G	G						G					
	Urogenital TB	A	G	G	A	G	G	A	G	G						G	G				
	Spinal TB	A	G	G	A	G	G	A	G	G						G	G				
	Intracranial TB	A	G	G	A	G	G	A	G	G						G	G				
Hepatitis	Viral Hep. A										A	A	G								
	Viral Hep. B										A	A	G								
	Viral Hep. C										A	A	G								
	Viral Hep. D										A	A	G								
	Viral Hep. E										A	A	G								
Cancer	Liver													A		G	G	A	A	G	G
	Stomach													A		G	G	A	A	G	G
	Trachea, bronchus													A		G	G	A	A	G	G
	Cervix													A		G	G	A	A	G	G
	Oesophagus													A		G	G	A	A	G	G
circula tory	cerebrovascular															G	G				
	Ischemic heart													A	A	G	G				
	Pneumonia	A	G	G	G			A	G	G	G	G		A	G	G					
	Liver cirrhosis										A	A	G	G		G	G				

Availability in Mongolia: good (green box) | medium (yellow box) | rare (orange box) | Only UB (red box) | Not available (dark red box)

[1]: Significant price reduction for low- and middle- income countries (€ 1,250.-) Flexile microscopic device, which can both, fluorescence- and bright light microscopy [63].

[2]: Significant price reduction for low- and middle- income countries (€3.75- - €7.50- per test, depending on the amount of line probe assays, which are bought). Devices for the use of this line probe assay are necessary; these are offered for reduced prices as well. Mycobacteria DNA is analyzed, known mutations for antibiotic resistances (rifampicin, isoniazid) are detected [67].

[3]: Significant price reduction for low- and middle- income countries (€17,000.- device, €9.98 per cartridge). Fast mycobacteria detection and rifampicin resistance testing [68].

[4]: Significant price reduction for low- and middle- income countries (USD $19,500.-) (not Mongolia). Fully automated liquid media system for bacteria growth, fluorescence detection and resistance testing [70].

6.5. Conclusion

In this chapter it was shown that there are gold standards for different medical problems (infectious diseases, cancer, circulatory and respiratory diseases). Some gold standards can be replaced by alternative technology, but with disadvantages in the fields of workload and quality control (manual methods compared with fully automated systems). Higher educated, experienced and properly trained personnel are required to use these alternative technologies in a way that their outcome is comparable to the outcome of the gold standard technologies.

Laboratory diagnostics are a wide field of different technologies. The existence of fully automated systems can increase the speed of the diagnosis and the accuracy, due to the absence of human errors. In Mongolia the GeneXpert system with its different cartridges (especially the Xpert MTB/RIF cartridge for the detection of tuberculosis) was introduced to some laboratories but is far away from being available in every area of Mongolia. Automated systems for PCR and line probe assays are available at the National Reference Tuberculosis Laboratory (NRTL) but not in the Aimag areas. Solid media culture growth dominates the microbiology in Mongolia, whereas the quality of the media is questionable (It was said that the Agar for Petri-plates is heated in pots on electrical heaters and filled into the plates everywhere in Mongolia). In order to get reliable results for the culture growth, it is necessary to perform quality control by incubating reference Petri-plates without samples in the same incubator. Whenever bacteria colonies are growing on the reference Petri-plate, the other samples are questionable because the plates can be contaminated prior to the preparation of the sample.

Microscopy is an important aspect of laboratory diagnostics, because the detection can be much faster than the culture growth systems can be. It is essential to have specially trained staff, which can handle the staining methods for different bacilli. Fluorescence microscopy is named as gold standard for microscopy because it is more sensitive and allows a faster and more fully observation of the sample, than it is done with the bright light microscopy (40x vs. 100x magnification). As there are only 5% of all smear microscopy places equipped with LED microscopes in Mongolia (Table A4.9, Annex III) it is important to invest into the infrastructure of adequate microscopic devices. The offer from FIND and WHO [63] is an option, because the microscope allows bright light as well as fluorescence microscopy.

Imaging is a difficult area as the imaging devices tend to be expensive in the acquisition as well as in the usage. For CT and MRI technology there is often no alternative possibility to obtain images needed for an adequate diagnosis. X-ray and ultrasonography (US) are alternative possibilities for some diseases, but require skilled and experienced medical personnel or medical doctors to acquire the desired images to detect irregularities in the patient's body. In Mongolia the MRI technology is only available in the Mongolian capital, whereas the CT technology is spreading nowadays also in some Aimag areas, due to financial investments of prime minister and the Ministry of Health (MOH) [40]. Because of problems in the electrical infrastructure (described in chapter 5) it is questionable whether the acquisitions of CT devices in the Aimags are a good investment or a waste of money. It was said that every one or two weeks a detector unit of the multi-slice CT device in a private Ulaanbaatar hospital is getting damaged by electrical spikes. Taking into account that the electrical infrastructure in the Aimag areas is even worse, the possible damages to the devices can be severe.

Ultrasonography (US) is available in some hospitals outside of Ulaanbaatar to perform images of the patient's body. But according to a Mongolian study about hepatocellular carcinoma (HCC) the quality of these devices is very low. In addition it says that the users of the US system are often not properly trained and experienced in the diagnosis of US images [59].

Cancer diagnosis and treatment is a special aspect of the Mongolian health care system, because cancer is responsible for more than 20% of all deaths in Mongolia in 2012 (Annex I) [54]. In Mongolia only the National Cancer Center (NCC) is allowed to treat cancer patients. With one CT device (Somatom Emotion 6) and no own MRI system, the possibilities for the adequate diagnosis of the cancer and possible metastasis is not available for every patient (4,544 new cancer cases in 2012) [54]. Without an appropriate three dimensional visualization of the cancerous area, it is nearly impossible to create an adequate treatment plan, which spares the health organs and body tissues.

Not only the diagnosis but also the treatment of cancer is centralized at the NCC in the Mongolian capital. Surgeries to remove the cancerous area are performed in this hospital. Unfortunately due to a lack of cancer screening, most cancer patients arrive in the hospital at a late stage, where it is too late for a surgery [59]. A gold standard multileaf collimator (MLC) linear accelerator (LINAC) is installed in the hospital in 2014, which will provide cancer patients with an adequate radiation therapy. MLC LINACS have the advantage, that the shape of the radiation beam can be adjusted to fit best with the cancerous area from its current point of view. Compared with not adjustable radiation beams it prevents the patient from absorbing high radiation energy with the healthy tissues and organs. A Cyberknife is not planned for the NCC although the head of engineering in the department of radiation therapy is sure that it would be helpful for the treatment of difficult cancer cases. The expected expenses of about six million pound sterling [78] in 2009 make the device a rare technology, which is found only in some carefully chosen locations in the world (shown in figure 16). In July 2014 there were Cyberknife systems in 37 European Cities, whereas the majority of Cities only had one Cyberknife System [79]. Because there are ten Cyberknife Systems in South Korea and 26 systems in Japan [79], it is questionable whether Mongolia would need an own system in the future or not.

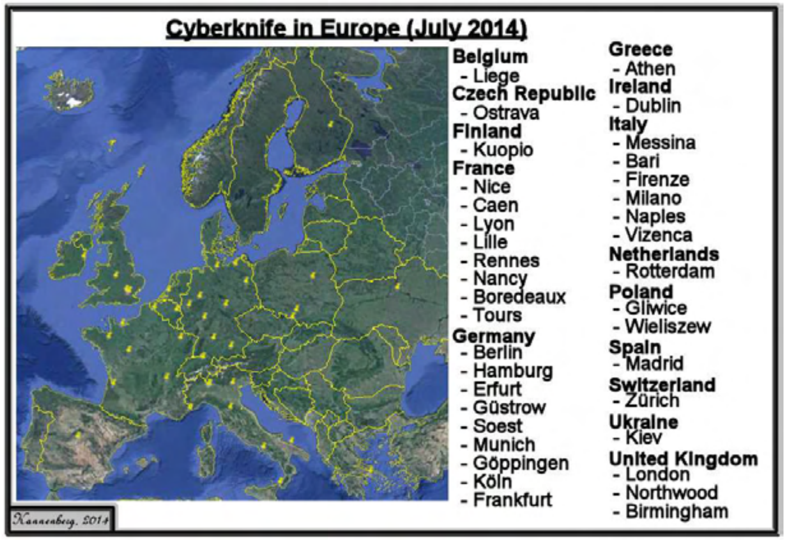


Figure 16: Cyberknife Systems in Europe (July 2014) [79].

Medical health care problems and possible solutions for developing countries:
Case study Mongolia

7. Technical Solutions: Infrastructure

7.1. Introduction

Quality of health care is very often related to the technology available in the observed area. Of course also aspects like education and training of staff and the access to drugs are important for the quality of health care. But nowadays the development of quality improvement relies more and more on technology. Modern drugs and international standards for drug using require fine dosages over a long period, generally applied by accurate syringe- or infusion pumps. High technology medical equipment has certain requirements to provide an accurate and safe usage and a long and stable functionality.

International and national standards set requirements to medical used rooms [80, 81]. Regularly inspections from certified specialists guarantee a safe environment for diagnosing and treating patients. In general it can be said that the investment in correct and standardized environment is more inexpensive than the costs of compensation for personal suffering and expenses for medical technology replacement.

Ulaanbaatar is a fast growing city, with regular population growth and immense building construction activity. A major problem of this development is that the infrastructure of the city cannot grow and be renewed in the same dimension to keep the balance. The result is that electricity outages occur often and hot water cannot be guaranteed. The streets cannot provide enough possibilities for the traffic, which results in daily traffic jams especially in the central area. Also the medical infrastructure faces more and more problems as the hospitals, which provide free service to people, who pay their health insurance, get older and older.

The National Central Hospital of Mongolia, also known as 1st general hospital, is the biggest hospital in Mongolia, providing various aspects of health care to people, who have a health insurance. But the hospital building was created in 1971 during the soviet time. Over and over again changes were made especially on the electricity system of the hospital, but most of the time they were isolated applications without general plan. International standards on medical rooms cannot be applied on this hospital, and also on many other hospitals, because the electricity system does not have the very basic protection measures. As shown in figure 17a the electric sockets, which are used very often are simple and without special protection.

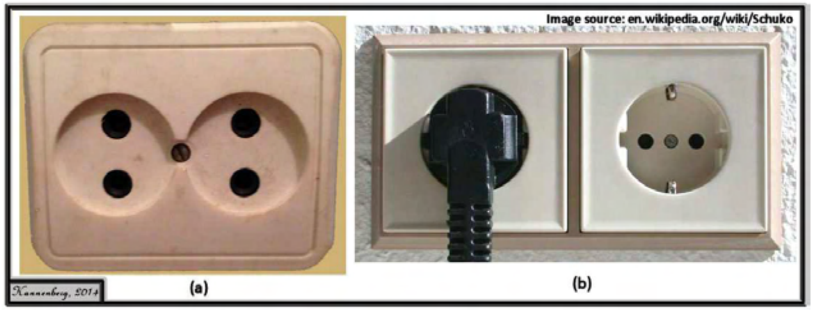


Figure 17: Electric sockets in Mongolia (a) and in most of Europe (b). Electric frequency and Voltage is the same, the European plugs can be connected with the Mongolian sockets, but with a number of disadvantages.

These sockets, which are closely related to the soviet GOST standard of electric plugs and sockets [82], are a security threat compared with the more commonly used "Schuko" system [83] shown in figure 17b. The major differences are the connections to the protective earth (PE) in the Schuko system (seen as metallic pins on the top and the bottom of the orifice of the electric socket, which provides a grounding of the mobile apparatus connected to this socket). Because of the depth of the socket's orifice, the socket prevents touching the metallic pins of the plug as soon as they are connect to the socket. In addition it provides a more stable connection between plug and socket.

Old hospital buildings in Mongolia, which play a key role in the Mongolian health care system, commonly use the electric sockets shown in figure 17a, which do not have safety features for personal, patients and apparatus. Connected with a line- and neutral cable each, the residual current in case of isolation failure cannot be safely removed and are a potential hazard for people close to the origin of the failure. In addition, the electric circuits powering the electric sockets are not designed to stabilize the electricity, which is running in the hospital. Therefore overvoltage and voltage spikes are a problem for medical devices. Most devices on the market, which guarantee a protection from voltage spikes, use the PE cable to remove the unwanted extra voltage from the electric system.

A more general problem in Mongolian Hospitals is the lack of medical infrastructure (described in chapter 5). Because there is no manufacturer of medical devices in Mongolia, all devices are imported from several countries, which have own standards for electric plugs and energy systems. Medical engineers and technicians at the hospitals often need to repair devices, which were designed for 110 V electricity systems but were connected to the 220 V electricity system of Mongolia. A modern electricity concept should include these problems and provide solutions for an efficient and safe use of different medical devices.

Intensive care units (ICUs) and operation theatres are the most protective areas in a hospital according to international and national standards [80, 81]. An electric outage in these areas would be life-threatening because medical operations could not be finished and life-supporting devices could not continue working. Therefore special requirements are set to these areas, e.g. separated electricity, an isolation transformer (figure 18a) for separating the system from the normal grounding, insulation monitoring devices (figure 18b) for monitoring the electric circuit, a special grounding for an equipotential bonding of all devices and metallic parts in the room (figure 18c) and Uninterruptible power supply (UPS) (figure 18d) to provide a stable electricity for vulnerable medical devices.

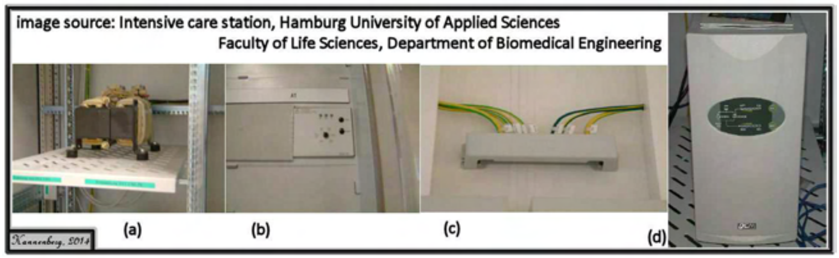


Figure 18: Protection devices for electric circuits in hospital. a) Isolation transformer, b) insulation monitoring device, c) equipotential bonding rail, d) uninterruptable power supply

7.2. Concept of grounding the National Central Hospital

The biggest problem of old hospital buildings in Mongolia is the lack of electricity protection. As described in 7.1, most electric sockets do not have a connection to the Protective Earth (PE) cable and therefore do not have any grounding. This results in a number of problems starting from the missing cable connections for power sockets and light systems, up to the problem of an appropriate grounding of the building. In fact, because only small areas of the hospitals are covered by a grounding system, the grounding system with earth electrode and equipotential bonding could not handle the electricity coming from the whole building.

In addition, it is very likely that the existing earth electrode does not work properly anymore, due to corrosion of the material, which was installed up to 45 years ago. Cold winter and hot summer create extreme conditions on the soil surrounding the earth electrodes. Soil erosion is a big problem in Mongolia and the humidity of the soil highly varies with the seasons of the year. A new concept for grounding the National Central Hospital of Mongolia needs to take these special conditions into account.

International standards require special protection for all buildings. Hospitals are special areas, where additional safety is needed. German standards declare that every update or improvement of old electric installations require to be in such a way that the whole electric installation is safe according to the actual electrical standards. Therefore, an improvement of only some parts of the electric installation in the hospital would not be allowed. A complete renewing of the whole electric system on the other hand is too expensive and time consuming for the Mongolian government. The long time closing of the hospital would lead to an immense health care problem in Mongolia.

The only possible solution is to develop a long-time concept for stepwise improvements of electrical installations, where the last step would lead to fulfilling all requirements of international standards. These steps need to be able to be performed without disturbing or interfering with the daily hospital work, to ensure the adequate providing of health care to customers over all time.

As a first step, a new grounding system needs to be established in the hospital. Modern safety devices and electric networks rely on an appropriate grounding system. A new earth electrode needs to be placed, which is adequate for the size of the hospital. German standards require for new buildings the construction of a “foundation earth electrode” (German: “Fundamenterder”, figure 19) [84]. It is a mesh grid of steel, which is placed into the concrete of the building’s basement, with a connection to the main electricity entrance of the building. The size of each mesh shall not exceed 20 m x 20 m for grounding purpose and not exceed 10 m x 10 m in case of connection to the lightning safety system.

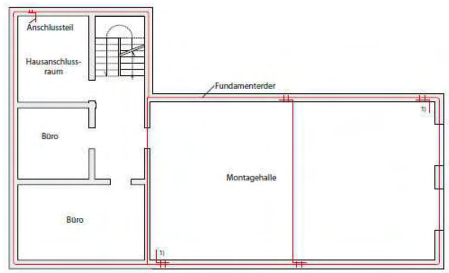


Figure 19: Example of a foundation earth electrode planned in the basement plate of the building. Note the separation of the building in three meshes (source: Elektro Plus – Fundamenterder [84])

Of course it is not possible to update an old building with a foundation earth electrode. Instead, adequate alternatives need to be found to reach a similar protection. Mainly this is done by placing a ring earth electrode around the whole building. The length of the ring earth electrode will provide enough direct soil contact to allow electrical interactions. In order to ensure the long survival of the electrode, special steel needs to be used, which is protected against corrosion. Taking the shape of the National Central Hospital with its two about 1800 m^2 and 1200 m^2 inner courtyards into account (see figure 20), it is possible to simulate a foundation earth electrode mesh grid by placing ring earth electrodes not only around the building but also around the inner courtyards. Stable connections between the ring earth electrodes can ensure a uniform spreading of electricity in the whole grounding system and therefore improves its functionality.

Figure 20: Shape of the main building of National Central Hospital. The two inner courtyards are about 1800 m^2 (left) and about 1200 m^2 (right) in size. (Source: Google Maps)

Because also the construction of the complete ring earth electrode network is time and cost consumptive, a step-by-step plan for the preparation of the grounding is developed. Every step provides an own stable expansion of the ring earth electrode and is fully functional. It is therefore possible to connect the internal grounding system with the 1st step of the grounding concept, although it is highly recommended to enlarge the earth electrode before connecting the whole building.

"The factors that influence the earthing resistance of an electrode or group of electrodes include the composition of the soil in the immediate neighborhood, the temperature of the soil, the moisture content of the soil and the depth of the electrode. Thus, the composition of a soil gives a very good indication as to what order of resistivity is to be expected."

"Assessment of Soil Resistivity on Grounding of Electrical Systems: A Case Study of North-East Zone, Nigeria" (page 28) [85]

The most important factor for the soil resistivity is the moisture content of the soil, which depends on the weather and normally changes within the seasons for the year. Therefore, a single measurement of the soil resistivity is not helpful as an indicator for the required size of the earth electrode. Instead a group of measurements during the year needs to be performed to detect the highest resistivity value. This value should be used for calculating the required size of the earth electrode.

This means that it is nearly impossible to pre-calculate the grounding situation for the earth electrodes. Measurements need to be taken out to measure the soil resistivity as well as the earth electrode resistance, after it was constructed.

The "Wenner four-pin-method" is the most cost-effective way to measure the soil resistivity [85]. Four probes are placed in a straight line with an equal distance ***a*** each (figure 21). The Depth where the probes are set should be ***b***. In this constellation, the soil resistivity in depth ***b*** can be calculated. Mostly it makes sense to use different values for the depth to create a soil resistivity profile. Between the outer probes, a current is running, while the probes in the middle can measure a potential difference [85].

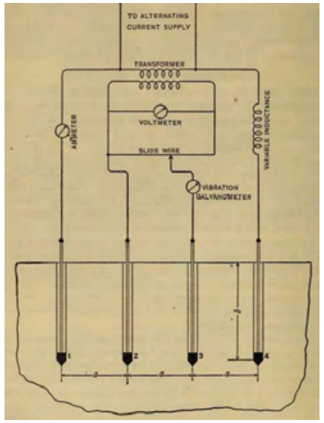


Figure 21: Sketch of the soil resistivity measurement with the Wenner-method [86]

A measurement device can obtain the voltage of the potential difference as well as the running current. According to "Ohm's law", the resistance can be calculated by dividing the voltage by the current (formula 7.1).

$$R = \frac{U}{I} \quad (7.1)$$

With ***R***: Resistance, ***U***: Voltage (potential difference), ***I***: current

The exact calculation formula to calculate the resistivity ***ρ*** depends on the distance ***a*** and the depth ***b*** of the probes (formula 7.2) [86].

$$\rho = \frac{4 \cdot \pi \cdot a \cdot R}{1 + \frac{2 \cdot a}{\sqrt{a^2 + 4b^2}} - \frac{2 \cdot a}{\sqrt{4a^2 - 4b^2}}} \quad (7.2)$$

With ***ρ***: soil resistivity, ***a***: probe distances, ***R***: resistance (calculated in 7.1), ***b***: probe depth

A concept was developed to build up an earth electrode system for the National Central Hospital by using all previously mentioned information. In four steps a combination of ring earth electrodes, which are connected through the building, simulate a foundation earth electrode with meshes of about 20 m x 20 m. The steps are listed in table 31. An overview of all steps is given in figure 22.

Table 31: Overview of the four steps of creating the new earth electrode system. The earth electrode should be made of special steel, listed in table 32, the cable mentioned are connections between the ring earth electrodes, the connections are positions where the earth electrode system should enter the building.

	Location	Earth electrode	Cable	connections
1st step	Laboratory, inner courtyard	≈ 320 m steel	≈ 60 m	16 connections
2nd step	Intensive care station	≈ 140 m steel	≈ 60 m	8 connections
3rd step	Buildings E and F	≈ 200 m steel	≈ 70 m	10 connections
4th step	Complete Building	≈ 310 m steel	≈100 m	13 connections
all	Complete Building	≈ 970 m steel	≈ 290 m	47 connections

The earth electrode material needs to be stainless steel, which can be placed into the soil without being damaged due to corrosion. It needs to be thick and stable enough to remain stable and unbreakable in moving earth. In Germany the stainless steel needs to be AISI 316 steel (chromium nickel molybdenum-steel) in order to be appropriately protected from corrosion. Table 32 shows details about the two steel sizes, which are allowed in Germany:

Table 32: Overview of the two in Germany allowed stainless steel sizes for ring earth electrodes [84]

		Material required	
	Dimensions	US name	German name
Round steel	10 mm x 10 mm	AISI 316 steel	V4A steel
Strip steel	30 mm x 3.5 mm	AISI 316 steel	V4A steel

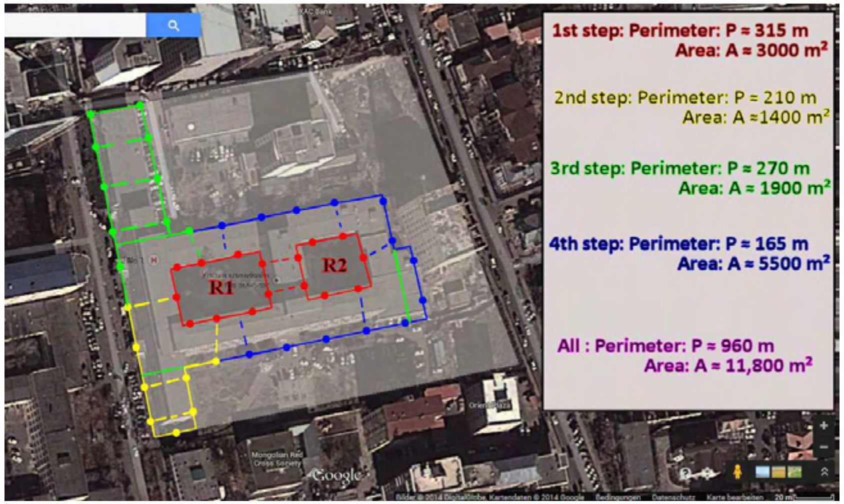


Figure 22: Map with the first general hospital and four steps of developing an earth electrode network (based on a Google Maps satellite photo; 53 pixels = 20 metre)

In the first step, the inner courtyards are chosen for the establishing of an initial grounding system, because the construction will be simpler than the construction at the outside of the building. In addition, the two rings are relatively small compared to the outer ring. The inner courtyards are in a central position of the building, which makes it easy to connect many parts of the building with the grounding system. The inner courtyards are mainly used as a gathering point for broken medical devices and trash. Trees are growing in the courtyards, which are mainly covered with concrete. The installation of the ring earth electrodes could be performed together with a restructuring of the inner courtyards, to make them more useful e.g. for patients. A more detailed plan of the inner courtyards with its trees and the garden shed is shown in figure 23.

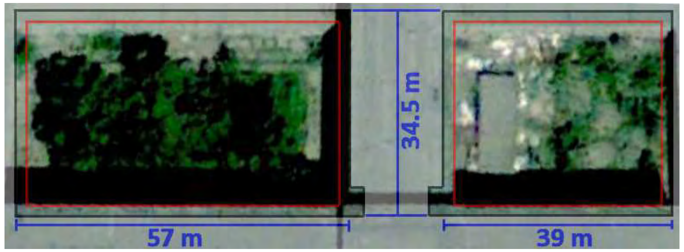


Figure 23: Inner courtyards of the National Central Hospital with its trees and the garden shed (right courtyard). In red the position of the ring earth electrodes is marked, one meter away from the building walls. (Image based on Google Earth, a satellite photo from 2007)

As a second step, the area around the intensive care station (ICU) is chosen, because international standards set high requirements on rooms of the ICU. In addition, its position in the main building of the hospital does not allow a direct connection to the ring earth electrode of the first step. By connecting the 2nd step ring with the 1st step ring, the functionality of the whole grounding system is improved. To protect the north area of the building with a grounding system, strong cables need to be placed over a long way and can cause irregularities in the grounding system. A safer and more effective alternative is shown in the 3rd step, where the ring earth electrode is extended to this building. It will provide a stable and safe connection to the grounding system and in addition improves its functionality. The 4th step completes the outer ring earth electrode and provides the best solution for grounding the main building completely. All steps are visualized separately in Annex IV.

An equipotential bonding needs to be done inside the building, by connecting the connection points of the earth electrode system with the steel construction of the building. A mesh grid with maximum 20 m x 20 m meshed should be produced with cable connections inside the first floor of the building, which allows connecting the Protective Earth (PE) cables from all floors to the equipotential bonding network. All together, this grounding system will fulfil the requirements of international standards and allow the electricity system to be named a TT-network, according to international standards [87]. According to the IEC 60364-5-54:2011 standard, three different electricity networks are possible for earthing (table 33):

Table 33: Possible network systems for earthing arrangements [87]

Name	Description
TN - network	A cable with three line conductors, one zero conductor and one protective earth (PE) conductor is coming from the electric supplier. The building does not need an earth electrode, because the grounding is done by connecting everything with the PE conductor.
TT - network	A cable with three line conductors and one zero conductors is coming from the electric supplier. The Building must have an earth electrode as protection from electric shock.
IT - network	A cable with three line conductors from the electric supplier is used. The zero conductor of the IT network is connected to the insulation monitoring device. The PE conductor is connected with an earth electrode.

7.3. Electricity protection at the National Central Hospital

A grounding system as described in chapter 7.2 is important to increase the security of the building. But the grounding itself is only a first step of preparing a security concept, as there are overvoltage protection systems and residual current devices (RCD, in German: FI-Schutzschalter), which need to be included into the electric system to prevent electric shocks.

In TT- electricity networks, RCDs are necessary according to German standards [88]. In new constructions, also TN-Networks needs to have at least two RCD, as the German standard says that a single RCD should be able to cut off the complete apartment from electricity in apartments and buildings partly used for industry [88] . RCDs compare the current going into the electric circuits with the current leaving the electric circuits again. In the normal situation, both should be the same, which results that the electromagnetic fields of the cable connections will eliminate each other. In case of isolation errors (e.g. parts of the current are travelling through the human body to earth), a difference between both currents will create a magnetic field, which induces another current in a coil inside the RCD. This current then cuts the electricity off [89].

In Germany RCDs are used for a long time with cut-off currents of 500 mA as a fire protection. Nowadays RCDs with cut-off currents of 30 mA are used in every installation, because it protects not just from fire in the building due to electricity, but also can protect the life of endangered people, who have contact with the electric circuit. RCDs are protecting against isolation errors, while normal circuit breakers only protect against shortcuts in the electric system. Nowadays also combinations of both devices are on the marked, which are called "**R**esidual **c**urrent **b**reaker with **o**ver-current protection" (RCBO). Their advantage is the more effective construction, which leads to smaller electric distribution boards (German: Verteilerkasten) [90].

Equipotential bonding, as described in chapter 7.2 is another important security installation. Not belonging to the grounding system, it needs to be connected to the earth electrode on the one hand and to all metal parts of the building on the other hand. Metal tubes for water supply or steel beams in the concrete of the building can transfer electricity from one place to another place, making them dangerous parts in case of electric problems. By connecting all parts with equipotential bonding to the earth electrode, the same electric potential can be ensured for all areas of the building. Without this protection method, it is possible to receive an electric shock only by being in contact with metal objects, which have different electric potentials (e.g. often seen at metallic door knobs). Therefore equipotential bonding is an important and necessary method to increase the protection against electric shock.

Protection from voltage spikes is reached by using surge protective devices (SPD's). Their general concept is to create connections between the phase and the protective earth (PE) with special elements like Varistors, Thyristors, transient-voltage-suppression-diodes or gas-discharge-tubes. Their ability is to isolate the phase and the PE up to a certain voltage. Whenever the voltage is reached, the element establishes a connection between phase and PE and therefore removes all electricity, which is above the desired voltage of the network.

Typically there are three levels of surge protection, each one reducing the voltage spikes to a lower level. All three levels need to be implemented in the safety concept, to protect each other and the electrical system. The first level is designed to remove very high voltages coming e.g. from lightning. Voltages from a lightning hit are strong enough to damage most electrical equipment including the level two and three surge protective devices.

Level two SPD's are lowering the voltage to a less dangerous level. It is normally attached before the distribution board to protect the electrical devices inside the board from damages from overvoltage. As device in the middle of the network (figure 24), it is essential for the connection between the first and the third step of reducing the voltage. The third step finally reduces the voltage spikes to a level, which is similar to the normal electric potential of the electricity network. It can be implemented in electric sockets or multi connector sockets. A complete network, as it is shown in figure 24 offers a reliable protection from overvoltage coming from the protected cable connection.

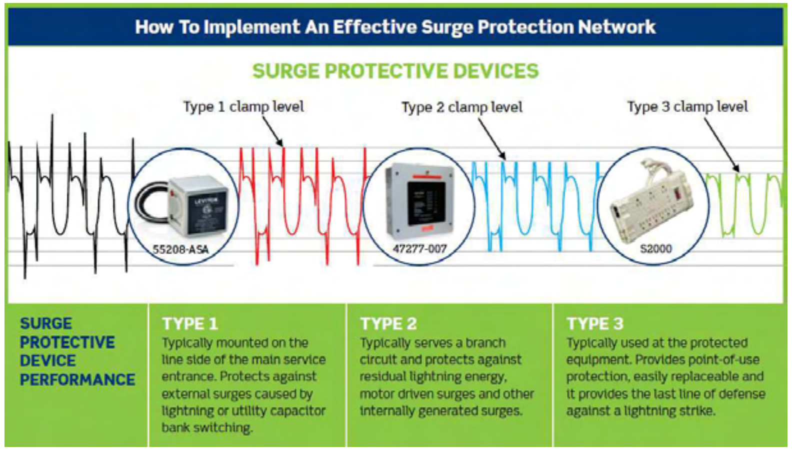


Figure 24: Surge protection network explained by Leviton Manufacturing Co. Inc. [91]

Protecting a hospital like the National Central Hospital requires a greater concept with planning and investigation. Because changes in the electricity network are not appropriately documented and the cable plan of the building is from 1971, it is difficult to say where the electricity is coming from and whether it is one connection or more than one. In case more than one cable connection is used for the electricity supply of the hospital, every cable connection need its own three step protection system, to ensure a general protection from overvoltage. Because these systems need a connection to the PE, the grounding concept needs to be considered to allow the electricity to spread in the soil instead of the building.

Also other Entrances to the building need to be protected, as electricity form lightning can enter through metallic water tubes and data cables. In German residences it is necessary to protect every circuit, which provides power sockets, with a RCD. Therefore circuit separations between light circuit and power socket circuit is often performed in German constructions. Whenever the cable system in a hospital is partly renewed, which makes sense because of the age of the original cables and because of possible damages due to cracks in the walls, a new organization of the circuits should be considered to increase the safety and efficiency of the construction.

7.4. General concept for the intensive care unit

As the medical devices in the intensive care unit (ICU) are most vulnerable to voltage spikes due to being active 24 hours a day, it seems to be appropriate to start a renewing of the electricity system in this department. The German national standard for medical rooms [81] as well as the related international standard [80] set ICU structures in the group 2 of medical rooms, showing that special requirements need to be done. This is due to high risks, when life-supporting medical devices stop working while energy fluctuations. According to the standard, the rooms of the ICU should have an own electronic circuit each, designed as a medical IT-network. As normal IT-networks, these circuits need to be isolated from the rest of the energy system, using own generators, batteries or isolation transformers. In medical IT-networks, single line alternate current circuits with isolation transformers are allowed only. These isolation transformers are allowed with apparent powers from 5 to 10 kilo volt ampere (kVA) only, to reach a high level of safety [80].

ICUs are normally more energy consuming than other parts of the hospital, due to the high amount of necessary life-supporting devices. A German recommendation [92] made by medical doctors working in ICUs suggests that 16 power sockets should be available for each patient: 12 power sockets connected to power supply (6 of them connected with an emergency generator) and 4 power sockets connected to uninterruptable power supply (UPS) and connected with an emergency generator. All power sockets need to be connected to an overvoltage protection. The four power sockets connected to UPS shall be in green colour, the six power sockets connected to the emergency generator shall be in red or orange colour [92].

In Mongolia a special situation needs to be taken into account referring to the electricity system. Because there is no medical device manufacturer in Mongolia, all medical devices are imported, mainly from America, Russia, South Korea, China or Japan. One big problem is the different power supply in Japan and America, which have 100 – 130 V instead of the 200 – 250 V, which is provided in most of the Eurasian continent. To allow the use of devices from these countries, the electricity supply in the ICU should allow 110 V networks besides 220 V networks. Only then the possibility is given to use all devices available at the hospital, when they are needed. Different standards are given for power sockets in dependence on their origin, but in general the socket types for 220 V are similar or related to each other, while the 110 V power sockets are different from them but share a very similar shape themselves. Therefore it is possible to construct the 110 V network and the 220 V network with different power sockets.

Another problem is the special situation in China, where different types of power sockets are in use at the same time. Especially power plugs, which have a similar shape to the 110 V power plugs cause problems, because the Chinese devices are mainly designed for 220 V. To avoid problems with the power supply e.g. connecting a device to the wrong energy supply, which is a common problem nowadays in Mongolia, all medical devices in the hospital should be checked about their power plugs. Irregularities can be solved by changing the cable/ power plug or by fixing an adapter to the power plug, to create two standard energy connectors. “Schuko” power sockets are most common in Europe and Asia for 220 V systems. An international standard for 220 V electricity networks was published in 1986 [93], providing a new shape of power plugs and sockets, which have advantages compared with all other systems. NEMA standard power plugs and sockets are most common for 110 V systems. NEMA 5 -15P plugs and sockets are the basis for the international standard for 125 V systems [94].

Taking into account the lack of medical equipment in ICUs in Mongolia, the recommendation from the German Interdisciplinary Association of Critical Care Medicine about the amount of power sockets is not necessary. The 16 power sockets can be separated into 220 V and 110 V systems to allow the use of medical devices from different countries. By using different socket types and unique power plugs/adapters, it becomes impossible to accidentally connect a device to the wrong voltage supply. Colours for the different socket modes (white: normal, orange: with emergency generator, green: UPS and emergency generator) can be the same for 110 and 220 V systems. A design idea is shown in figure 25. It is based on an internet based ICU photo research, where internet photos from the following hospitals (table 34) were gathered and compared.

Table 34: List of hospitals, where photos from the internet were taken for comparison and for developing a design concept for the ICU.

Name of the Hospital	City, District	Country
Mount Saint Joseph Hospital	Vancouver	Canada
White Horse Hospital	White Horse	Canada
University Hospital	Heraklion	Greece
Sanjivani Hospital	Udaipur	India
Vaishnavi Hospital	Visakhapatnam	India
Rejang Medical Centre	Sarawak	Malaysia
National Institute of cardiovascular diseases	Bratislava	Slovakia
NP Istanbul Neuropsychiatry Hospital	Istanbul	Turkey
Royal Hallamshire Hospital	Sheffield	United Kingdom
University of Pretoria	Pretoria	South Africa
Kaiser Medical Center	Oakland, California	United States of America

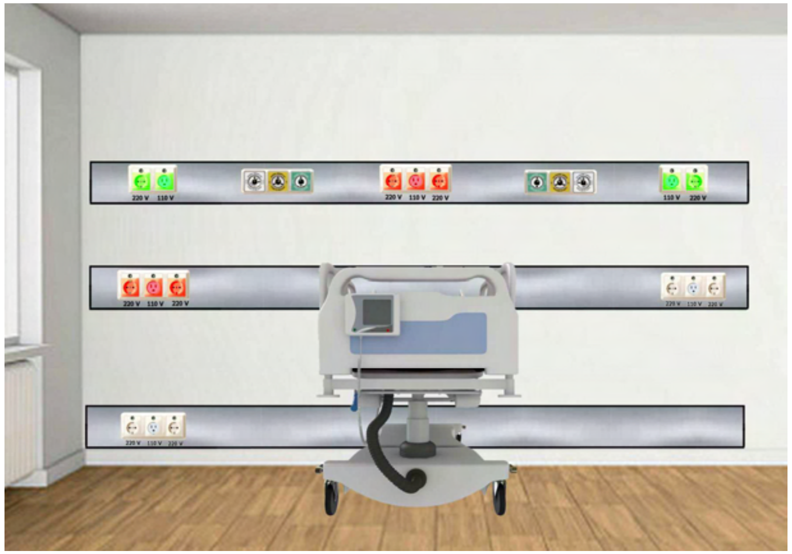


Figure 25: Design concept for the ICU at the National Central Hospital. "Schuko" 220 Volt and Nema 5-15P 110 Volt sockets in white, orange and green colours for their specific purposes.

In this design there are 16 power sockets planned for every patient area (a detailed list of all sockets is given in table 35). They are separated into different colours for visualizing their different types. In addition by providing "Schuko" sockets for 220 V and Nema 5-15P sockets for 110 V, there is a socket based separation between both electrical systems. The ICU receives the possibility to use high quality and secure equipment from different manufacturers in the world by choosing appropriate adapters for the devices to allow only the electrical connection to the right voltage.

Table 35: Amounts of power sockets per patient area according to the design concept.

	220 V	
Grey	TN-S system (RCD protected)	4
Red	Medical IT-system (Generator)	4
Green	Medical IT-system (Generator + UPS)	2

	110 V	
Gray	TN-S system (RCD protected)	2
Red	Medical IT-system (Generator)	2
Green	Medical IT-system (Generator + UPS)	2

A German language manual about the planning for electrical supply of medically used rooms provides several information about the correct construction and security measures for ICUs [95]. It says that an IT-network should not be used for more than four patient areas, due to the limitations on medical IT- isolation transformers. As the biggest allowed isolation transformer can provide 10.000 VA (volt ampere, used instead of the symbol W for power to take into account that some power gets lost in the system without being effectively used by connected technical equipment), there are limitations in the planning of the electricity. The manual is making suggestions to the average use of power per patient bed, which is shown in table 36.

Table 36: Average power needed per IT-system according to a planning manual [95].

	One bed	Four beds	IT-system
power	600 W	2,400 W	2,400 W
High energy device	-	-	2,000 W
Total	-	-	4,400 W
Safety reserve (20%)	-	-	880 W
total	-	-	5,280 W
Optimal transformer	-	-	6,300 VA

When this calculation is used, it is possible to create the four-patient room of the Mongolian ICU by using two isolation transformers with 6.300 VA each. A cable plan for this situation is shown in figure 26. In this case, the expected average power used is 600 W per IT-system, which means 1200 W per patient-area provided by the IT-systems for medical equipment. Other technical equipment, which does not have medical purpose, can be supplied by the TN-S system (gray sockets). Especially for Mongolian ICUs, where is a lack of medical equipment, this solution with two isolation transformers are appropriate. However, as the intensive health care requires more and more medical technology and the Mongolian ICUs also should be equipped state-of-the-art, the planning should consider the possibility to separate the system into IT-systems for patient area 1 and 2 and other IT-systems for patient area 3 and 4. In this case, enough power could be supplied per patient area to use several equipments also in times where all patient areas are in use. Therefore the cable plan in figure 26 shows separated cable ways for the patient areas, which allows the simpler upgrade from two IT-systems in the room to four IT-systems.

Medical health care problems and possible solutions for developing countries:
Case study Mongolia

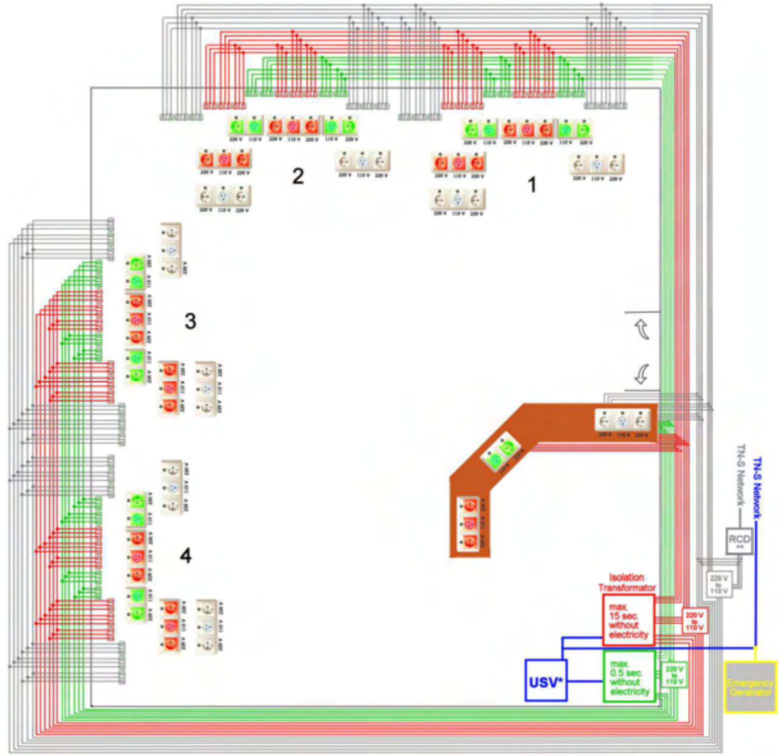


Figure 26 : Design of a possible cable plan for one of the ICU rooms. The electricity of patient area 3 and 4 is visualized seperately from the electricity of patient area 1 and 2, to show the possibility to establish four medical IT-networks in the room (in this case also four isolation transformers are needed). This becomes necessary in case of high electricity consumption per patient.

Light in the room can be supplied with electricity by using TN-S circuits, which are protected with Residual Current Devices (RCDs). Two of these RCD protected circuits shall supply the lights in the room in an alternation (Lamp 1 - RCD1, Lamp 2 - RCD2, Lamp 3 - RCD1 ...) in order to keep a uniform illumination of the room, whenever one RCD is shutting down. Emergency lights need to be connected to the green (patient areas) or the red (other areas) infrastructure to ensure an adequate illumination in case of energy outages. Important other aspects for the ICU room are the complete electrical separation from the rest of the hospital, including a special floor layer to isolate the room from electric potential from outside the room. It should be considered to create a small room for the Uninterruptable Power Supply (UPS) and the isolation transformers, as the international standards do not allow these supply devices to be placed inside a class two room [80]. Hygienic aspects are not mentioned in this design concept, but they would recommend a special wall layer and floor layer with anti-bacterial properties and without edges or fissures, where the cleaning would become difficult.

7.5. Patient transport to hospitals

Health care not only includes medical treatment at hospitals or medical offices. It also includes the transport from injured or ill people to the hospital. Several different kinds of ambulance cars can be seen in Mongolia's capital. Due to the daily traffic in the central area of Ulaanbaatar, ambulance cars on duty are often trapped in traffic jams, which result in a long period of time until the start of appropriate care at the hospital.

Different solutions can be suggested to improve this situation. The long term solution should be to reorganize the street infrastructure. Nowadays there are special street lanes only for bus transportation. Enlarging this bus lane system under recognition of ambulance-, police- and fire-fighter cars, which also should use these lanes, would shorten the transportation time of patients as well as shorten the time until a police car arrives as its destination.

A second option is the improvement of ambulance cars. Special medical devices in the ambulance car can establish a first care of the patient during the transportation. During the transportation before the arrival at the hospital, the health care service inside the ambulance car can save lives, especially when the ambulance car got stuck in a traffic jam. Besides the technical equipment, needed in the ambulance car, a specialist for first care, the paramedic, needs to be with the patient all the time, to check his or her medical status and to initialize the medical treatment. Projects like the Mongolian Emergency Service Hospital Hygiene Project (MeshHp) by the German Ministry of Health and the University Hospital of Essen are working on the training of ambulance drivers and the hygiene of the transportation [96]. Regular disinfection of the inside of the cars and the use of standardized working clothes instead of private clothes already improved the hygiene and the knowledge of the people responsible for the patient transport. It should be mentioned that medical care in the ambulance car can never be compared with medical care in the hospital. Therefore the most important aim should be to shorten the patient's time in the ambulance car to a minimum.

To achieve this aim, a possibility is to help the ambulance car driver to find the best way from his starting point to the endpoint. Some computer algorithms exist, which perform these tasks for robots. The D-star algorithm for example is a path planning algorithm, where the calculated best path can be recalculated in case of path blockings, which are not previously included into the calculation. Performing different steps, it is possible to create an automatic traffic recognition system, which gives input into the path planning calculation for the ambulance car. As a result the best path from the start position to the end position can be shown to the ambulance car driver, who can avoid the traffic jams by using alternative routes. The fastest route should be the best choice for the ambulance car. Real time calculation could react on the actual traffic situation in Ulaanbaatar.

7.5.1. Traffic recognition

Before an algorithm can calculate the fastest path from point A to point B, the algorithm needs to get information about the operation area. In case of robots, sensors can detect blockings or obstacles in the way. Of course, a path planning algorithm, which reacts on sensors within the ambulance car, does not make sense as the ambulance car driver would detect the problem before the sensor would.

A solution for this is a traffic observation system, which documents the current traffic flow for the main streets and sends this input to the algorithm. As the standard roadmap of the city is already in the computer system, the algorithm can start and adjusting the planned route immediately with real-time data from the entire city. This leads to a suggested path, which avoids present and developing traffic jams. Real-time data during the transportation also can be used to correct the path e.g. in case of new developing traffic jams or cleared roads An example is shown in figure 27, where the main roads of the inner city (figure 27a) are converted into a digital system, where the streets get individual numbers (figure 27b).

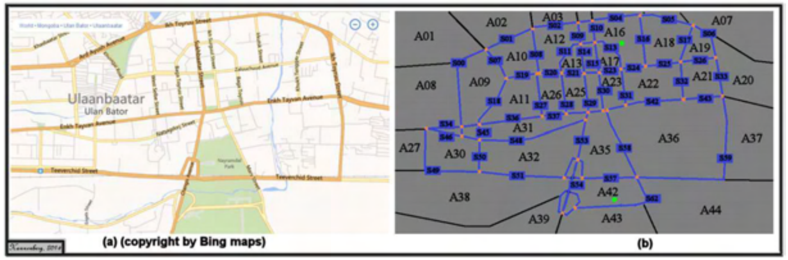


Figure 27: Digitalization of the street map of central Ulaanbaatar. a) Original map of central Ulaanbaatar (taken from Bing maps). b) Converted image providing a separation into areas (A) and streets (S), where every area and every street gets an individual number for the further process.

Some areas of Ulaanbaatar already have a video based traffic observation system. It is possible to enlarge this camera system to cover all main streets in the traffic affected areas. Different automatic image recognition software is developed by several computer science departments or software companies e.g. for face recognition, mimic recognition, or cancer recognition. The basic concept for these software variations is always the same; the pixel composition of an image is analyzed in many possible ways to detect desired structures. In following images of the camera, or images of the image stack in case of medical image recognition, the shape or the position of the structure change. In case of traffic recognition, cars are the desired structures in the images and can be detected. By comparing the pictures over time, a movement of these structures can be observed and a speed of movement can be calculated. The result is an automatic system, which detects the driving speed of cars, which can be seen as an indicator for the traffic situation of that observed streets.

The same system can be used for statistical purpose and to detect, how changes in the street infrastructure affect the traffic situation. It is therefore a possible tool to measure the effects of infrastructure changes and to indicate, which areas of the city are in special need of an improvement of street infrastructure.

ImageJ is a java based image processing software, programmed by Wayne Rasbrand from the United States National Institutes of Health (NIH) [96]. The public domain based software can be used as stand-alone software or can be integrated into other software. ImageJ not only allows to use given image processing and image editing tools but also to develop own tools by programming plug-ins in java. There are many java-based software solutions as java plug-ins available as freeware on the official ImageJ website [97]. But due to its focused use on medical and microbiological purposes, none of these plug-ins fit with the desired situation. Therefore it is necessary to develop an own plug-in, which is specialized for detecting the movement of cars.

A first step of the program needs to detect the objects in the image. Image processing specialist use edge-detection algorithms to find objects in the image. A commonly used edge detection filter is the canny filter, developed by John Canny in 1986 [98]. The basic idea is to perform different steps of adjusting the image to provide a more efficient detection of real edges. A more simple edge detection algorithm already shows promising results (figure 28). To avoid single pixels to be discovered as edge, the image needs to be blurred. Gaussian filters are in general used to remove single pixels, but have the disadvantage that also real edges are removed or blurred in the image. A solution for this is a method named anisotropic diffusion, where the effect of blurring depends on the neighbours of each pixel [99]. The second step is to create a gradient field of the image, where the colour changes between two neighbouring pixel is described. Big changes between the colours indicate the edge of an object. As this kind of gradient field is already created for the anisotropic diffusion method, this gradient field can be reused instead of creating another algorithm for the calculation of gradients.

Figure 28: Comparison of the original image (left) with a calculated image of an easy edge detection algorithm (right). The original camera image is from the YouTube movie: "Ulaanbaatar - Metro tusliin taniltsuulga"

After the gradient calculation, the gradients need to be weighted, to declare edges, which follow a certain direction, as most interesting. This weighting algorithm strengthens the desired edges while weakening all other edges. As a result, an image with only the edges wanted is calculated. When this is done, a comparison between one picture and the following pictures can be performed to describe the movement of these edges. A subtraction of neighbouring images will eliminate edges, which stay at the same position (e.g. buildings, trees, parking cars) which leads to images, where only movement is described. The results are seen in figure 29. More accurate edge detection can further enhance the system, resulting in more clear images.

Seven pictures were taken out of a small traffic observation sequence, where the movement of cars can be observed. Using the built in edge-detection tool from the ImageJ software, an easy and fast edge-detection image can be constructed from the original image. The seven resulting edge detection images are seen in the middle column of figure 29. When performing a graphical subtraction of two images, one image is the result. Subtracting picture 2 from picture 1, picture 3 from picture 2 and so on, six subtraction images are generated, where the edges of fixed objects are mainly removed. These images are shown on the right column of figure 29.

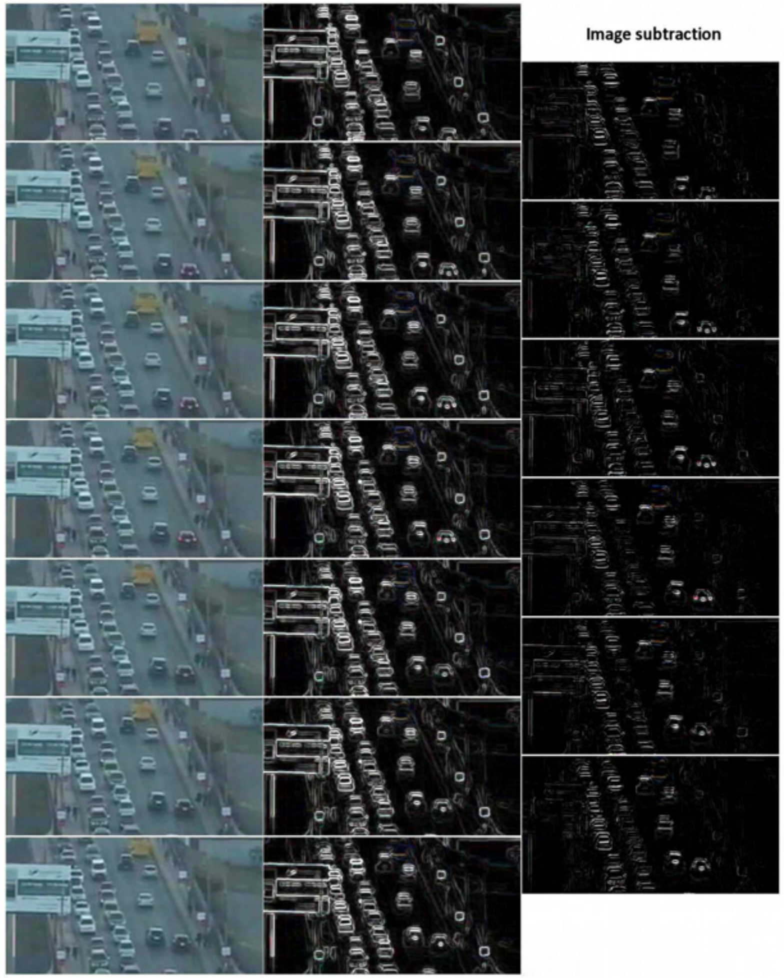


Figure 29: Original camera images (left), their edge detection results (middle) and the subtraction of the edge detection results (right).

Detailed information and the source code of the traffic recognition software are shown in Annex V.

7.5.2. City path planning

The D*-algorithm is a path planning algorithm, which is designed for robots [100]. On the basis of a known terrain, the robot should find the best path from his actual position to the desired position. On its way, the robot detects obstacles and needs to avoid them. The algorithm helps to analyze alternative routes in case of suddenly blocked ways. This is its main advantage compared with other path planning algorithms like the A*-algorithm. The main differences between both algorithms are listed in table 37.

Table 37: Comparison of the A*-algorithm with the D*-algorithm [100]

A* - algorithm	D* - algorithm
Path planning starts at position and stops as soon the end-position is reached by the algorithm.	Path planning starts at end-position and finishes its planning step, when all possible positions are reached.
The shortest accessible path is stored, no other information available.	The shortest accessible path is preferred, all other calculations are stored.
In case of a sudden blocking of the planned path, the algorithm starts new from the new position.	In case of a sudden blocking of the planned path, the algorithm starts his correction step, by checking calculated neighbouring positions, to find an alternative route.
Initial calculation is faster, No reaction on changed situations	Initial calculation takes longer, Fast reaction on changed situations possible.

When the algorithm is designed for a special area, it can be made more time effective, by preparing a city map with several positions, which know the details of their neighbouring positions. Whenever the algorithm starts working, it gets a start-position and an end-position as input and can search the nearest connection from these points to the pre-calculated map grid. After this connection, the map grid sub-program can calculate the best path between both positions. In difference to the robot path planning, where the robot sensors detect obstacles in the way, the traffic recognition system can provide an average movement rate on the all observed streets. It is therefore possible to take the actual traffic situation of the street connections into account, while calculating the best path. The result can be that the path planning algorithm suggests an alternative route, which avoids traffic jams, as the shortest way must not be the fastest one. It is visualized in figure 30, where the shortest path (figure 30a) can be replaced by the faster route (figure 30b) due to heavy traffic.

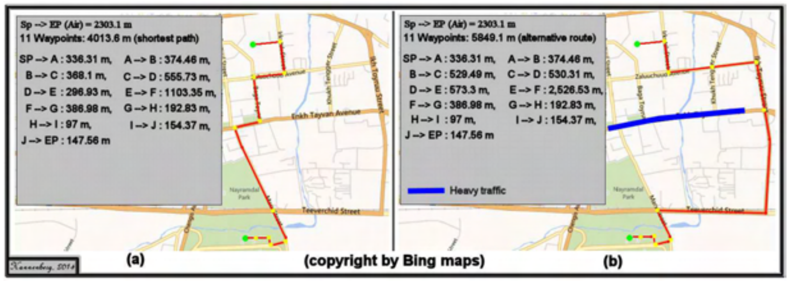


Figure 30: Two possible pathways from Start point (SP) to Endpoint (EP). a) Shortest path. b) Alternative route to avoid the traffic jam.

As it is shown in figure 30, the algorithm chooses the small streets only to enter the individual areas where the start point and the endpoint are located. Information about those small streets within the areas can be loaded separately, in case they are needed. This is helpful because the ambulance car will not be sent through streets, which are not covered by the automated traffic recognition system. Limiting the number of possible streets also reduces the calculation time for all possible paths from the start point to the endpoint.

A GPS-based tracking system enables the system to locate the current position of the ambulance car and to renew the path planning algorithm from the current position to update the planned route and correct it, if necessary.

Although the system is based on the idea of the D* star algorithm, it needs to be mentioned that a number of changes need to be done to work the way it was mentioned above. Different improvements have been made by a number of researchers, some of them also affecting the work discussed in this thesis. A first improvement was the D* Lite algorithm published by Sven Koenig and Maxim Likhachev in 2002 [100, 101]. Further improvements were made by Dave Ferguson and Anthony Stentz in 2006 with the publication of the Field D* algorithm [102]. Finally there was a new introduced algorithm based on D* Lite published in the International Journal of Engineering Research and Applications (IJERA) in 2012, focusing on Real-Time Multi-Agents in Dynamic Environments [103].

In contrast to these algorithms, the algorithm above differs in some ways. The terrain is not unknown and therefore does not need to be discovered. The possible pathways are limited due to the road system of the city. Therefore the obstacle system in the algorithm needs to be changed to a traffic condition analyzing system, in order to calculate the fastest possible way from position A to position B. Therefore, the first part of the D* algorithm, where the possible pathways are calculated, is not needed, as all information are already stored in the system. The second part of the D* algorithm is the behaviour in case an unknown obstacle does not allow to use the chosen road. As all information from the traffic control system is available immediately, the algorithm does not need to wait until an obstacle is detected, but the algorithm can directly start with the calculations, taking the current traffic situation of the different streets into account. A more detailed explanation is shown in Annex VI.

7.6. Conclusion

Chapter seven has shown that there are several technical solutions to strengthen the Mongolian infrastructure. In the introduction is was shown that Mongolian public hospitals suffer from a lack of new constructions, leaving the public health care in old constructions without any standards and protection measures. Newly developed interactions between different medical departments in Europe and America cannot be applied to Mongolian hospitals as the buildings do not allow a standardized partnership between the medical departments. While the electrical Infrastructure and other aspects as air filtering can be newly installed in existing systems, interactions and international construction standards cannot be effectively applied due to the room arrangements of the buildings. Therefore new building constructions, which fit the newest needs and ideas of hospital management, would be needed to reach state-of-the-art status for public hospitals.

It is important to choose specialists in building design for hospitals to ensure a high quality planning and construction of the building. Prof. Popp showed in his Health 5 Trip –report [40] how the planning and construction of the new Bayangol district hospital is made. Operation theatres and Intensive care unit (ICU) are relocated during the construction and the ICU shall be now build in the room, which was planned as a kitchen. Rooms and walls were made with many holes for cable connections, the holes closed again and new ones made due to the relocation (figure 31b). Windows were not installed in high quality (figure 31c) and the air conditioning system was made without being recognized in the building planning, as new holes needed to be made in the walls to construct the system (figure 31a) [40]

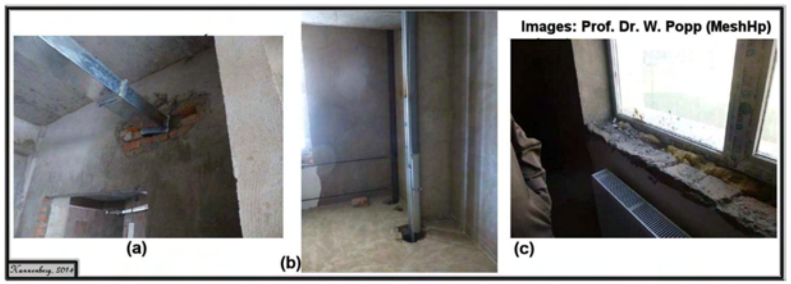


Figure 31: Photos taken from the construction site of the new Bayangol district hospital (photos taken by Prof. Dr. W. Popp (MeshHp) [40]

"ICU is in a room which was planned first for the kitchen. Everywhere holes are closed and new holes with pipes and channels are made. So it seems that it was not planned really well and all plans are changing and something might have been forgotten. This is the reason for a lot of more costs! Most of the installation pipes are in the room and not in the wall."

"Health 5 Trip in April 2014 - Report" by Prof. Dr. W. Popp (MeshHp) [40]

This replanning and reshaping will be the main reason, why the costs for the construction of the building are much higher as initially planned. An accurate and high quality planning and construction would allow using the money available for infrastructure projects more effectively.

Nevertheless, the National Central Hospital, which faces many problems due to its age, needs to get an time-to-time upgrade with certain stages of accurately planned renewing, as it is the biggest hospital in Mongolia and cannot be replaced by another, new facility. New buildings belonging to the hospital should be created with regards to international standards, to allow a state-of-the-art status for health care within the new rooms of the hospital, while the older parts of the hospital can be renewed step by step. The chapters about grounding, protecting and the reshaping of the ICU are giving some ideas how the stepwise upgrade of the older buildings can be performed.

Street infrastructure does not have a direct connection to health care, but it is shown in the chapter about the traffic situation, that medical patients suffer from the traffic situation in Ulaanbaatar, when their ambulance cars are stuck in a traffic jam and adequate care can start too late. Especially stroke patients are known to be diagnosed and treated as fast as possible to prevent permanent brain damages of the patient. It was shown that a traffic observation system would allow to measure the speed of the cars in this area and to provide suggestions to ambulance cars about the fastest way to the hospital.

Of course these are not the only solutions for problems in the infrastructure. As described in chapter 5 the infrastructure is getting worse outside of Ulaanbaatar. Also the infrastructures in laboratories need to be upgraded, as it was described in chapter 6 that there are high potentials in the electricity infrastructure but also the water supply. Mrs. Maazouz from the Mongolian Emergency Service Hospital Hygiene Project (MeshHp) showed the problems due to poor water quality in Central Sterile Service Departments (CSSDs) in Mongolia [104]

Other infrastructure problems require additional solutions outside of the technical area. It was shown in chapter 6 that alternative methods are available for some diagnosis and treatment of diseases. These alternative methods require knowledge and experience, which needs to be educated to the personnel. In fact, education is a key factor for strengthening the Mongolian infrastructure. Only in case the personnel know how to use devices and how to perform methods properly, a high quality outcome can be ensured. Quality control is an essential aspect in European and American health care and should be strengthened in Mongolia as well. Quality Manager and Risk Manager are highly paid jobs in developed countries, to take the importance of their work into account.

Some infrastructure improvements are easier to implement than others. While the solution to adjust the electricity cables of devices with unique power plugs for 220 V and 110 V is simpler, the solution for grounding the National Central Hospital of Mongolia will take years to be completed. This is due to the high expenses to buy about 1000m of corrosion free electrode material to create the ring earth electrode. Additional costs are due to the digging of the trench, where the ring earth electrode will be placed (at least 1.5 meters deep, because the soil is frozen in winter also in more than 1 meter depths).

The educational infrastructure is one of the most important ones, but also one of the most time consuming ones. Therefore a concept should be established for the education infrastructure as fast as possible. Specialists with international standard knowledge would be able to improve the infrastructure of Mongolia in many ways, including water and electricity. In fact, Mongolian specialists with international standard education can be even more useful for Mongolia than foreign specialists, because the Mongolian people know their country and understand the countries problems more easy than the foreigners do. This can be seen in the case of the Health 5 project from the Asia Development Bank, as they were assuming a better quality infrastructure and did not consider the possibility of serious damages of medical devices due to unstable electricity or water supply. During the authors investigation there were meetings with members from the Health 5 project as well as with the team of the Mongolian Emergency Service Hospital Hygiene Project (MeshHp). These meetings resulted in the statement that the infrastructure problems need to be considered for their projects in the future [105].

8. Technical Solutions: Advanced Medical Technology

8.1. MRI: General introduction

Magnetic Resonance Imaging (MRI) is a medical imaging technology, which uses basic physics and the general properties of a human body to create accurate images of the inside of the human body. These images are separated image slices of the human body, which can be calculated to a 3D image. Hydrogen atoms are used in most cases or Magnetic Resonance (MR) measurements because the human body consists mainly of water and therefore contains a high number of hydrogen atoms.

Protons in every atom are constantly rotating around their own axis, which is called a spin (Figure 32a). These moving protons can be seen as moving electrical current, which always produces a magnetic field. Atoms with an even amount of protons have pairs of protons, which are spinning in opposite directions (Figure 32b). As a result, the magnetic fields of the pair can be seen as zero, because their forces eliminate each other. Therefore only atoms with an odd number of protons have a magnetic field, which can interact with other atoms as well as with magnetic fields from outside the body.

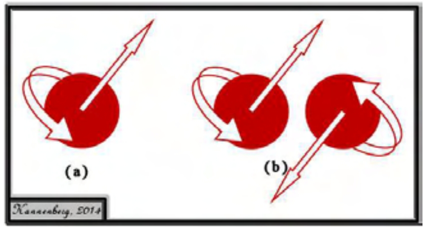


Figure 32: Spin of a single proton (a) and of a pair of protons (b). In (b) the two spins create magnetic forces in opposite directions, which eliminate each other.

In case the human body enters a strong external magnetic field, all single protons of the body will be affected. Comparable with tiny magnets, about 50% of all protons adjust their orientation in a way that their own magnetic field aligns with the external field. The other protons point exactly in the opposite direction (figure 33a). Both directions have different energetic levels, whereas the second possibility has the higher energy level. When there are ten million protons in the higher energy state, then there will be ten million and seven protons in the lower energy state. Same as with the situation inside one single atom, also single protons from different atoms can eliminate their magnetic force by pointing in opposite directions (figure 33b). As a result only 7 of the 20.000.007 single protons are creating a magnetization of the human body (figure 33c).

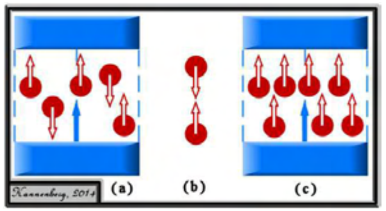


Figure 33: Proton orientation in a magnetic field (a), whereas opposing protons eliminate each other (b). As a result all protons in the higher energetic state (infinitesimal smaller than 50% of all protons) are eliminated (c).

Every proton is performing a precession like a spinning top in the direction of the magnetic field (figure 34a), whereas the speed of precession depends on the strength of the external magnetic field as well as on the tissue structure and therefore the position of nearby single protons. This fast precession is usually described with the precession frequency[16] and can be calculated with the Larmor equation (described in the technical introduction). The higher the strength of the external magnetic field, the higher is the precession frequency of the affected protons. Because the body has many single protons at the same position of a body, several precession positions are creating a force on the same point. These precession positions are randomly distributed, which means that their transversal vector parts eliminate each other (opposite directions on the x-y plane) (figure 34b). Only the longitudinal vector parts create a magnetization (in z-direction), which is parallel with the magnetic field and therefore cannot be measured accurately.

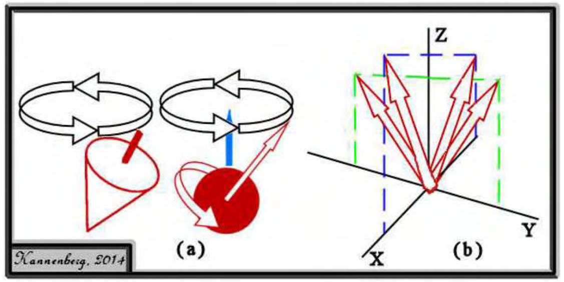


Figure 34: Precession of protons in a magnetic field. a) Precession of a single proton. b) Precession of several protons at the same location. Their precession forces show into different directions and eliminate each other in their transversal parts. Only the longitudinal part (showing up) remains, as it is summed up.

As there is a specific frequency for the precession of the protons in the human body, a process named resistance can be used to align all protons to the same orientation. By using an electrical coil, which is producing a short electromagnetic field, named radiofrequency (RF) pulse, having the same frequency as the precessing protons, these protons are receiving additional energy. This energy leads to the creation of a balance between the energetic levels of the protons. The 7 protons creating a magnetization in the longitudinal axis (shown in figure 33) now also create a balance by partly changing their direction. As a result, the longitudinal magnetization can be entirely eliminated depending on the RF pulse. At the same time by aligning all protons into the same direction, a transversal magnetization is created. This transversal magnetization precesses with the precession frequency. Being a rotating magnetic field, the transversal magnetization induces an electrical current in an antenna, in case of the MRI system a signal receiving coil. But because the energy from the RF pulse does not stay in the protons, the protons start to get out of synchronization again as well as falling back into their original energetic level. This results in a reduction of the transversal magnetization (transversal relaxation) while the longitudinal magnetization increases again (longitudinal relaxation, also T_1-relaxation). During this process the energy from the RF-Pulse is given to the surrounding area, which is named lattice. That is the reason why the longitudinal relaxation is also named "spin-lattice-relaxation".

[16] precession frequency: the amount of complete precession rotations per second

The resulting signal from the protons is shown in figure 35. The name of the signal is free induction decay (FID), as the induction from the RF-pulse is getting less and less. While the signal is getting more and more weak, the wave frequency remains stable during the time. Therefore a Fourier transformation of the signal produces one peak at the precession frequency of the protons (figure 35 right side). In order to receive an image of the patient's body, named slice, special areas of the body need to be induced while all other areas remain silent. This is done by using a second coil system, named gradient coils. These gradient coils create a gradient field within the external field, which was homogeneous. The new field fusions with the external field and together they generate a weighted magnetic field, where every location can be assigned to its own magnetic field strength. Together with the individual magnetic strength, there are individual precession frequencies for every location.

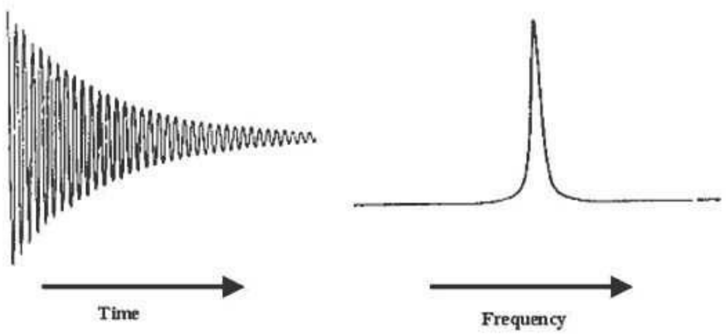


Figure 35: Free induction decay (left) and the Fourier transformed signal. (Copyright by Harvard Medical School)

An MRI device therefore receives several FIDs with different frequencies, which can be Fourier transformed. The transformation result offers the possibility to not only read the position of every FID according to the precession frequency, but also the time until the FID is lowered to a certain level. The time duration of the FID depends on the amount of and relationship between protons in the specific location. The reason is that the process of transferring the energy from the RF-pulse to the lattice depends on the amount of protons in the area, which desires to transfer their gained energy. Therefore it is possible to make suggestions about the properties of the tissue at a special location.

Observing the longitudinal magnetization over a time period the magnetization curve shows an exponential shape. Images with an MRI device can be made T_1-weighted, which means that the separation between the tissues is performed according to their time differences in the T_1-relaxation. In opposite, the transversal magnetization disappears over the time showing a logarithmical shape in the magnetization curve. This is the visualization of the T_2-relaxation, which is used for obtaining T_2-weighted images. In this case, the tissue depending time of the magnetization loss is used to define different tissues.

8.2. MRI: Technical introduction

Atomic nuclei have a positive charge and a spin, which means that they are rotating around an axis. Rotating objects with a charge generate small magnetic fields, comparable with tiny magnets [106]. In case there is no magnetic field the spinning direction is randomly distributed, which means that summing up all magnetic vectors results in a summed vector with the value zero. However, the magnetic field of the earth expose the nuclei to a weak magnetic field, which aligns the spins and therefore results in a positive value for the summed magnetic vector. When the nuclei are exposed to a strong external magnetic field, they align in an either parallel or anti-parallel state [106]. Their spin now changes into a precession, a periodic rotation around the z-axis, which is the axis of the external magnetic field.

When aligning into a parallel or anti-parallel state, slightly more protons decide for the parallel state, as it requires less energy than the anti-parallel state. This results in a recognizable magnetization vector, which is the sum of all magnetization vectors. It can be separated into a longitudinal magnetization and a transversal magnetization, whereas the transversal magnetization remains zero, because of the randomly distributed "phase" of the precession [107]. Unfortunately the longitudinal cannot be accurately measured, as it overlays with the external magnetic field.

In medical MRI the hydrogen nuclei are chosen for the image, because the human body consists mainly of water and therefore contains many hydrogen nuclei. The precession of different nuclei varies because of their individual gyro magnetic ratio γ. For hydrogen nuclei for example the gyro magnetic ratio is $\gamma_0 = 42.58$ MHz/T [106]. Multiplying this ratio with the strength of the external magnetic field allows calculating the precession frequency of all hydrogen atoms in the exposed patient's body. The complete formula is shown in formula 8.1, which is named "Lamor equation".

$$\omega_0 = \frac{\gamma}{2\pi} \cdot B_0 = \gamma_0 \cdot B_0 \quad (8.1)$$

With ω_0: Lamor frequency in Megahertz (MHz),
γ: Gyro magnetic ratio in rad s^{-1}/T
γ_0: Gyro magnetic ratio in MHz /T
B_0: Strength of the magnetic field in Tesla (T)

Therefore it can be said that the hydrogen nuclei precession frequency, which is also named Lamor frequency due to the name of the equation, is about 63.9 MHz in an external magnetic field of 1.5 Tesla, while the earth's magnetic field varies between 0.023 mT in South America and 0.066 mT in the ocean south of Australia, according to the World Magnetization Model 2010 [108].

"While the spin system relaxes and settles into a stable state, longitudinal magnetization M_z is building up in the z-direction because the magnetic vectors representing the individual magnetic moments add together. This also happens in the earth's magnetic field but the resulting longitudinal magnetization is only weak. The magnetic field B_0 of an MR imager is 60,000 times stronger and the resulting longitudinal magnetization is correspondingly larger. Because the MR signal is very weak, magnetization must be large enough to obtain a signal at all."

How does MRI work? An introduction to the Physics and Function of Magnetic Resonance Imaging [106]

A second magnetic coil now produces a short duration alternating pulse (electromagnetic wave) with the frequency similar to the precession frequency of the hydrogen nuclei, to give additional energy to these precessing protons. This is named resonance condition, a situation where the protons absorb additional energy, which is named excitation of the spin system. Because the precession frequency of hydrogen nuclei in a 1.5 Tesla external magnetic field is in the area of radiofrequency, the electromagnetic wave is named radiofrequency (RF) pulse. Two important changes occur because of the additional energy in the spin system: first of all, the difference between parallel and anti-parallel aligned protons change up to a balance, where all positive magnetic vectors are eliminated by negative (anti-parallel) magnetic vectors. The second change is that all precessions, which were in random distributed phases, now are in synchronisation, a status named phase coherence. Their magnetisation vectors summed up result in a transversal magnetisation vector.

The RF pulse only lasts for a short time period to energize the hydrogen nuclei. The energy, which was given into the spin system does not remain inside but vanishes away. Two different processes are responsible for these energy losses. The first one is the transfer of energy from the spinning protons to the surrounding tissue, which is named lattice. During this process, the protons turn back into their original state what means that anti-parallel aligned protons become parallel protons again and the longitudinal magnetization vector increases. This is called "longitudinal relaxation", "Spin-Lattice-relaxation" or "T_1-relaxation". In the second process, the transversal magnetisation decreases due to an energy transfer between the protons, which have been in coherence before. By transferring energy from one to another and inhomogenities in the magnetic field, the protons receive slightly different precession rates and gain different speed. This process is called "transversal relaxation", "Spin-Spin-relaxation" or "T_2-relaxation".

"In other words, transverse relaxation is the decay of transverse magnetization because spins lose coherence (dephasing). Transverse relaxation differs from the longitudinal relaxation in that the spins do not dissipate energy to their surroundings but instead exchange energy with each other."

How does MRI work? An introduction to the Physics and Function of Magnetic Resonance Imaging [106]

The MRI device detects these activities in the object, because the magnetization of the moving protons creates a voltage in the receiver coil of the device. The T_2-relaxation is visualized by the loss of transversal signal strength as the signal has a frequency similar to the precession frequency of the protons, where the signal is coming from. The signal, which is called "Free Induction decay" (FID), shows the characteristics of alternating signals with a logarithmical decay of the signal strength. Therefore T_1- and T_2- relaxation can be used to weight the image. While the transversal relaxation is a very fast process, the longitudinal relaxation depends on the strength of the external magnetic field B_0 and the internal motion of the molecules (Brownian motion). This results in T_1 relaxation time values from 0.5 seconds to several seconds for biological tissues in a 1.5 Tesla external magnetic field [106]. Therefore it is necessary to make clear that both processes do not interfere or interact with each other, although they take place at the same time.

"T_1 and T_2 relaxations are completely independent of each other but occur more or less simultaneously! The decrease in the MR signal due to T_2 relaxation occurs within the first 100-300 msec, which is long before there has been complete recovery of longitudinal magnetization M_z due to T_1 relaxation (0.5-5sec.)"

How does MRI work? An introduction to the Physics and Function of Magnetic Resonance Imaging [106]

8.3. Low field- and earth field MRI

Low field MRI systems produce a weak magnetic field with the help of permanent magnets or electromagnetic coils. Their main disadvantage is a lower signal-to-noise ratio, which means that the desired signal is only slightly bigger than the noise coming from electro smog (electrical devices) and radio stations. Therefore every MRI system must be placed in a special room with special walls to protect from electro smog and radio waves. Also other magnetic fields need to be cancelled out inside the room, because they would interfere with the internal magnetic field and cause uncontrolled precession changes that would damage the signal. Advantages of low field MRI systems are the smaller construction size and, in case of permanent magnets, no need to cool the MRI device with liquid helium. Permanent magnets are compact but heavy to perform external magnetic fields of specific strengths. Therefore the weight of these magnets can be up to 8 tons.

An earth field MRI is the next step of development. It does not produce its own external magnetic field anymore, but uses the magnetic field of the earth instead to align the protons parallel or anti-parallel to the earth magnetic field. Their development is very rare, due to the difficulties coming from the low signal-to-noise ratio. In developed countries, where the infrastructure of liquid helium can guarantee a high quality and safe cooling liquid for MRI devices, there is no need to invest into this kind of technology. In opposite, the manufacturers of MRI systems develop MRI systems with more and more strong external magnetic fields to increase the signal-to-noise ratio. The results are MRI systems that can visualize more details but also faces new problems in the accuracy of the image. Another disadvantage of these systems is the more and more difficult cooling system to reduce the coil temperature to a level where the material of the coil is super-conducting.

The possibility to use earth field MRIs depend on the position of the device in relation to the magnetic field of the earth [109] as well as on the strength of the field (see figure 36). In addition the manufacturers of these devices need to be investigated as manufacturers from the southern hemisphere produce mainly devices, which are optimized for the southern hemisphere (e.g. Magritek Limited). The Hamburg University of Applied Sciences had much trouble with the Magritek educational earth field MRI device, before a project team realized that the way the coils were produced was optimized for the southern hemisphere. Therefore the complete device needs to be turned upside down to use it properly in the northern hemisphere.

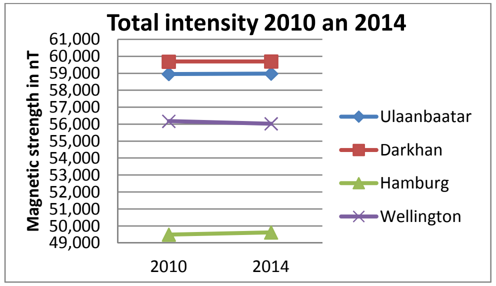


Figure 36: Diagram of the total intensity of the earth magnetic field in chosen locations [110].

Figure 36 shows the total intensity of the earth magnetic field (complete in figure 37) in four different locations: Ulaanbaatar and Darkhan, which are major cities in Mongolia, where earth field MRI technology could be used (other areas as well, but their similar intensities indicate that other places in Mongolia are similar as well).

Hamburg in Germany is the location of Hamburg University of Applied Sciences, where the Magritek educational earth field MRI system is analyzed. Wellington in New Zealand is the location of the Magritek Company, which is manufacturing the educational earth field MRI system. The figure shows that there are higher intensities in Mongolia than in Wellington and much higher than in Hamburg. This visualizes the high potential of this kind of technology in the Mongolian country instead of conventional MRI systems, which are difficult to handle due to the necessary cooling liquid infrastructure.

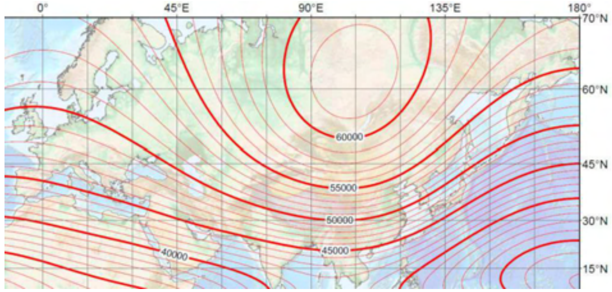


Figure 37: Part of the Main Field Total Intensity map of the US/UK World Magnetic Model showing most parts of the Eurasian continent [111].

The Terranova educational earth field MRI device from Magritek [112] offers an easy to install and use possibility to educate students in the basics of magnetic resonance imaging. A small device with different coils replaces the huge MRI device, while the technical components of the conventional system are fit together in a small device with USB port connection to a computer, where the controlling software is located. The software is designed to allow the students to learn every step from the different magnetic fields, to the free induction decay (FID), from the T_1- and T_2- values to the resulting three dimensional image. The complete set if the MRI system is shown in figure 38.

Figure 38: Terranova MRI set. The probe (upper left) and the spectrometer (upper middle) are the key elements of the educational MRI. Phantoms for the experiments are shown on the upper right [112].

As there are other values of the earth magnetic field as important as the total intensity, the complete list of values provided by the NGDC Geomagnetic calculator is shown in Annex VII. The aim of developing an earth field MRI for medical purpose faces a number of hardware problems, as the Magnetic field weakens with a bigger diameter of the coil. This can be compensated by higher currents in the coil, but this again causes problems with the temperature of the coil, as copper has a higher resistance with hot temperatures and a higher resistance result in a higher temperature of the copper. Therefore a balance needs to be developed between an effective but easy cooling system for the coil, which does not interfere with the image creation (signal-to-noise ratio).

8.4. Raspberry Pi

The Raspberry Pi (Pi for "Python[17] interpreter") is a credit-card sized single-board computer developed by the Raspberry Pi Foundation [113]. The comparably simple and inexpensive fully functional computer was developed with the aim to motivate young people in educating themselves in programming languages and hardware knowledge. It was published in 2011 and is facing great success in a big community.

Unlike personal computers (PCs) the Raspberry Pi is having a System on Chip (SoC) solution, which means that not just the central processing unit (CPU) but also the graphics processing unit (GPU) and other things as USB and memory (SDRAM) are created together in one single computer chip [114]. This reduces the needed electricity significantly, which makes it the favourite solution for embedded systems (smart phones, tablets, etc.). Raspberry Pi models use the Broadcom BCM2835 SoC, which provides a 700 MHz ARM 11 CPU (ARM1176JZF-S) with 256 MB (Model A, figure 39a) or 512 MB (Model B, figure 39b, and Model B+ [115], figure 39c) shared SDRAM memory for CPU and GPU [116]. Over clocking of the processor is possible and up to 1000 MHz accepted by the Raspberry Pi Foundation without voiding the warranty.

Therefore the power of the Raspberry Pi can be compared with eBook-readers, IPods and several smart phones, which were published before 2012. A List with different SoCs using the ARM 11 family CPUs is shown in table 38:

Table 38: List of products using ARM 11 CPUs (chosen products). BCM: Broadcom, MSM: Qualcomm, S: Samsung, i.MX: Freescale

System on chip	ARM11 CPU	Used in the following products
BCM21553	1136JF-S, 832 MHz	Samsung Galaxy Y (384 MB)(2011)
MSM7227-1	1136JF-S, 800 MHz	Samsung Galaxy Ace (384 MB)(2011)
S3C6410	1176JZF-S, 800 MHz	Samsung Omnia II, Samsung Galaxy Spica (256 MB, 2009)
BCM2835	1176JZF-S, 700 MHz	Raspberry Pi (256MB or 512 MB, 2011)
S5P6422	1176JZF-S, 667 MHz	Samsung Galaxy 3 (256 MB, 2010)
S5L8723	1176JZF-S, 667 MHz	iPod Nano 6G (64 MB, 2010)
S5L8730	1176JZF-S, 667 MHz	iPod Nano 5G (64 MB, 2009)
MSM7227	1136JF-S, 600 MHz	2010: HTC (Aria, Legend) (384 MB), Samsung Galaxy 5 (256 MB) 2011: HTC Wildfire S (512 MB), Samsung Galaxy mini (384 MB)
i.MX31	1136JF-S, 532 MHz	Amazon Kindle 2 (32 MB, 2009)
i.MX35	1136JF-S, 532 MHz	Amazon Kindle 3 (256 MB, 2010)
S5L8720	1176JZF-S 532 MHz	iPod touch 2G (128 MB), iPod Nano 4G(32 MB) (2008)
MSM7200A	1136JF-S, 528 MHz	Samsung Galaxy (128 MB), HTC (Magic, Hero)(288 MB) (2009)
S5L8900	1176JZF-S, 412 MHz	iPhone, iPhone 3G, iPod touch(128 MB, 2007)

With the new model B+ [115], which is published in July 2014, there are 3 models of Raspberry Pis, offering different specifications for users. Its compact size and the energy efficiency make them usable as microcontroller as well as controlling units for robots and automated systems. With the possibility to install adjusted Linux distributions the Raspberry Pi can be used as a replacement of PCs and as media centres connected to television. It has the licence and the capabilities to run blue ray movies fluently with Full HD resolution (1920 x 1080). A detailed list of the specifications can be seen in table 39.

[17] Python: Python is a programming language

Table 39: Specifications of the three Raspberry Pi models [114, 115]

Model	Model A	Model B	Model B+
System on chip (SoC):	Broadcom BCM2835 (CPU, GPU, DSP, SDRAM, single USB port)		
Central Processing unit(CPU):	700 MHz ARM1176JZF-S core (ARMv6 architecture, ARM11 family)		
Graphics Processing unit(GPU):	Broadcom VideoCore IV 250 MHz with full HD support		
Memory (SDRAM)	256 MB (shared)	512 MB (shared)	512 MB (shared)
USB 2.0 ports	1 (from SoC)	2 (via internal USB port)	4 (via internal USB port)
Video input	CSI input connector for RPF designed camera modules.		
Video output	Composite RCA, HDMI, DSI with resolutions up to 1920x1200 pixels (FBAS)		
Audio output	3.5 mm jack (analogue), HDMI (digital), I²s (revision 2 boards only)		
harddisk	SD/MMC/SDIO card slot		Micro SD card slot
Onboard network	none	10/100 Mbit/s Ethernet (connected to the USB hub)	
Low-level peripherals:	UART, I²C bus, SPI bus with two chip selects, I²S audio, +3.3V, +5V, ground		
	26 PIN GPIO (8 x)		40 pin GPIO (17x)
Power ratings	300 mA (1.5 W)	700 mA (3.5 W)	600 mA (3.0 W)
Power source	5V via MicroUSB or GPIO header		

Of special interest is the General Purpose Input / Output (GPIO) connection, which allows to control sensors, LEDs, etc. Libraries for the programming of the GPIO are online available and offer possibilities for a wide variety of projects for the community, e.g. to control a microwave, coffee machine or the garage door, to create weather stations by connecting specific sensors or implementing a Raspberry Pi into a mobile robot. There is a wide variety of possibilities what the Raspberry Pi can do. Extra devices have been developed for the GPIO system (e.g. PiFace Digital, figure 39 f [117], or PiFace Control and Display [118]), which are additional boards for extending the possibilities of the Raspberry Pi. PiFace Racks (figure 39d) [119] is an extension of the GPIO socket to allow more than one extension board to be connected to the Raspberry Pi at the same time. Camera connection (figure 39e) or connection possibilities with motors, sensors and magnet coils can be established with the Gertboard (figure 39g) [120] or the xtrinsic-sense-board [121], which is published as a sensor board also for medical applications. An extension board named GertDuino (figure 39h) [122] allows the connection the wide area of Arduino microcontrollers [123]. Another possibility to extend the connectivity of the Raspberry Pi is by connecting the Z-Wave RaZberry board [124], which allows radio wave controlling of home automation devices using the Z-Wave standard [125]. A full list of extension boards is available at www.elinux.org [126].

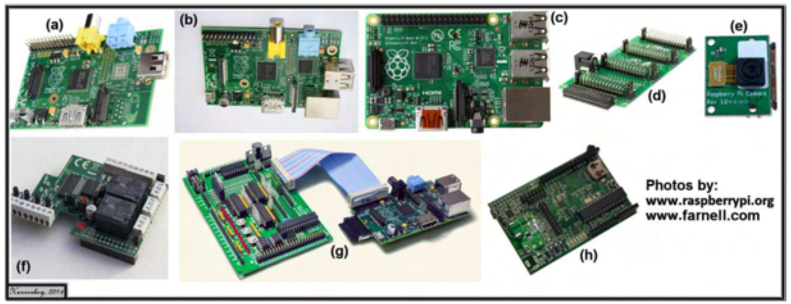


Figure 39: Chosen products related to Raspberry Pi. a) Raspberry Pi model A, b) Raspberry Pi model B, c) Raspberry Pi model B+, d) PiFace Racks, e) PiCam, f) PiFace Digital, g) Gertboard, h) GertDuino

8.5. Earth field MRI control

8.5.1. Hardware

Taking into account that medical MRI devices also include big computer systems for the controlling of the device and calculation of the image and that this controlling unit is fit into a comparably small box in the Terranova educational earth field MRI system from Magritek [112] there is a high potential in minimizing the space and energy consumption of the controlling devices. In addition single board computers like the Raspberry Pi offer possibilities to also include the computer inside the controlling box instead of creating a USB connection between a computer and the controlling box.

Apple Inc, a company producing and distributing the famous embedded system family (iPhone, iPad and iPod) besides its computer system family (MacBook, ...) has proven that software which is specially designed for a specific hardware is running more fast and stable than operating systems (OS) designed for a wide variety of hardware (e.g. Microsoft Windows, several Linux distributions). That Apples computer operating system MacOS is not faster and more stable in general can be seen when installing MacOS on personal computers (PC), which are not designed by or for Apple. That OS loses its advantages compared with other OSs in that case. In fact, it will face even more compatibility problems than the competitive ones because it is only designed for a special hardware-software combination.

Combining the information from above, an earth field MRI could benefit from combining the control unit with a fixed and included computer system. A Raspberry Pi can be a basis for the system, as it allows the normal work of computers and offers direct connections to fitting boards for measurement and controlling systems. The possibility to include Arduino microcontroller in the system offers several combinations for measurement and control of the system. Disadvantages due to the low processing speed of the Raspberry Pi (comparable with a 300 MHz Pentium II processor) can be compensated by connecting several Raspberry Pi's to one computer network. A Professor from Stanford University showed how it is possible to create a super-computer with up to 64 Raspberry Pi's, a project which is named Iridis Pi [127,128,129].

Therefore it is possible to combine a certain number of Raspberry Pi's to reach the performance necessary while optimizing the software and controlling hardware to this computer system. Together it is possible to construct an efficient and low-cost system for the handling of earth field MRI systems. In addition, this concept has the potential to be an education project for next generation engineers, as the costs for the Raspberry Pi and additional boards are about 150 USD. All components can be used for other projects as well, which allows to prepare a construction kit for a number of educational engineering projects in the field of medical engineering. It is therefore a technical solution, which can be used to strengthen the educational infrastructure as well.

8.5.2. Software

The software for using earth field MRI systems must include self-testing and position control plug-ins, to determine the correct position of the device. As the outcome of the measurements rely highly on the earth magnetic field, the device must be turned into the correct angle to receive an adequate signal. The signal received by the coil can be improved by using the inductance and the resistance of the coil for creating an LRC circuit, which amplifies the signal. Changing the capacity of the system, the optimized balance can be found for each position of the device. It should be mentioned that the coils of the earth field MRI system should allow to measure the B_0 external magnetic field. Software tools for measuring can help to find the best position of the device.

A second tool for the device must be for the measurement of the signal-to-noise-ratio. Because the amplification of the LRC circuit does not separate between signal and noise, the noise created e.g. by electro smog needs to be reduced by choosing the position of the device carefully. At Hamburg University of Applied Sciences the system is influenced by the current position of the elevator nearby the laboratory. Also the position and amount of cars outside at the parking lots influence the signal quality. Therefore it is necessary for systems like the earth field MRI to use shimming coils to harmonize the earth magnetic field. Room protections as they are used for medical MRI technology in several hospitals cannot be applied as they would keep the earth magnetic field outside of the room and make the use of these devices impossible.

After the location depending calibration of the system, a fine tuning with the shimming coils need to be done. Shimming coils are special coils to create magnetic fields to fusion with the external magnetic field. In opposite to the gradient coils they do not intend to create a weighted magnetic field but to remove inhomogenities in the external magnetic field. In high level MRI systems this active shimming can be replaced by a passive shimming, where service technicians place special metallic plates at certain locations of the device to make the magnetic field become more homogeneous. A plug-in for searching for the best shimming values is necessary to improve the signal-to-noise-ratio.

Gradient coils should be include in a self-diagnose plug-in to allow an analysis of their proper functionality. Problems with the gradient system will lead to images, which seem to be full of noise, because the position of the received signals are not defined as they should. In earth field MRI devices a location dependant higher noise seems to be more likely than a damage of the gradient system. Therefore a tool needs to be included to separate between both problems.

A program concerned with the acquisition of Free Induction Decays (FIDs) is necessary to analyze the signal quality of the complete system. The T_1- and T_2- values of the longitudinal and transversal relaxation need to be detected precisely to allow an accurate image in the image acquisition sequence. A Fast-Fourier-Transformation (FFT) is necessary to analyze the frequency of the single signals, to make it possible to assign individual locations to the different signals detected by the MRI system. This can be done because the gradient field changed the precession frequencies of the hydrogen nuclei in a unique way before. Therefore a single frequency is reconsidered as special location in the volume of the imaging body.

Spin-echo-sequences are often used in medical MRI imaging because of its higher accuracy. The idea is to use 180°-pulses to turn the magnetization around. The transversal relaxation is turned around and the previously faster hydrogen nuclei are now the ones with the highest delay. As they are still the fastest ones, they precession will gain phase coherence at a special point in time again. This method needs to be implemented as a plug-in for the earth field MRI, as it is the most robust possibility to obtain three dimensional data.

Details about hardware and software realization will be described in Annex VIII.

8.6. Conclusion

Chapter eight was dedicated to the MRI-technology, which is one of the most frequently used diagnosis methods in the 21th. century due to its accuracy and possibilities to visualize soft tissues. Several illnesses and diseases only can be visualized by MRI-technology, several other diseases can be diagnosed with alternative methods but with a lack of accuracy. Therefore it is one of the most important medical technologies and should be accessible everywhere in the world. But due to its specific requirements and high installation costs, many countries in the world only can provide limited access to this technology.

Research about MRI technology is mainly done for improving the signal-to-noise ratio by more and more complicated technologies. These technologies mostly consume more energy, are more expensive and require a more effective cooling system based on liquid helium. Only little research is done to make MRI technology more cost-effective to make it accessible for developing countries. Therefore research in this area is important.

This chapter gave a simple introduction in the procedures of MRI technology and the differences between high level and low level MRI systems. Suggestions for future research are given by describing the Raspberry Pi as a cost-effective single-board computer for calculation and controlling of data and device. In combination with measurement boards and Arduino microcontroller systems, a wide variety of possibilities are available. Solutions to control engines, relays and coils are presented by the Raspberry Pi Foundation [113] and related companies and manufacturers [121, 130].

To make MRI technology more accessible in the world, especially the coils need to be in focus of future research. Coils with diameters big enough to allow patients to be placed inside need high currents to induce a magnetic field strong enough to prepare images. High currents normally lead to a temperature rise in conducting materials like copper due to the specific resistance of the materials. As MRI coils need to have big diameters, they often use more than one kilometre of the conducting material, which results in a high resistance within the coil and additional temperature rise. Therefore superconducting materials are mostly used to create the coil, which needs to be cooled down by cooling liquids, which are not available in most areas of the world. Methods for reducing the resistance in copper could allow the creation of MRI coils with copper materials, which are less expensive and can be used with alternative cooling methods instead of liquid helium.

Research in the area of homogeneity of magnetic fields created by separated coils could create alternative possibilities, where Helmholtz coils or Maxwell coils could be used to create the magnetic fields needed for MR-imaging. Recent research is done to make semiconductors become superconducting in cold environments [131] or to create hybrids of semiconducting and superconducting materials [132]. Also combinations of magnets are under development using the Halbach-array (HA) constellation of magnets, which allow strong magnetic forces in one direction, while they are eliminated in the opposite direction [133]. HAs are a common and inexpensive technology in modern life as the arrangement of magnets is e.g. used for magnets for the refrigerator to increase the magnetic field of the small magnets in one direction.

9. Main results and their implications

9.1. Facts

This thesis offered an overview about several aspects to achieve a general overview of the health care situation in Mongolia. The medical point of view was observed by analyzing the health indicators of Mongolia. Reviewing publications and reports about Mongolia and visits to several hospitals in Mongolia's capital Ulaanbaatar as well as interviewing health care workers, public health scientists, medical doctors and hospital management specialists helped to create a full picture, which includes several different point of views. Technical aspects were included by conversations and experience exchanges with technicians, university teachers and company workers.

Chapter 4.1 focused on the definition of developing countries, which is not easy, as there are different points of views also within single institutions. The United Nations (UN) admits that there is no list about countries, which can be described as developed countries and no list, which defines developing countries [8]. Only the least developed countries (LDCs) are listed in a document of the UN [10].

"Since there is no established convention for the designation of "developed" and "developing" countries or areas in the United Nations system, this distinction is made for the purposes of statistical analysis only."

Millennium Development Goals Report 2013 [8] page 59

Nevertheless the health care situation in many countries faces similar problems as it is shown in chapter 4.3, which need specific solutions. While counties like the Democratic Republic of Korea or Singapore, which are seen as developing countries in some of the UN documents but are listed in the top 20 countries of the Human Development Index 2013 [6], can be assumed to have a relatively high level of health care, a high number of developing countries face more basic problems like lack of medical devices or not appropriately working old medical devices. The World Health Report 2013 [5] and the Global Tuberculosis Report 2013 [56] from the World Health Organization (WHO) describe a situation in the developing world, where the mortality rate of several diseases could be significantly reduced, when the education of the population would be high enough to understand the necessity of taking their medicine regularly and to avoid close contact to infected people (also the Ebola epidemic in parts of the African continent show these problems [134,135,136]).

Mongolia faces similar problems like many other developing countries, whereas the situation is more complicated due to the size of the country and the low population. Chapter 4.4. and 4.5. explain the situation of people living as nomads without a fixed location do not have access to sanitized and clean water supply and the medical treatment in rural areas is mostly not appropriate. Hygiene and appropriate medicine are missing, also hospitals do not have a stable electricity- and water- supply [40]. The health care infrastructure throughout the country suffers from old buildings, old devices and a lack of standards, which lead to possible electricity hazards due to electric shock because no protection measures are included in the construction. Also the devices are getting damaged very often due to unstable electricity supply. Because medical technology is imported instead of manufactured, the devices do not fit the real needs of the health care system, are often not fitting for the Mongolian 220 V electricity supply and cannot be appropriately installed and operated. In the need to safe money Mongolian health care institutions often buy devices without paying for instructions and installation of the device, which leads to devices out of operation or damaged devices due to inappropriate installation or operation. Quality Management as well as Risk Management are not considered in the Mongolian health care system, resulting in repairing and maintenance measures for medical devices, where safety-related checks and functional checks with calibration control are not performed according to international standards. This is shown in chapter 5.

The health care situation in Mongolia faces problems in the field of communicable diseases as well as circulatory and respiratory non-communicable diseases. A special health care threat is cancer, as the numbers of new cancer patients are growing steadily, while there is only one hospital in Mongolia focussing on cancer diagnosis and treatment. Chapter 6 shows that the lack of screening for diseases within the Mongolian population leads to the problem that diseases are mainly detected in late stages, where the treatment is getting more complicated; in case of cancer surgery as a treatment is often not possible anymore. Modern technology for state-of-the-art diagnosis and treatment is often missing, the working conditions in laboratories often do not meet the international requirements of laboratories [39]. Alternative methods for diagnosis and treatment are often available in health care institutions, but faces difficulties due to the lack of experience and knowledge of the personnel and the condition of the technical instruments (missing maintenance, lack of hygiene, age of the device).

Solutions presented in this thesis are separated in infrastructure solutions shown in chapter seven and advanced technology solutions presented in chapter eight. The infrastructure solutions are giving suggestions about possible measures to improve the electricity supply of hospitals by installing a high qualitative grounding system (chapter 7.2), implementing a protective earth (PE) cable connection in the electrical supply network (e.g. for all electrical sockets) (chapter 7.1) and to establish surge protective devices (SPDs) and Residual Current Devices (RCDs) to protect the system from overvoltage, voltage spikes and failure currents (e.g. due to electric shocks, chapter 7.3). Suggestions are given in chapter 7.4 how one room of the intensive care unit (ICU) of the National Central Hospital of Mongolia can be upgraded to a state-of-the-art electricity network using medical IT- arrangements to protect personnel, medical doctors, patients and devices from harm due to electrical hazards or energy outages. By implementing 110V as well as 220V electricity networks in the ICU with unique and unchangeable power plugs and sockets the safe use of 110V and 220V devices can be ensured. Also the transportation infrastructure for patients is analyzed and a traffic based guidance for ambulance cars is introduced.

The chapter eight about advanced medical technologies focuses on Magnetic Resonance Imaging (MRI) as the key diagnostic device for many diseases and illnesses. As this technology has high requirements for a safe and accurate operation, it is not available for many people in the world. In Mongolia only five MRI devices are in operation, all of them located in the capital Ulaanbaatar (chapter 5.1), whereas other major cities cannot provide their citizens these devices for making accurate images especially of soft tissues as brain, inner organs or joints. Low field and earth field MRI technology are introduced in chapter 8.3 as an alternative for the future, whereas the earth field MRI technology needs some major improvements due to research before it can be useful for medicine. It was shown by presenting the World Magnetic Model of the U.S. National Geophysical Data Center that the earth magnetic field is strong within the Mongolian country.

New inexpensive technology concepts like the Raspberry Pi presented in chapter 8.4 allow low cost research in the area of advanced computerization and provide possibilities for the software- and hardware- based communication in technical devices. The final part of chapter eight explains some possibilities of these highly integrated systems, as they are small in size and low in energy consumption, which makes the technology interesting for research concerning the mobility of medical devices. Mobile medical devices can become an important part of the Mongolian health care system, as they allow technology sharing between local hospitals and therefore save money especially in rural areas, where expensive technology for a small population is not efficient.

The facts are gathered in table 40, providing a compact summary of all findings of the thesis.

Table 40: List of results obtained in the chapters 4 to 8.

Ch.	Result
4.1 - 4.2	A general definition and list about developing countries does not exist, the development status of single countries varies strongly between the aspects recognized by the Human Development Report. For example concerning the literacy rate of countries Myanmar is on a higher level (92.3%) than the United Arab Emirates (90.0%) or the Seychelles (91,8%), although it is in general listed as low developed country whereas the other two countries are ranked as very high developed countries.
4.3 - 4.5	Developing countries have similar problems with their health care system. Only small money is available, which in addition is less effectively used than in developed countries, due to the lack of Health technology Assessment (HTA) and accurate management. Private hospital groups with several hospitals in South Africa have shown that a strict management with standard procedures can save money and can offer high quality treatment for a lower price than the public health system. Mongolia faces trouble due to their inhomogenious distribution of population in the country. Wandering Nomads in rural areas and only small settlements lead to the problem that hospitals are not cost-effective in every region of Mongolia.
5.1 - 5.3	Medical technology is mostly old (e.g. Draeger Ventilators manufactured in 1987 found in a Mongolian Intensive Care Unit (ICU)) and not appropriately maintained. Modern medical devices for diagnosis (e.g. Magnetic Resonance Imaging (MRI)) and cancer treatment (Linear Accelerator (LINAC)) are only available in Ulaanbaatar, while other big cities as Erdenet or Darkhan suffer from the lack of these technologies. These devices are all imported and often maintained by service technicians sent by the manufacturers from other countries. Own medical technology manufacturers do not exist only companies focused on the import of products. The infrastructure is very low level without electricity protection measures and overvoltage protection devices. The water quality often does not meet the requirements of safe sterilization and usage of medical equipment.
5.4	Technology is developing in Mongolia with manufacturers importing electronic components to assemble technical devices (e.g. smart phones, televisions, computers) with an own brand. Also solar- and wind- farms are constructed in Mongolia, mainly with the help of foreign companies.
6.1	Tuberculosis and Hepatitis are a long-term problem in Mongolia, causing trouble for more than20 years with stable infection rates although several national and international programs were taking care about these diseases. Cancer is a more and more growing problems, especially liver cancer due to hepatitis infections and alcohol; Respiratory diseases (e.g. Pneumonia) are mainly caused by the air pollution and extreme weather conditions; circulatory diseases are main mortality reason.
6.2 - 6.4	Diagnosis of the diseases mentioned in 6.1 often rely on imaging methods, which are not always available in Mongolian hospitals. MRI systems for soft tissue and brain diagnosis often do not have an alternative method for the diagnosis due to the special conditions and restrictions of alternative imaging technologies. Laboratory equipment in Mongolia varies from WHO-recommended standard equipment down to inappropriate culturing methods, which allow contamination of the culture growth media.
7.1 - 7.4	The electrical infrastructure can be improved by creating appropriate grounding systems, which base on ring earth electrodes made of stainless steel. Electrical sockets often do not provide a connection to the protective earth (PE) and therefore cannot be protected with residual current devices (RCDs) to ensure patient safety. Intensive care units (ICUs) need special electrical protection, as their life-supporting devices run up to 24 hours a day. Different imported medical devices created for 110 V or 220V power supply are in use, which make it necessary to create electrical circuits with unique power plugs to provide correct electricity for usable devices.
7.5	Traffic recognition and path planning can reduce the time a patient is without appropriate treatment. Using the existing street observation system limit the costs for the traffic observation and recognition system.
8.1 - 8.5	MRI technology in low field and earth field variations face difficulties in their signal-to-noise ratio and therefore their image quality but are more inexpensive in installation and operation and therefore are attractive alternatives for countries with small health care budget. Combining research with the Raspberry Pi board are a promising project to create mobile medical devices, which allow transportation of high quality medical devices to different hospitals to save money.

9.2. Appraisal

This thesis has shown that Mongolia and other developing countries face serious health care problems, which can be prevented with organization and investments. It is shown that not just the medical equipment is the problem but that different aspects play a key role in adequate and balanced health care. Medical equipment only can be used, when it is correct installed and operated. Supply materials and drugs, which are used together with the device, need to be available and accessible together with the device to make the operation of the device useful, prevent damages on the expensive technology and to prevent potential hazards from the patient and/or the device operator. The operator of the device need to know the specifications of the equipment to understand what the device can do, what it cannot do, where the advantages are and where are disadvantages. The user of the device should understand his/her responsibility when performing imaging or treatment on a patient that the imaging is useful for making a diagnosis and that the patient suffers as less as possible. The ALARA principle should be considered always: As Low As Reasonable Achievable.

The operator of the device, which is normally the hospital or health care institution, needs to take care of an adequate usability of the device, by realizing a quality controlled repairing and maintenance of the devices. Biomedical Engineers in European and American hospitals mainly do not repair devices themselves but do paperwork for their departments to ensure a regular maintenance and functional control, that medical doctors and technical assistance can rely on the correct functionality of the device. Quality- and Risk- Management are therefore important aspects in hospitals to improve the general health care situation.

These Quality- and Risk- Management also need to take care of safety and quality issues related with infrastructure. Laboratories need access to improved and sanitized water to perform their tests, central sterile service departments (CSSDs) need high quality water to ensure that reusable medical instruments do not get damaged due to the reprocessing and sterilization. Electricity infrastructure is essential for the operation of all technical and medical devices. Their quality and functionality therefore needs to be part of the Quality- and Risk- Management as well as the Hygiene infrastructure, which takes care that infectious diseases cannot spread within the patients and workers of the hospital.

The thesis has shown that there are sometimes Mongolian National Standards (MNS) for different aspects, but often not related to international standards or guidelines. Medical standards often are older than 10 years and therefore cannot be in accordance with current WHO guidelines. Even more dangerous is that there are nearly no standards concerning medical equipment or hospitals, leaving much space for inappropriate health care methods and safety threats. Defining standards for the infrastructure of health care institutions, the operation and maintenance of medical devices and the use of medicines according to current international standards and guidelines would help to improve the health care. In addition this would help to make health care more equal everywhere in Mongolia.

10. Overall discussion of the results

In this thesis a number of private and public hospitals were explored and interviews were made with very different people, who are involved in the health care system. Together with reviewing publications and reports about Mongolia one big picture is created for the Mongolian health care system. A detailed literature research using PubMed, an internet based search engine to look for international publications in the MEDLINE database, provided several publications with the key words "developing country" or "Mongolia". Taking into account that developing countries should be considered to be developing also in the field of medicine, only publications published less than 15 years ago where chosen to create a picture of the medical situation of developing countries. The authors knows that many aspects written in publications older than 15 years still can be relevant and can be missing in the picture created in this thesis. It needs to be considered that a more detailed literature review including older publications can be useful to find additional problems and possible solutions. Nevertheless, this document is a technical master-thesis and therefore needs to focus on technical aspects.

Also increasing the number of people to be interviewed and the number of hospitals explored can result in additional information, which are missing in this thesis. It needs to be said that these kinds of investigations are not easy, especially for foreigners, because the permission of interviewing and exploring depends highly on connections to responsible people and the ability to speak multiple languages. As the author is only beginner in learning the Mongolian language, several interviews were not possible or faced difficulties due to misunderstanding. Again it should be said that there is space for improvements, which could be interesting for social sciences as well as medical sciences, but do not affect the engineering sciences, which are in focus of this thesis.

It also needs to be mentioned that official documents from different governmental institutions did not fit with their information, which makes the investigation even more difficult. For example the Health Indicators 2012 [54] report that there were no cases of measles reported in 2011 or 2012. However, the National Statistical Office published in their National Statistical Yearbook 2012 [4] that there were cases of Measles in 2009, 2010, 2011 and 2012. Therefore it is questionable, which data is reliable and which data is not.

The picture created with the help of the information is mainly for the Mongolian Capital Ulaanbaatar. Taking into account that outside of Ulaanbaatar the situation is worse, that there are no MRI systems, no cancer treatment facilities, and that the countries electrification rate is only 67% [6] while about 51% of all Mongolians are living in rural areas [4], it only can be assumed how the situation in the countryside area of Mongolia looks like. The health 5 trip report from Prof. Dr. W. Popp [40] is giving an overview of some Aimag centre hospitals. More detailed analysis by exploring these hospitals and interviewing people related to health care could help to receive additional information, but the communication possibilities for foreigners are even lower, which makes it difficult to obtain information besides statistical information from governmental institutions.

Ulaanbaatar is the city with the highest population in Mongolia, which makes the city face many infrastructure problems. While rural areas suffer from the problem that there have never been infrastructures installed, Ulaanbaatar faces the problem that the implemented infrastructure cannot grow fast enough and is reaching its limits. Therefore also more general infrastructure solutions could be helpful for the capital, which would improve also the health care. Streets, Water supply and rain water management are only a few examples for the need of infrastructure improvements. But because these aspects are hard to connect with biomedical technology but more environmental technology, these things should not be analyzed within this thesis.

As there is no medical technology manufacturer in Mongolia and only a few import companies for medical products in Ulaanbaatar, the medical infrastructure is a big problem in Mongolia. Even in the capital, where all companies and organizations related to health care are located, the infrastructure is not stable. Outside of Ulaanbaatar, it can only be assumed how the situation is. But the exploring of the National Central Hospital of Mongolia showed that mobile medical devices throughout Mongolia were often transported to this hospital to be repaired at this location. Also a one-man installation and repairing company in Ulaanbaatar is often called from hospitals throughout Mongolia to give him a repairing job.

For the analysis of the medical situation in Mongolia, the documentation "Health Indicators 2012" from the Mongolian Ministry of Health [54] is mainly used, because their values were fitting with most international reports and publications about Mongolia. Because these data are given to the WHO for their Asia and Global reports they should be considered as the most accurate ones available in Mongolia.

Infrastructure solutions can be done very detailed with component suggestions and prize calculations. But it needs to be taken into account that Mongolia is a landlocked country between China and Russia and therefore does not have access to the global market of products. Several online stores decline to ship products to Mongolia and China as well as Russia are trying with transfer taxes to make their own products more attractive to Mongolian people. Therefore it does not make sense to prepare detailed information about infrastructure changes. Preparing general requirements and giving suggestions about the correct implementation are a better way to make Mongolians become aware of their situation and possible improvements. In fact in many situations components could be manufactured in Mongolia to safe costs and to keep the invested money in the Mongolian economy.

Advanced research concerning MRI technology is important for developing countries to make this technology available for the global population. Due to the transfer taxes and import control of the neighbouring countries it is difficult to create a laboratory including modern equipment for appropriate research. Especially the construction of coils for MRI experiments is difficult to prepare due to the high costs of imported coated magnet wire. Due to the fact that Mongolia is the biggest exporter of copper, it could be possible to buy the copper wire and to prepare an own coating for the wire. But because these coils can contain hundreds of meters of copper wire, an automatically working machine for the coating needs to be constructed. Therefore an own infrastructure needs to be created for the efficient research of MRI technology.

The more promising aspect is the design of a computer system based on Raspberry Pi with its sub-components, as these boards and components can be bought in online-shops also shipping to Mongolia and are available for low costs. The components can be used for a number of different projects and the Raspberry Pi has an active community, which is providing information about their projects to give ideas and suggestions for other projects. In combination with the Arduino microcontroller, many possibilities are available to build simple versions of medical devices. Of course they are not comparable with real medical devices, as their quality and accuracy is not proven with these simple constructions. But they are a first step to create own platforms and combinations, which is the basis for own manufacturing companies in Mongolia and therefore a good investment into the education system for strengthening Mongolia in general.

11. Conclusions

The results show that it is possible to improve the health care system in Mongolia and many other developing countries as well, by analyzing the health care system and finding the root of the problems in the health care system. It could be shown that not the medical devices are the main problem in Mongolia but that there are many cornerstones which need to be improved to create a stable basis for the health care system. It is important to critically review the progress of the health care system, to see what was done, but also what has not been done until now. As the World Health Report 2013 produced by the World Health Organization wrote: "*Every nations should be producer of research as well as consumer of it*" [5]. Research in Mongolia about the situation of the health care system is important, because the roots of problems can be different in different countries and even within one single country although the general problem might look similar.

As a conclusion it needs to be said that the key aspect for improving the health care is a quality management system, which includes the education of the health care workers, medical doctors and technicians but also the infrastructure of the health care institution with its electricity, water supply and hygiene aspects. The quality management system also should take care of introducing modern standards for health care and infrastructure in health care institutions, to create an equal health care system throughout the country.

Possibilities to improve the technical situation of health care in Mongolia must base on an infrastructure improvement, as expensive state-of-the-art medical equipment will be very vulnerable when connected to an unprotected electricity network. Not only the unstable situation in general, but especially dangers due to thunder is a big problem, which can cause overvoltage and voltage spikes in wide areas in Mongolia. The longer a device is connected to the electricity network, the higher is the chance that the device it hit by overvoltage or voltage spikes, which is likely to damage the device. Therefore especially devices at intensive care units (ICUs) are likely to get damaged, because they are often running 24 hours a day as a life-support for critically ill patients. Therefore ICUs should have the highest priority when developing a protection plan for hospitals. Hygiene is an aspect, which is not highly considered in Mongolian health care, as there exist even problems with the regular hand washing of the hospital personnel.

Even more dangerous it is in the central sterile service department (CSSD) where reusable medical instruments are cleaned and sterilized to prepare them for the next use. Sterilization technology belongs to the medical technology as it is a key technology to prevent the spreading of diseases due to medical device usage. A high quality water supply infrastructure is not only necessary to protect the medical instrument from corrosion and other damages, but it also prevents the sterilization technology from getting damaged.

In general for medical devices it should be said, that it is more cost-effective to pay additional money for a correct installation and instruction of the device, because the manufacturer's warranty will protect from additional costs for the next three years. In case of own installation without involving the company, the warranty will get lost and the safe and long time operation of the device cannot be ensured. Installation and repairing service for medical devices in Mongolia needs to be certified by international authorities and medical technology manufacturers to ensure a safe and quality controlled servicing of the medical products by local technicians. Otherwise the more expensive alternative of foreign technicians should be preferred to guarantee a condition of the device where the medical doctor or operating technician can ensure its correct functionality.

A big advantage for the Mongolian health care system would be a systematic improvement of the electronic industry in Mongolia. By establishing technology manufacturers more possibilities also for medical technology companies will be created. As it is difficult for a medical technology manufacturer to create a complete infrastructure with semiconductor and board producing industry, steel producing companies and plastic manufacturers on its own, the basis should be created by a systematic economy improvement project. Also companies concerned with the electricity networks and electricity planning in buildings as hospitals should be improved to work with a higher quality level. Establishing standards related to these topics would help to reach state-of-the-art status everywhere in Mongolia. Technology companies could produce components necessary for these state-of-the-art improvements and establish a new infrastructure, which is also needed for the most important aspect, the research.

Research is done in many countries to find solutions for national and international needs or to improve an existing solution. Health Technology Assessment (HTA) is an important part of medical research as it can investigate the most cost-effective possibilities for health care problems. Cooperation between different fields of professions is necessary for a successful HTA, as the research can show in many cases that a screening and possible early treatment of diseases cost less money than a lifetime treatment of heavy diseases in the late stages.

Also research of new medical technologies is an important part for developing countries like Mongolia due to the fact that international medical technology manufacturers cannot produce devices to fit exactly the needs of single nations. In addition, the creation of a technology industry, which is highly cooperating with the technical education system, can result in modern and high technology devices, as it was seen with the Cyberknife cancer treatment device, which was developed by the Accuray company in cooperation with a Professor of Stanford University. In fact many medical devices are created by combining the knowledge of medical doctors, university teachers and companies.

The MRI technology as a key technology for the future of health care should be considered as a university project for developing countries. New components like the Raspberry Pi allow completely new possibilities for low-level research to have high-level impact. As minimization was the long-term success for personal computers, it will be the trend for medical technology as well. Minimized mobile medical devices are maybe the best solution for many health care problems in Mongolia, as they allow mobile health care institutions in rural areas of Mongolia. Nowadays international manufacturers of MRI systems start offering Mobile MRI systems installed in Trucks to be movable to different positions. Developing mobile solutions by minimizing the devices are not considered in nowadays medical research. Therefore it allows a completely new perspective for medical technology and would allow Mongolia to start research in the medical technology area, which can influence not just national but also international research.

To achieve this aim of strengthening the Mongolian health care system, a long-term plan with systematic investment in different areas need to be created and collaboration between many different fields, the education, the economy and the government needs to be established. But before this can be realized, the basic infrastructure needs to be improved to fulfil necessary requirements and to ensure stable and protected conditions.

VII. Annex I: List of most common mortality reasons in 2012

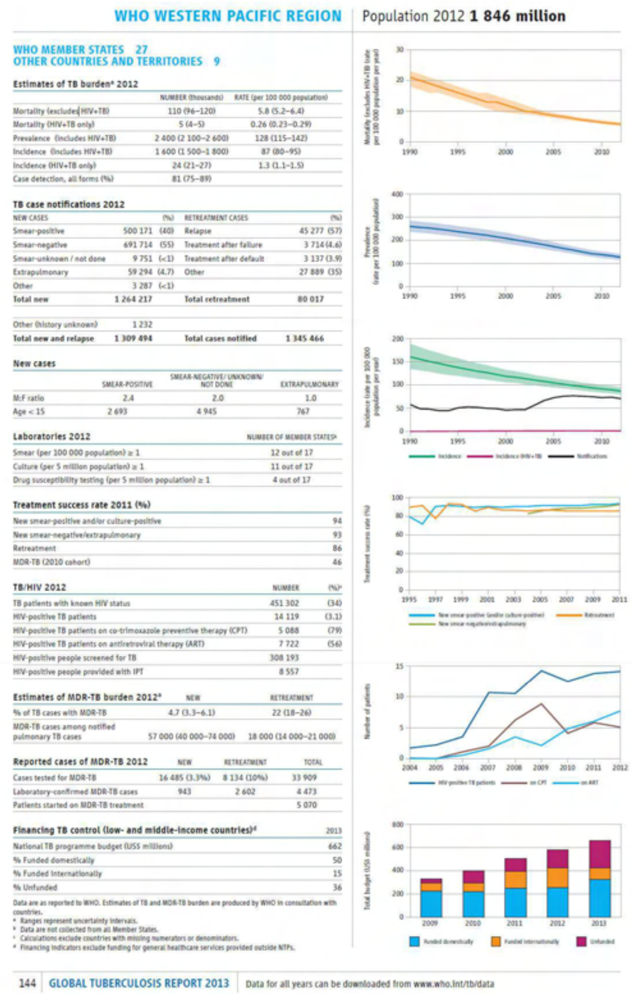
According to the Health Indictors 2012 there were 16,923 deaths in Mongolia in 2012 [54]. A list with the major mortality reasons is shown in table 41.

Table 41: List of most common mortality reasons in 2012 [based on data from 54]

1.Diseases of the circulatory system	**5,939**	**35.09%**
1 a. Cerebrovascular diseases	2,350	13.89%
1 b. Ischemic heart diseases	1,617	9.56%
1 c. Acute myocardial infarction	875	5.17%
1 d. Hypertension	339	2.00%
1 e. Rheumatic fever & rheumatic heart diseases	51	0.30%
1 f. others	707	4.18%
2. Tumours and neoplasm's	**3,591**	**21.22%**
2 a. Liver	1,619	9.57%
2 b. Stomach	556	3.29%
2 c. Trachea, bronchus and lung	336	1.99%
2 d. Oesophagus	281	1.66%
2 e. cervix	85	0.50%
2 f. Leukaemia	74	0.44%
2 g. others	640	3.78%
3. Injuries, poisoning, etc.	**3,195**	**18.88%**
3 a. road traffic accidents	593	3.50%
3 b. suicide	482	2.85%
3 c. homicide & violence	271	1.60%
3 d. occupational injuries	43	0.25%
3 e. others	1,806	10.67%
4. Diseases of the digestive system	**1,511**	**8.93%**
5. Diseases of the respiratory system	**640**	**3.78%**
6. certain conditions originating in the perinatal period	**626**	**3.70%**
7. Diseases of the genitourinary system	**207**	**1.22%**
8. Infectious and parasitic diseases	**302**	**1.78%**
9. diseases of the nervous system	**318**	**1.88%**
10. Congenital malfunctions, deformations and chromosomal abnormalities	**199**	**1.18%**
sum	**16,528**	**97.67%**
all	**16,923**	**100.00%**

VIII. Annex II: Tuberculosis facts - Western Pacific Region

A WHO published fact sheet concerning Tuberculosis in the Western Pacific Area is shown in figure 40.



WHO WESTERN PACIFIC REGION | Population 2012 1 846 million

WHO MEMBER STATES 27
OTHER COUNTRIES AND TERRITORIES 9

Estimates of TB burden* 2012

	NUMBER (thousands)	RATE (per 100 000 population)
Mortality (excludes HIV+TB)	110 (96–120)	5.8 (5.2–6.4)
Mortality (HIV+TB only)	5 (4–5)	0.26 (0.23–0.29)
Prevalence (includes HIV+TB)	2 400 (2 100–2 600)	128 (115–142)
Incidence (includes HIV+TB)	1 600 (1 500–1 800)	87 (80–95)
Incidence (HIV+TB only)	24 (21–27)	1.3 (1.1–1.5)
Case detection, all forms (%)	81 (75–89)	

TB case notifications 2012

NEW CASES		(%)	RETREATMENT CASES	(%)
Smear-positive	500 171	(40)	Relapse	45 277 (57)
Smear-negative	691 714	(55)	Treatment after failure	3 714 (4.6)
Smear-unknown / not done	9 751	(<1)	Treatment after default	3 137 (3.9)
Extrapulmonary	59 294	(4.7)	Other	27 889 (35)
Other	3 287	(<1)		
Total new	**1 264 217**		**Total retreatment**	**80 017**
Other (history unknown)	1 232			
Total new and relapse	**1 309 494**		**Total cases notified**	**1 345 466**

New cases

	SMEAR-POSITIVE	SMEAR-NEGATIVE/ UNKNOWN/ NOT DONE	EXTRAPULMONARY
M:F ratio	2.4	2.0	1.0
Age < 15	2 693	4 945	767

Laboratories 2012	NUMBER OF MEMBER STATES[b]
Smear (per 100 000 population) ≥ 1	12 out of 17
Culture (per 5 million population) ≥ 1	11 out of 17
Drug susceptibility testing (per 5 million population) ≥ 1	4 out of 17

Treatment success rate 2011 (%)	
New smear-positive and/or culture-positive	94
New smear-negative/extrapulmonary	93
Retreatment	86
MDR-TB (2010 cohort)	46

TB/HIV 2012	NUMBER	(%)[c]
TB patients with known HIV status	451 302	(34)
HIV-positive TB patients	14 119	(3.1)
HIV-positive TB patients on co-trimoxazole preventive therapy (CPT)	5 088	(79)
HIV-positive TB patients on antiretroviral therapy (ART)	7 722	(56)
HIV-positive people screened for TB	308 193	
HIV-positive people provided with IPT	8 557	

Estimates of MDR-TB burden 2012*	NEW	RETREATMENT
% of TB cases with MDR-TB	4.7 (3.3–6.1)	22 (18–26)
MDR-TB cases among notified pulmonary TB cases	57 000 (40 000–74 000)	18 000 (14 000–21 000)

Reported cases of MDR-TB 2012	NEW	RETREATMENT	TOTAL
Cases tested for MDR-TB	16 485 (3.3%)	8 134 (10%)	33 909
Laboratory-confirmed MDR-TB cases	943	2 602	4 473
Patients started on MDR-TB treatment			5 070

Financing TB control (low- and middle-income countries)[d]	2013
National TB programme budget (US$ millions)	662
% Funded domestically	50
% Funded internationally	15
% Unfunded	36

Data are as reported to WHO. Estimates of TB and MDR-TB burden are produced by WHO in consultation with countries.
* Ranges represent uncertainty intervals.
b Data are not collected from all Member States.
c Calculations exclude countries with missing numerators or denominators.
d Financing indicators exclude funding for general healthcare services provided outside NTPs.

144 GLOBAL TUBERCULOSIS REPORT 2013 | Data for all years can be downloaded from www.who.int/tb/data

Figure 40: Copy of page 144 of the Global Tuberculosis Report 2013 concerning Tuberculosis in the Western Pacific region [56]

IX. Annex III: Tuberculosis statistics about Mongolia

The Global Tuberculosis Report 2013 includes 10 tables about statistics concerning Tuberculosis in every country of the Western Pacific Region. For each of these tables the part about Mongolia was cut to focus on the situation in Germany. The tables are shown in Figure 41 and 42.

TABLE A4.1 Estimates of the burden of disease caused by TB, 1990–2012

			MORTALITY (EXCLUDING HIV)		PREVALENCE (INCLUDING HIV)		INCIDENCE (INCLUDING HIV)	
	YEAR	POPULATION (MILLIONS)	NUMBER (THOUSANDS)	RATE[a]	NUMBER (THOUSANDS)	RATE[a]	NUMBER (THOUSANDS)	RATE[a]
Mongolia	1990	2	0.52 (0.400–0.650)	24 (18–30)	20 (9.3–36)	938 (425–1 650)	8.8 (7.5–10)	405 (345–470)
	1995	2	0.42 (0.300–0.560)	18 (13–24)	14 (7.1–24)	625 (308–1 050)	7.2 (6.3–8.2)	314 (274–356)
	2000	2	0.32 (0.190–0.470)	13 (8.1–20)	10 (5.3–17)	431 (221–710)	6.1 (5.5–6.7)	254 (228–281)
	2005	3	0.24 (0.120–0.400)	9.4 (4.6–16)	8.5 (4.1–14)	335 (162–569)	5.7 (5.2–6.1)	225 (207–243)
	2010	3	0.2 (0.079–0.390)	7.5 (2.9–14)	9.6 (4.9–16)	353 (181–580)	6.1 (5.7–6.5)	224 (209–240)
	2011	3	0.2 (0.077–0.390)	7.4 (2.8–14)	10 (5.3–16)	364 (191–591)	6.1 (5.7–6.6)	223 (208–239)
	2012	3	0.2 (0.075–0.390)	7.2 (2.7–14)	11 (5.7–17)	380 (204–608)	6.2 (5.8–6.7)	223 (208–239)

[a] Rates are per 100 000 population.

TABLE A4.2 Incidence, notification and case detection rates, all forms, 1990–2012

			INCIDENCE (INCLUDING HIV)		INCIDENCE HIV-POSITIVE		NOTIFIED NEW AND RELAPSE[b]		CASE DETECTION
	YEAR	POPULATION (MILLIONS)	NUMBER (THOUSANDS)	RATE[a]	NUMBER (THOUSANDS)	RATE[a]	NUMBER	RATE[a]	PERCENT
Mongolia	1990	2	8.8 (7.5–10)	405 (345–470)			1 659	76	19 (16–22)
	1995	2	7.2 (6.3–8.2)	314 (274–356)			2 780	121	39 (34–44)
	2000	2	6.1 (5.5–6.7)	254 (228–281)			3 109	130	51 (46–57)
	2005	3	5.7 (5.2–6.1)	225 (207–243)	<0.01 (<0.01–<0.01)	<0.1 (<0.1–<0.1)	4 601	182	81 (75–88)
	2010	3	6.1 (5.7–6.5)	224 (209–240)	<0.01 (<0.01–<0.01)	0.2 (0.21–0.24)	4 458	164	73 (68–79)
	2011	3	6.1 (5.7–6.6)	223 (208–239)	<0.01 (<0.01–<0.01)	0.3 (0.27–0.31)	4 217	153	69 (64–74)
	2012	3	6.2 (5.8–6.7)	223 (208–239)	0.011 (<0.01–0.011)	0.4 (0.38–0.41)	4 128	148	66 (62–71)

[a] Rates are per 100 000 population. [b] NOTIFIED NEW AND RELAPSE includes cases for which the treatment history is unknown.

TABLE A4.3 Case notifications, 1990–2012

				NEW CASES							
	NEW AND RELAPSE NOTIFICATION RATE[a] 1990–2012	YEAR	NEW AND RELAPSE[b]	SMEAR-POSITIVE	SMEAR-NEGATIVE/UNKNOWN	EXTRA-PULMONARY	OTHER	RELAPSE	RE-TREAT EXCL. RELAPSE	TOTAL RETREAT	HISTORY UNKNOWN	% SMEAR-POS AMONG NEW PULM
Mongolia		1990	1 659									–
		1995	2 780	455	1 330	976		82		82		26
		2000	3 109	1 399	732	862		126		126		65
		2005	4 601	1 868	897	1 620	0	216	125	341	0	68
		2010	4 458	1 837	701	1 675	0	245	343	588	0	72
		2011	4 217	1 723	684	1 578	0	232	316	548	0	72
	• 76 … 148 •	2012	4 128	1 716	617	1 611	0	184	325	509	0	74

[a] Rates are per 100 000 population. [b] NEW AND RELAPSE includes cases for which the treatment history is unknown.

TABLE A4.4 Treatment outcomes, new smear-positive cases, 1995–2011

						% OF COHORT					
	TREATMENT SUCCESS (%)[a] 1995–2011	YEAR	NUMBER NOTIFIED	SIZE OF COHORT	COHORT AS % NOTIFIED	CURED	COMPLETED	DIED	FAILED	DEFAULTED	NOT EVALUATED
Mongolia		1995	455	455	100	66	7	8	6	10	2
		2000	1 389	1 389	100	83	4	3	3	4	3
		2005	1 868	1 868	100	82	6	3	5	3	2
		2009	1 809	1 809	100	84	4	2	7	2	0
		2010	1 837	1 837	100	83	3	2	8	3	0
	• 74 … 86 •	2011	1 723	1 723	100	82	3	2	7	4	1

[a] TREATMENT SUCCESS = percent cured + percent completed then rounded to the nearest digit.

TABLE A4.5 Treatment outcomes, retreatment cases, 1995–2011

						% OF COHORT					
	TREATMENT SUCCESS (%)[a] 1995–2011	YEAR	NUMBER NOTIFIED	SIZE OF COHORT	COHORT AS % NOTIFIED	CURED	COMPLETED	DIED	FAILED	DEFAULTED	NOT EVALUATED
Mongolia		1995	82	23	28	61	0	9	13	13	4
		2000	126	126	100	57	14	8	8	7	6
		2005	341	443	130	39	34	9	11	4	3
		2009	569	380	67	60	13	4	17	4	2
		2010	588	234	40	19	61	9	6	2	4
	• 61 … 74 •	2011	548	548	100	39	35	5	15	4	2

[a] TREATMENT SUCCESS = percent cured + percent completed then rounded to the nearest digit.

Figure 41: First half of WHO statistics concerning Tuberculosis in Mongolia [56]

TABLE A4.6 HIV testing and provision of CPT, ART and IPT, 2005–2012

	% OF TB PATIENTS WITH KNOWN HIV STATUS 2005–2012	YEAR	% OF TB PATIENTS WITH KNOWN HIV STATUS	NUMBER OF TB PATIENTS WITH KNOWN HIV STATUS	PATIENTS NOTIFIED (NEW AND RETREAT)	NUMBER OF HIV-POSITIVE TB PATIENTS	% OF TESTED TB PATIENTS HIV-POSITIVE	% OF HIV-POSITIVE TB PATIENTS ON CPT	% OF HIV-POSITIVE TB PATIENTS ON ART	NUMBER OF HIV-POSITIVE PEOPLE PROVIDED IPT
Mongolia		2005	<0.1	1	4 726	1	100	100	100	
		2010	89	4 256	4 801	2	<0.1	100	100	0
		2011	80	3 612	4 533	3	<0.1	100	100	0
	• 0 … 78 •	2012	78	3 465	4 453	4	0.12	75	75	0

TABLE A4.7 Testing for MDR-TB and number of confirmed cases of MDR-TB, 2005–2012

				NEW PULMONARY CASES			PREVIOUSLY TREATED CASES		
	YEAR	TOTAL CONFIRMED CASES OF MDR-TB[a]	ESTIMATED CASES OF MDR-TB AMONG NOTIFIED	ESTIMATED CASES OF MDR-TB AMONG NOTIFIED	NUMBER OF BACT+VE[b] TESTED FOR MDR-TB	% OF BACT+VE[b] TESTED FOR MDR-TB	ESTIMATED CASES OF MDR-TB AMONG NOTIFIED	NUMBER OF NOTIFIED TESTED FOR MDR-TB	% OF NOTIFIED TESTED FOR MDR-TB
Mongolia	2005	0			0	0		16	4.7
	2010	187			40	2.2		561	95
	2011	185			157	9.1		602	110
	2012	210	170 (140–190)	33 (15–58)	196	11	130 (120–150)	681	130

[a] TOTAL CONFIRMED CASES OF MDR-TB includes cases with unknown previous treatment history (i.e. not included under NEW CASES or PREVIOUSLY TREATED CASES).
[b] BACT+VE = bacteriologically positive cases.

TABLE A4.8 New smear-positive case notification by age and sex, 1995–2012

		MALE								FEMALE								
	YEAR	0–14	15–24	25–34	35–44	45–54	55–64	65+	UNKNOWN	0–14	15–24	25–34	35–44	45–54	55–64	65+	UNKNOWN	MALE-FEMALE RATIO
Mongolia	1995	37	99	111	68	19	13	15		30	70	78	33	15	9	25		1.4
	2000	6	181	260	171	68	38	23		32	200	213	113	41	26	17		1.2
	2005	7	271	253	232	147	52	36		15	320	270	145	63	32	25		1.1
	2010	3	285	255	231	154	50	40	0	12	296	246	112	83	42	28	0	1.2
	2011	2	246	289	205	170	71	41	0	10	250	192	121	61	40	25	0	1.5
	2012	7	257	268	191	184	63	37	0	11	250	208	97	82	28	33	0	1.4

TABLE A4.9 Laboratories, NTP services, drug management and infection control, 2012

	LABORATORIES								FREE THROUGH NTP			
	SMEAR LABS PER 100K POPULATION	% OF SMEAR LABS USING LED[a]	CULTURE LABS PER 5M POPULATION	DST[b] LABS PER 5M POPULATION	LPA[c] LABS PER 5M POPULATION	NUMBER OF LABS USING XPERT MTB/RIF	SECOND-LINE DST AVAILABLE	NRL[d]	TB DIAGNOSIS	FIRST-LINE DRUGS	RIFAMPICIN USED THROUGHOUT TREATMENT	TB NOTIF. RATE PER 100 000 HEALTH CARE WORKERS
China	0.2	2	3.7	0.7	<0.1	16	In country	Yes	Yes (all suspects)	Yes	Yes	
China, Hong Kong SAR	0.4	3	9.1	1.4	1.4	9	In country	Yes	Yes (all suspects)	Yes	Yes	
China, Macao SAR	0.4	0	9.0	9	0	0	In country	No	Yes (all suspects)	Yes	Yes	
Lao People's Democratic Republic	2.4	0	2.3	0.8	0.8	0	No	Yes	Yes (all suspects)	Yes	No	
Malaysia	2.6	4	6.2	0.2	0.3	0	In country	Yes	Yes (all suspects)	Yes	Yes	106
Mongolia	1.4	8	3.6	1.8	1.8	0	In country	Yes	Yes (all suspects)	Yes	Yes	53
Philippines	2.7	0	0.7	0.2	<0.1	17	In country	Yes	Yes (all suspects)	Yes	Yes	
Republic of Korea	1.0	–	51.0	0.7	2	2		Yes	Yes (all suspects)	Yes	Yes	204
Viet Nam	0.9	0	1.4	0.1	0.1	22	In country	Yes	Yes (for smear-positive TB)	Yes	No	

[a] LED = Light emitting diode microscopes [b] DST = Drug susceptibility testing [c] LPA = Line probe assay [d] NRL = National Reference Laboratory

TABLE A4.10 Measured percentage of TB cases with MDR-TB[a], most recent year available

	New TB cases				Previously treated TB cases			
	Year	Source	Coverage	Percentage	Year	Source	Coverage	Percentage
China	2007	Survey	National	5.7 (4.5–7.0)	2007	Survey	National	26 (22–30)
China, Hong Kong SAR	2012	Surveillance	National	0.97 (0.59–1.5)	2012	Surveillance	National	2.6 (0.95–5.5)
China, Macao SAR	2012	Surveillance	National	0.77 (<0.1–2.7)	2012	Surveillance	National	21 (8.3–41)
Lao People's Democratic Republic								
Malaysia	1997	Survey	Sub-national	0.1 (0–0.56)	1997	Survey	Sub-national	0 (0–17)
Mongolia	2007	Survey	National	1.4 (0.66–2.5)	2012	Surveillance	National	26 (23–30)
Philippines	2004	Survey	National	4 (2.9–5.5)	2004	Survey	National	21 (14–29)
Republic of Korea	2004	Survey	National	2.7 (2.1–3.4)	2004	Survey	National	14 (10–19)
Viet Nam	2006	Survey	National	2.7 (2.0–3.7)	2006	Survey	National	19 (14–25)

[a] Empty rows indicate an absence of high-quality survey or surveillance data. In the absence of high-quality national data, high-quality sub-national data are used.

Figure 42: Second half of WHO statistics concerning Tuberculosis in Mongolia [56]

X. Annex IV: Grounding steps for the National Central Hospital

The National Central Hospital of Mongolia consists mainly of a building created in 1971. It is about 12.000 m² in size and has between three and six levels. Two inner courtyards are included in the construction, which are mainly used as storage for trash instead of offering a clean and healthy atmosphere for patients. The National Central Hospital faces trouble with their grounding system and asked for a usable long-term solution. As described in chapter 7.2 the solution can be a four step plan to create a ring earth electrode network around the building, with interconnections to create a mesh grid, which is most effective. As the effectiveness of the mesh grid relies on the interconnection, it makes sense to start with creating an earth electrode network in the inner courtyards, which can be connected later with the outside ring earth electrode. A scheme of this first step is shown in figure 43.

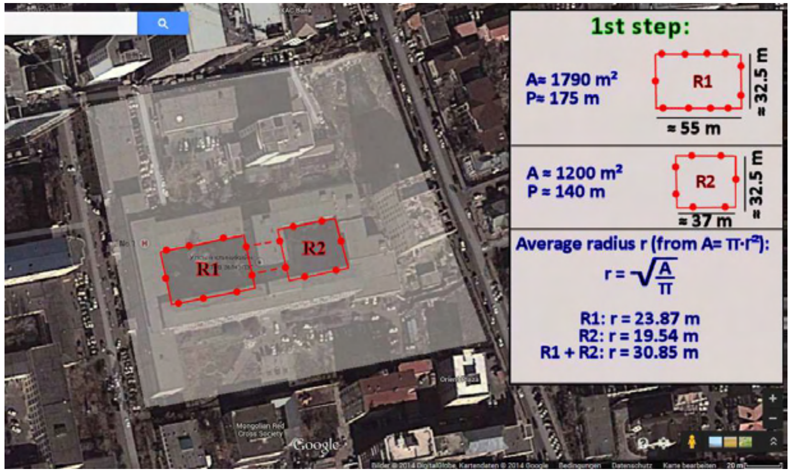


Figure 43: Image of the first step of creating a grounding system for the National Central Hospital.

The connections are made by making a hole into the building, where a steel connector can enter the building (the red dots on the lines). Every connector should be connected to an equipotential bonding rail, which is again connected to the metallic steel construction of the building. The second step should include the intensive care unit (ICU) into the network, because it contains many vulnerable technologies, which needs to be protected accurately. Figure 44 shows the addition, which should be done after the first step. Mention that a part of the first step is needed to close the second circle. Due to this connection, it can be seen as one big ring. Building F (according to the electricity plan of the hospital) is far away from the connection points of the earth electrode. When connecting them to a grounding system, long cables would be needed, to create an appropriate installation. Instead it can be more useful to extend the earth electrode system to this building, which provides nearby access to the building wide grounding and improves the grounding at the same time, by increasing the area covered by the mesh grid. Figure 45 shows the extension in addition to the other steps.

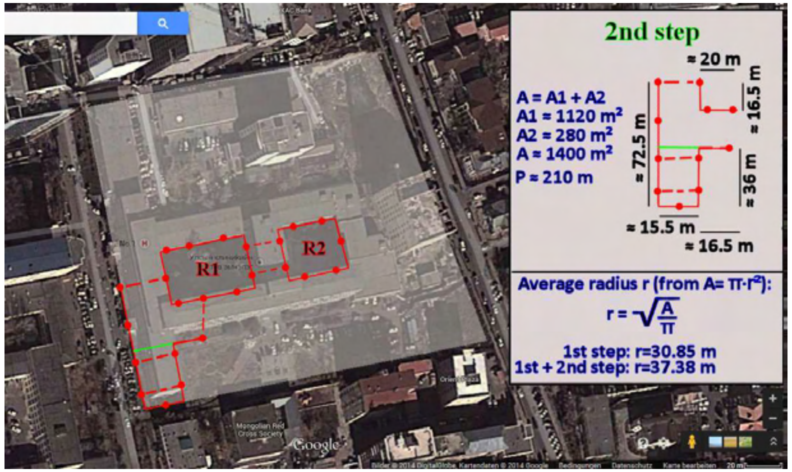


Figure 44 : Image of the second step of creating a grounding system for the National Central Hospital.

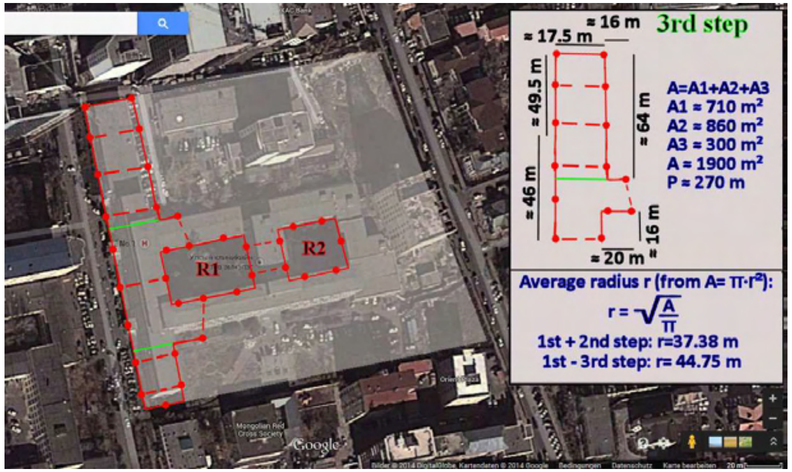


Figure 45 : Image of the third step of creating a grounding system for the National Central Hospital.

The last step is to complete the electric ring around the building and to improve the interconnections with the existing parts of the grounding system. The whole main building will be protected and connected to the earth electrode, which is large enough to face even strong voltage peaks. As shown in figure 46, a complete ring of steel as earth electrode is placed around the building. By setting the complete building at the same equipotential level, also data communication networks will work more stable.

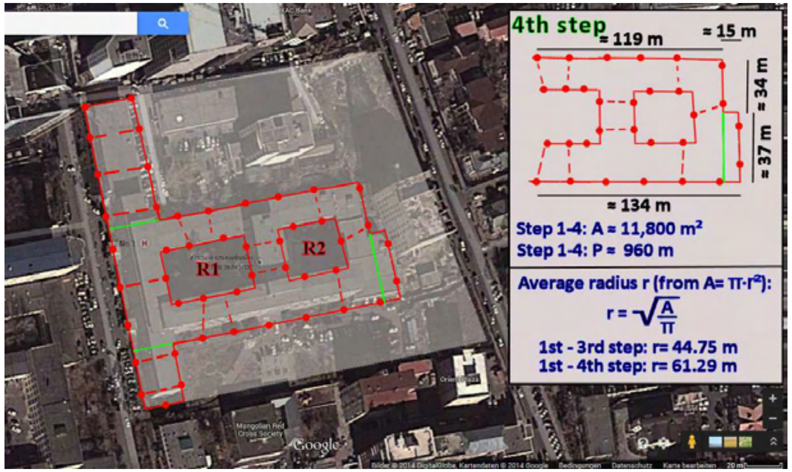


Figure 46 : Image of the fourth step of creating a grounding system for the National Central Hospital.

XI. Annex V: The traffic recognition program in detail

An automated traffic recognition system need to consist of several aspects, which need to work together. The first part is to load the images into a stack, to allow a comparing of the pictures later. The second step is to make greyscale pictures out of all RGB (Red-Green-Blue) pictures, because the following steps only work with greyscale pictures. A smoothing of the pictures is needed to remove noise from the image before it can be processed. Different smoothing procedures are available to remove noise, but the anisotropic diffusion is one of the most appropriate methods because it smoothes single pixels with high colour differences while sparing pixels, which are detected as part of an edge. Therefore a smoothing can be made without damaging the edges, which should be detect in the later steps. Edge detection is performed with a Sobel filter, which needs to be convoluted with the smoothed greyscale picture to highlight the edges. These edges need to be analyzed further by maximum-gradient processes and by weighted orientation of the edges. A fully processed image contains the main edges, which need to be separated into edges of moving objects (e.g. cars) and fixed objects (e.g. buildings, walls, trees, etc.). By image subtraction of following images of the image stack, the edges of fixed objects will be removed, while the moving objects will be visible. Using two subtracted images, a registration of the images can be performed to find the best fit. By separating the picture in two pictures for the two directions of the street, the best fit registration can be performed independently for both directions of the observed street, which also enhances the accuracy of the speed calculation. After the registration process found a movement of the edges from one picture to the next, the distance between old edge position and new edge position can be combined with the image frequency of the camera, to receive the time between the compared pictures. As speed can be described as way passed during a certain time, the combination of edge distance and time difference lead to the speed of the observed cars.

1. Reading of Stacks

Reading a stack with several pictures inside requires some special arrangements from the basic programs, which are shown separately with their single purposes. In the end the combined program is shown. The stack reading java source code is shown in table 42.

Table 42: Source code for the stack handling (stack must be opened manually).

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;
import ij.gui.*;


public class stack_ implements PlugInFilter {
  ImagePlus imp;
  public int setup(String arg, ImagePlus imp) {
    this.imp = imp;
    return DOES_ALL;
  }
public void run(ImageProcessor ip) {
  ImageStack st1 = imp.getStack();
  int rgb_in[]  = new int[3];
  int red, green, blue, gray;
int width  = st1.getWidth();
int height = st1.getHeight();
int x,y;
int stackSize = imp.getStackSize();
  ImagePlus impOut = NewImage.createByteImage("grey_stack", width, height, stackSize, NewImage.FILL_BLACK);
  ImageStack st2 = impOut.getStack();
  impOut.show();
  for(int i=1; i<(StackSize+1); i++){
    ImageProcessor ip1 = st1.getProcessor(i);
    ImageProcessor ip2 = st2.getProcessor(i);
    impOut.updateAndDraw();
  }
}
```

2. RGB to Greyscale

Changing the original picture format to 8-bit greyscale is a process, which can be performed in different way. One possibility is to take the red, green and blue values of every pixel (1 to 255 values possible each) add all of them and divide the result with 3. With this step an average of all three colour values is calculated. This average value can be placed into the new greyscale image. Another aspect prepares a weighted average by taking into account that the human eye has different sensitivity for different colours. In this case the calculations weights red with 21%, green with 72% and blue only with 7%. The calculation formulas for both calculations are described as formula A.1 (average) and A.2 (weighted average):

$$Grey = \frac{Red + Green + Blue}{3} \quad (A.1) \qquad Grey = \frac{0.21 \cdot Red + 0.72 \cdot Green + 0.07 \cdot Blue}{3} \quad (A.2)$$

A third method with the name lightness method is searching for the highest value (0 to 255) and the lowest value in the pixel. Mathematically it can be described as (MAX(Red, Green, Blue) + MIN (Red, Green, Blue))/2. Because it mainly reduces the contrast of the image, it is not an appropriate method for the automated traffic recognition, as it would reduce the delectability of the edges. Therefore only one of the two formulas shown above should be chosen. As the system is designed for an automated detection, there is no need to adjust the grey values according to the sensitivity of the human eye. Therefore the image can be averaged normally without changing the picture. The java program for this method is shown in table 43.

Table 43: Source code of the RGB to Grey java plug-in.

#	Source code	#	Source code
1	import ij.*;	11	public void run(ImageProcessor ip) {
2	import ij.plugin.filter.PlugInFilter;	12	ColorProcessor cp = (ColorProcessor) ip;
3	import ij.process.*;	13	
4	import ij.gui.*;	14	int rgb_in[] = new int[3];
5		15	int red, green, blue, gray;
6	public class rgbtogrey_ implements PlugInFilter {	16	int width = cp.getWidth();
7		17	int height = cp.getHeight();
8	public int setup(String arg, ImagePlus imp) {	18	int x,y;
9	return DOES_RGB;	19	
10	}		

#	Source code
20	ImagePlus imp2 = NewImage.createByteImage("grey", width, height, 1, NewImage.FILL_BLACK);
21	ImageProcessor ip2 = imp2.getProcessor();
22	imp2.show();
23	for(y=0; y<height; y++) {
24	for(x=0; x<width; x++) {
25	cp.getPixel(x,y, rgb_in);
26	red =rgb_in[0];
27	green=rgb_in[1];
28	blue =rgb_in[2];
29	gray = Math.abs((rgb_in[0]+rgb_in[1]+rgb_in[2]) /3);
30	ip2.putPixel(x,y, gray);
31	}
32	}
33	imp2.updateAndDraw();
34	}
35	}

3. Anisotropic Diffusion

Smoothing of pictures can be performed with a number of different smoothing algorithms to remove the noise from the image. Most of these algorithms work similar on every pixel of the picture, which can result in smoothing edges, which are planned to be discovered. Therefore it is necessary to use an algorithm, which already detects edges and avoids smoothing at the edges. This is done by the Anisotropic Diffusion algorithm presented by Perona and Malik [99]. It works by analyzing all 8 neighbouring pixels before the real pixel is changed. Therefore the smoothed image need to be saved in two different arrays, one with the original values and the second one with the changed values. In case the newly changed pixel would be used as a neighbour of the next pixel, a logical error is occurring. The resulting image in that case would not be smoothed as it should. The neighbouring condition is visualized in figure 47.

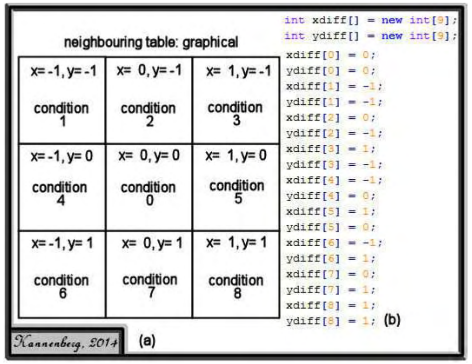


Figure 47: neighbouring in Anisotropic diffusion. a) graphical visualization, b) programming realization [99].

Using the conditions shown in figure 47, it is possible to create the anisotropic diffusion as a plug-in for ImageJ. The source code gets larger due to the detailed declaration of the conditions (row 24 to 41 of the source code shown in table 44).

Table 44: Source code of the Anisotropic Diffusion plug-in

#	Source code	#	Source code
1	import ij.*;	11	public void run(ImageProcessor ip) {
2	import ij.plugin.filter.PlugInFilter;	12	int width=ip.getWidth();
3	import ij.process.*;	13	int height=ip.getHeight();
4	import ij.gui.*;	14	int numberofiterations = 10;
5		15	int lamda = 40;
6	public class AnDiff_ implements PlugInFilter {	16	int xdiff[] = new int[9];
7		17	int ydiff[] = new int[9];
8	public int setup(String arg, ImagePlus imp) {	18	int value1[][] = new int[width][height];
9	return DOES_ALL;	18	int value2[][] = new int[width][height];
10	}	20	

#	Source code
21	ImagePlus imp2 = NewImage.createByteImage("anisotropic diffusion", width, height, 1, NewImage.FILL_BLACK);
22	ImageProcessor ip2 = imp2.getProcessor();
23	imp2.show();

#	Source code	#	Source code	#	Source code	#	Source code	#	Source code
24	xdiff[0] = 0;	28	xdiff[2] = 0;	32	xdiff[4] = -1;	36	xdiff[6] = -1;	40	xdiff[8] = 1;
25	ydiff[0] = 0;	29	ydiff[2] = -1;	33	ydiff[4] = 0;	37	ydiff[6] = 1;	41	ydiff[8] = 1;
26	xdiff[1] = -1;	30	xdiff[3] = 1;	34	xdiff[5] = 1;	38	xdiff[7] = 0;		
27	ydiff[1] = -1;	31	ydiff[3] = -1;	35	ydiff[5] = 0;	39	ydiff[7] = 1;		

```
for(int x=1; x<width-1; x++){
  for(int y=1; y<height-1; y++){
    value1[x][y] = ip.getPixel(x,y);
    value2[x][y] = ip.getPixel(x,y);
  }
}
for(int i=1; i<(numberofiterations+1); i++){
  for(int x=1; x<width-1; x++){
    for(int y=1; y<height-1; y++){
      int w = value1[x][y];
      double sum = 0.0;
      double sum_line = 0.0;
      double sum_diag = 0.0;
      for(int k=1; k<9; k++){
        int v = value1[(x+xdiff[k])][(y+ydiff[k])];
        int div = v-w;
        double g = Math.exp(-1.0*(div*div)/(lamda*lamda));
        if (k == 1 || k == 3 || k == 6 || k == 8) { sum_diag = sum_diag + (g*div); }
        else { sum_line = sum_line + (g*div); }
        sum = sum + (g*div);
      }
      int dxy=1*1;
      double dd=Math.sqrt(2)*Math.sqrt(2);
      double w2= w + (int)(((1.0/dxy)*sum_line+(1.0/dd)*sum_diag)/8.0);
      value2[x][y] = (int)w2;
    }
  }
  for(int y=1; y<height-1; y++){
    for(int x=1; x<width-1; x++){ value1[x][y]=value2[x][y]; }
  }
}
for(int y=1; y<height-1; y++){
  for(int x=1; x<width-1; x++){ ip2.putPixel(x,y, value2[x][y]); }
}
imp2.updateAndDraw();
}
}
```

4. Sobel-operator

The Sobel operator is a method to detect edges in pictures by convoluting the original image in the x-axis and the y-axis with fitting Sobel filters. Gradients will be detected and visualized, by creating the Euclidian average (square root of the sum of the squares of both convolutions). This is named gradient magnitude. The gradient direction, which is necessary for further processing of the edges, is not included in this source code, as the exact mathematical operation need high performance. A single 666 X 675 pixel image took about 2min. 15 sec. for the calculation of all gradient direction values (about 3,334 pixels per second). As a result it can be said, that this edge detection enhancement is not suitable for a real-time traffic recognition software. In comparison the combined plug-in for preparing seven RGB images of the same size in a stack to greyscale pictures, performing the anisotropic diffusion and calculating the gradient magnitude takes about 25 seconds (about 124,873 pixels per second). The source code shown in table 45 therefore focuses on the calculation of the gradient magnitude.

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Table 45: Source code for the gradient magnitude calculation by using Sobel filters in x and in y axis.

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;
import ij.gui.*;

public class Sobel_ implements PlugInFilter {

  int sobel_x[][] =  {{-1, 0, 1},
                      {-2, 0, 2},
                      {-1, 0, 1}};
  int sobel_y[][] = {{-1,-2,-1},
                     { 0, 0, 0},
                     { 1, 2, 1}};
  int pixel_x;
  int pixel_y;

  public int setup(String arg, ImagePlus imp) {
    return DOES_ALL;
  }

  public void run(ImageProcessor ip) {
    int width = ip.getWidth();
    int height = ip.getHeight();

    ImageProcessor copy = ip.duplicate();

for (int y=1; y < height-2; y++) {
  for (int x=1; x < width-2; x++) {
    pixel_x = (sobel_x[0][0] * copy.getPixel(x- 1,y-1)) + (sobel_x[0][1] * copy.getPixel(x,y-1)) +
              (sobel_x[0][2] * copy.getPixel(x+1,y-1)) + (sobel_x[1][0] * copy.getPixel(x-1,y)) +
              (sobel_x[1][1] * copy.getPixel(x   ,y   )) + (sobel_x[1][2] * copy.getPixel(x+1,y)) +
              (sobel_x[2][0] * copy.getPixel(x-1,y+1)) + (sobel_x[2][1] * copy.getPixel(x,y+1)) +
              (sobel_x[2][2] * copy.getPixel(x+1,y+1));

    pixel_y = (sobel_y[0][0] * copy.getPixel(x-1 ,y-1 )) + (sobel_y[0][1] * copy.getPixel(x,y-1)) +
              (sobel_y[0][2] * copy.getPixel(x+1,y-1 )) + (sobel_y[1][0] * copy.getPixel(x-1,y)) +
              (sobel_y[1][1] * copy.getPixel(x    ,y    )) + (sobel_y[1][2] * copy.getPixel(x+1,y)) +
              (sobel_y[2][0] * copy.getPixel(x-1,y+1)) + (sobel_y[2][1] * copy.getPixel(x,y+1)) +
              (sobel_x[2][2] * copy.getPixel(x+1,y+1));
    int val = (int)Math.sqrt((pixel_x * pixel_x) + (pixel_y * pixel_y));
    if(val < 0) { val = 0; }
    if(val > 255) { val = 255; }
    ip.putPixel(x,y,val);
      }
    }
  }
}
```

5. Subtraction method

After the edges of each picture have been detected, it is necessary to separate the edges into edges of moving objects and fixed edges. The reason is that whenever the movement of edges shall be detected, fixed edges would disturb the calculation of the average edge movement. By subtracting the second image of the first image, the fixed edges of parking cars, walls, buildings and other standing objects can be removed, while the edges of the cars, which were in a different position in the second image, will remain in the resulting image. As a result, the seven edge detection images can be calculated to six subtraction images, where the changing position of the cars is highlighted in contrast to the edges, which remain in the same position in all pictures. The source code safes the data of each slice in a separated array to be able to perform a subtraction of the slices. The filling of the different slice arrays is partly shown in the source code of table 46, leaving the gathering and calculation of the data in the value1 array away (symbolized with the "(...)" symbol). These were shown in the previous sub-programs already.

Table 46: Source code of the subtraction sub program, which subtracts two edge detection pictures to remove the fixed edges, that only the moving edges remain. Value1 is an array filled with the information for the different slices, the generation of the information is shown in the Source codes before.

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;
import ij.gui.*;

public class subtract_ implements PlugInFilter {
  public int setup(String arg, ImagePlus imp) {
  this.imp = imp;
  return DOES_ALL;
  }
  public void run(ImageProcessor ip) {
    ImageStack st1 = imp.getStack();
    int width = ip.getWidth();
    int height = ip.getHeight();
    stackSize = imp.getStackSize();
int value1[][] = new int [width][height];
int value2[][] = new int [width][height];
int slice1[][] = new int [width][height];
int slice2[][] = new int [width][height];
int slice3[][] = new int [width][height];
int slice4[][] = new int [width][height];
int slice5[][] = new int [width][height];
int slice6[][] = new int [width][height];
int slice7[][] = new int [width][height];
int subtract[][]=new int[width][height];
ImagePlus impOut = NewImage.createByteImage("subtraction", width, height, stackSize-1,
NewImage.FILL_BLACK);
ImageStack st = impOut.getStack();
impOut.show();
for (int s=1; s < stackSize+1; s++) {
 ( ... )
  for(int y=1; y<height-1; y++){
    for(int x=1; x<width-1; x++){
      if (s ==1) { slice1[x][y] = value1[x][y]; }
      if (s ==2) { slice2[x][y] = value1[x][y]; }
      if (s ==3) { slice3[x][y] = value1[x][y]; }
      if (s ==4) { slice4[x][y] = value1[x][y]; }
      if (s ==5) { slice5[x][y] = value1[x][y]; }
      if (s ==6) { slice6[x][y] = value1[x][y]; }
      if (s ==7) { slice7[x][y] = value1[x][y]; }
    }
  }
}
for (int s2 = 1; s2 < stackSize; s2++) {
  ImageProcessor ip = st.getProcessor(s2);
  for (int y=1; y < height; y++) {
    for (int x=1; x < width; x++) {
      if (s2 ==1) { subtract[x][y] = slice1[x][y] - slice2[x][y]; }
      if (s2 ==2) { subtract[x][y] = slice2[x][y] - slice3[x][y]; }
      if (s2 ==3) { subtract[x][y] = slice3[x][y] - slice4[x][y]; }
      if (s2 ==4) { subtract[x][y] = slice4[x][y] - slice5[x][y]; }
      if (s2 ==5) { subtract[x][y] = slice5[x][y] - slice6[x][y]; }
      if (s2 ==6) { subtract[x][y] = slice6[x][y] - slice7[x][y]; }
      ip.putPixel(x,y,subtract[x][y]);
    }
  }
}
impOut.updateAndDraw();
}
}
```

6. Registration

The last step of the program is to chose areas of the moving edges, which will be used as small images. These small images are moved through the complete picture of every slice, calculating the value difference between small image and complete image in every position. The minimum difference between both is likely to be the correct position, which is associated with exact x- and y- coordinates. While the minimal difference should become zero in the picture, where the small picture was taken from, the following slices will have a minimum difference bigger than zero, because the perspective of the camera will lead to a small increase in size from one picture to the next (when the car is moving away from the camera, the size will decrease slightly instead). Because there are several methods for registration, which are all time consumptive, there is no example shown for this step. The full source code of the program presented in this annex is shown in table 47.

Table 47: Full source code of the automatic traffic recognition. The registration routine is not included due to different possibilities and performance issues.

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;
import ij.gui.*;

public class subtract_ implements PlugInFilter {
  ImagePlus imp;

  public int setup(String arg, ImagePlus imp) {
    this.imp = imp;
    return DOES_ALL;
  }
  public void run(ImageProcessor ip) {
    ImageStack st1 = imp.getStack();
int rgb_in[]  = new int[3];
int red, green, blue, grey;
int width  = st1.getWidth();
int height = st1.getHeight();
int stackSize = imp.getStackSize();
int numberofiterations = 20;
int lamda = 40;
int value1[][] = new int [width][height];
int value2[][] = new int [width][height];
int slice1[][] = new int [width][height];
int slice2[][] = new int [width][height];
int slice3[][] = new int [width][height];
int slice4[][] = new int [width][height];
int slice5[][] = new int [width][height];
int slice6[][] = new int [width][height];
int slice7[][] = new int [width][height];
ImagePlus impOut = NewImage.createByteImage("grey_stack", width, height, stackSize, NewImage.FILL_BLACK);
    ImageStack st2 = impOut.getStack();
    impOut.show();
    for (int s=1; s < stackSize+1; s++) {
      ImageProcessor ip1 = st1.getProcessor(s);
      ImageProcessor ip2 = st2.getProcessor(s);
      for( y=0; y<height; y++ ) {
        for( x=0; x<width; x++ ) {
          ip1.getPixel( x,y, rgb_in );
          red  =rgb_in[0];
          green=rgb_in[1];
          blue =rgb_in[2];
          grey =
              Math.abs((rgb_in[0]+rgb_in[1]+rgb_in[2])
/3);
          value1[x][y] = grey;
          value2[x][y] = grey;
        }
      }
    int xdiff[] = new int[9];
    int ydiff[] = new int[9];
    int sobel_x[] = new int[9];
    int sobel_y[] = new int[9];
xdiff[0] =  0;
ydiff[0] =  0;
xdiff[1] = -1;
ydiff[1] = -1;
xdiff[2] =  0;
ydiff[2] = -1;
xdiff[3] =  1;
ydiff[3] = -1;
xdiff[4] = -1;
ydiff[4] =  0;
xdiff[5] =  1;
ydiff[5] =  0;
xdiff[6] = -1;
ydiff[6] =  1;
xdiff[7] =  0;
ydiff[7] =  1;
xdiff[8] = 1;
ydiff[8] = 1;
sobel_x[0] =  0;
sobel_y[0] =  0;
sobel_x[1] = -1;
sobel_y[1] = -1;
sobel_x[2] =  0;
sobel_y[2] = -2;
sobel_x[3] =  1;
sobel_y[3] = -1;
sobel_x[4] = -2;
sobel_y[4] =  0;
sobel_x[5] =  2;
sobel_y[5] =  0;
sobel_x[6] = -1;
sobel_y[6] =  1;
sobel_x[7] =  0;
sobel_y[7] =  2;
sobel_x[8] =  1;
sobel_y[8] =  1;
int pixel_x;
int pixel_y;
for(int i=1; i<(numberofiterations+1); i++){
  for(int x=1; x<width-1; x++){
    for(int y=1; y<height-1; y++){
      int w = value1[x][y];
      double sum = 0.0;
      double sum_line = 0.0;
      double sum_diag = 0.0;
      for(int k=1; k<9; k++){
        int v = value1[(x+xdiff[k])][(y+ydiff[k])];
        int div = v-w;
        double g = Math.exp
                   (-1.0*(div*div)/(lamda*lamda));
        if (k == 1 || k == 3 || k == 6 || k == 8) {
          sum_diag = sum_diag + (g*div); }
        else { sum_line = sum_line + (g*div); }
        sum = sum + (g*div);
      }
      int dxy=1*1; // Distance between straight points
      double dd=Math.sqrt(2)*Math.sqrt(2);
                 // Distance between diagonal points
      double w2= w + (int)(((1.0/dxy)*sum_line
                       +(1.0/dd)*sum_diag)/8.0);
      value2[x][y] = (int)w2;
    }
  }
}
```

```
  for(int y=1; y<height-1; y++){
    for(int x=1; x<width-1; x++){
      value1[x][y]=value2[x][y];
    }
  }
}
for (int x=1; x < width-2; x++) {
  for (int y=1; y < height-2; y++) {
    pixel_x=0;
    pixel_y=0;
    for(int k=0; k<9; k++){
      int v = value2[(x+xdiff[k])][(y+ydiff[k])];
      pixel_x= pixel_x + (sobel_x[k]*v);
      pixel_y= pixel_y + (sobel_y[k]*v);
    }
    int val = (int)Math.sqrt((pixel_x * pixel_x)
                            + (pixel_y * pixel_y));
      if(val < 0){ val = 0; }
      if(val > 255) { val = 255; }
      value1[x][y] = val;
    }
  }
  for(int y=1; y<height-1; y++){
    for(int x=1; x<width-1; x++){
      ip2.putPixel(x,y, value1[x][y]);
      if (s ==1) { slice1[x][y] = value1[x][y]; }
      if (s ==2) { slice2[x][y] = value1[x][y]; }
      if (s ==3) { slice3[x][y] = value1[x][y]; }
      if (s ==4) { slice4[x][y] = value1[x][y]; }
      if (s ==5) { slice5[x][y] = value1[x][y]; }
      if (s ==6) { slice6[x][y] = value1[x][y]; }
      if (s ==7) { slice7[x][y] = value1[x][y]; }
    }
  }
}
```

```
ImagePlus imp2Out = NewImage.createByteImage("subtract", width, height, stackSize-1, NewImage.FILL_BLACK);
ImageStack st3 = imp2Out.getStack();
imp2Out.show();
```

```
int subtract[][]=new int[width][height];
for (int s2 = 1; s2 < stackSize; s2++) {
  ImageProcessor ip3 = st3.getProcessor(s2);
   for (int y=1; y < height; y++) {
     for (int x=1; x < width; x++) {
       if (s2 ==1) { subtract[x][y] = slice1[x][y] - slice2[x][y]; }
       if (s2 ==2) { subtract[x][y] = slice2[x][y] - slice3[x][y]; }
       if (s2 ==3) { subtract[x][y] = slice3[x][y] - slice4[x][y]; }
       if (s2 ==4) { subtract[x][y] = slice4[x][y] - slice5[x][y]; }
       if (s2 ==5) { subtract[x][y] = slice5[x][y] - slice6[x][y]; }
       if (s2 ==6) { subtract[x][y] = slice6[x][y] - slice7[x][y]; }
      ip3.putPixel(x,y,subtract[x][y]);
     }
   }
  }
int piece[][] = new int [width][height];
int i=0;
int s=0;
ImageProcessor ip3 =
                        st3.getProcessor(1);
for ( int y=350; y<531; y++) {
  for ( int x=260; x<350; x++) {
    piece[x+i][y] = ip3.getPixel( x+i, y);
  }
  s=s+1;
  if (s==3) {
    i = i+1;
    s = 0;
  }
}
```

```
    ImagePlus     imp4 = NewImage.createByteImage("compare piece" , 150, 180, 1, NewImage.FILL_BLACK );
    ImageProcessor ip4  = imp4.getProcessor();
    imp4.show();
    for (int y=0; y< 180; y++) {
      for (int x=0; x<150; x++) {
        ip4.putPixel (x,y, piece[260+x][350+y]);
      }
    }
    impOut.updateAndDraw();
    imp2Out.updateAndDraw();
    imp4.updateAndDraw();
  }
}
```

The calculation speed of the program is about 26.5 seconds for the seven pictures until the complete calculation of all six subtraction images is performed. The program also creates a small picture of one side of the road, which can be used for the registration process.

XII. Annex VI: The path planning algorithm in detail

Path planning algorithms have been designed for the automated path finding of autonomous robots. Their basic idea is to have a known environment in which the robot moves into a defined direction until it detects an obstacle in the way. In this case, a new calculation from its current position is necessary to decide for the new best way, taking the obstacle into account. When a traffic recognition system is established on streets, this path planning algorithm can be changed in a way, that each waypoint contains not just information about the possible routes from the waypoint and their distance to the next waypoints, but also can calculate the estimated time for reaching the waypoints. This allows a path planning, which not only relies on the shortest paths as the fastest possibility but can directly use the estimated time from one point to the next one, to plan the best route. The logic code for the algorithm is shown in table 48.

Table 48: Logic code for the dynamic A-Star path planning algorithm (based on the Robotics lecture, Hamburg University of Applied Sciences, Prof. Tolg)

```
While (openList.isNotEmpty())
{  point = openList.getFirstElement();
    expand(point);
}   void expand(currentPoint)
{   boolean isRaise= currentPoint.isRaise();
    double cost= 0;
    foreach(neighbourInCurrentPoint.getNeighbours())
    {  If (isRaise)
       { If (neighbour.getNextPoint() == currentPoint)
          {  neighbour.setNextPointAndUpdateCost(currentPoint);
              openList.add(neighbour);
          } else
         {  cost = neighbour.computeCostOver(currentPoint);
         If (cost < neighbour.getCurrentCost())
          {  currentPoint.setCost(cost);
              openList.add(currentPoint);
          }
        }
     } else
     {  cost = neighbour.computeCostOver(currentPoint);
         If (cost < neighbour.getCurrentCost())
         { neighbour.setNextPointAndUpdateCost(currentPoint);
             openList.add(neighbour);
         }
      }
   }
 }  Bool Point::isRaise()
{  Double cost = 0;
    If (getCurrentCost() > getMinimalCost())
    {  Foreach (neighbour in getNeighbours())
       {  cost = computeCostOver(neighbour);
       If (cost < getCurrentCost())
           { setNextPointAndUpdateCost(neighbour);
         }
    }
  }  return getCurrentCost() > getMinimalCost();
}
```

In difference to the original path planning algorithm, the environment for this algorithm is known in detail, with all its possible waypoints and their distance from each other. Combining this information with the actual traffic on the streets, the algorithm can calculate the time needed to move from one waypoint to the next. In this concept, the lengths for the streets was calculated by using image processing software to measure the amounts of pixel of a line. Using the pixel length of the Google Maps lengths reference, for every street their length can be calculated. The calculated values are listed in table 49. Although the lengths seem to be very accurate because of the given values up to centimetres, but are only a representation of the exact calculation with the digital values (78 pixel were 500 metres, therefore 1 pixel ≈6.41m).

Table 49: Streets in the concept with its estimated lengths (calculated with pixel lengths from a Google Maps picture).

Street	Length (m)	Street	Length (m)	Street	Length (m)	Street	Length (m)
S00	1,446.82	S16	776.03	S31	555.73	S47	270.50
S01	774.49	S17	579.93	S32	553.06	S48	1652.11
S02	684.52	S18	841.91	S33	573.30	S49	1436.13
S03	226.62	S19	461.55	S34	539.03	S50	474.49
S04	710.76	S19a	40.54	S35	265.60	S51	1286.33
S05	816.90	S20	339.78	S36	950.91	S52	135.82
S06	634.10	S21	346.18	S37	367.37	S53	595.86
S07	542.92	S22	237.25	S38	333.86	S54	821.47
S08	668.12	S23	343.56	S39	239.32	S55	384.82
S09	316.42	S24	368.10	S40	58.04	S56	241.64
S10	323.61	S25	529.49	S41	296.93	S56a	276.29
S11	607.83	S26	530.31	S42	867.13	S57	820.67
S12	226.62	S27	640.88	S43	592.51	S58	1,103.35
S13	678.40	S28	608.25	S44	128.35	S59	2,526.53
S14	446.89	S29	602.18	S45	230.84	S60	855.38
S15	453.24	S30	581.17	S46	538.11	S61	220.07
						S62	1,498.22

A grid of waypoints at the cross-sections of the street system can be used for the algorithm to provide all necessary information for the correct calculation. Possibilities of this system range from a single calculation of the fastest route to the desired hospital up to a automatic recalculation of the best path shortly before the arrival at the next waypoint. The information stored at each waypoint is shown on some examples in figure 48.

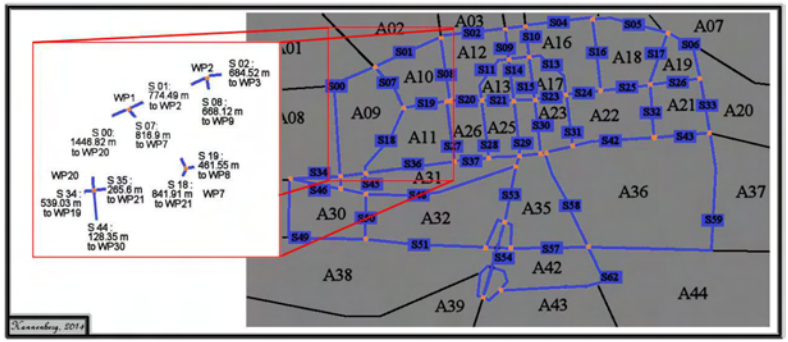

Figure 48: Example for the information stored about waypoints in a street map for the path planning algorithm.

XIII. Annex VII: Earth magnetic field calculations

For the use of the earth magnetic field for MRI technology, not only the total intensity of the field is important but also the components in different directions have influence in quality of the produced images. Therefore the complete list with all values given by the NGDC Geomagnetic calculator is shown in table 50. Four cities were chosen due to their importance. Ulaanbaatar and Darkhan are major cities in Mongolia, where the earth field MRI technology could be used in the future. Hamburg in Germany is chosen due to the works of the Hamburg University of Applied Sciences in the field of earth field MRI and Wellington in New Zealand because it is the location of the Terranova educational earth field MRI system manufacturer.

Table 50: List of values concerning the earth magnetic field at four different locations in 2010 and 2014 [110]

City	Ulaanbaatar	Ulaanbaatar	Darkhan	Darkhan
Country	Mongolia	Mongolia	Mongolia	Mongolia
Date	2014.07.09	2010.07.09	2014.07.09	2010.07.09
Latitude (°)	47.93000	47.93000	49.90000	49.90000
Longitude (°)	106.91000	106.91000	106.18000	106.18000
Elevation (m)	1,310.00	1,310.00	665.00	665.00
Declination (nT)	-4.54851	-4.28140	-4.38820	-4.11036
Declination (nT) SV	-4.03322	-3.99090	-4.19666	-4.15030
Inclination (nT)	68.02226	67.89338	69.89481	69.77435
Inclination (nT) SV	1.92842	1.93603	1.80253	1.80971
X component (nT)	22002.97402	22127.27941	20462.06432	20583.41327
X component (nT) SV	-31.07635	-31.07635	-30.33724	-30.33724
Y component (nT)	-1750.41801	-1656.53344	-1570.23031	-1479.17675
Y component (nT) SV	-23.47114	-23.47114	-22.76339	-22.76339
Z component (nT)	54692.50324	54627.30975	56063.89285	56010.94610
Z component (nT) SV	16.29837	16.29837	13.23669	13.23669
Horizontal Intensity (nT)	22072.49032	22189.20001	20522.22452	20636.49355
Horizontal Intensity (nT) SV	-29.10197	-29.22246	-28.49133	-28.61256
Total Intensity (nT)	58978.51083	58961.88233	59701.94118	59691.63215
Total Intensity (nT) SV	4.23194	4.11223	2.64455	2.53687

City	Hamburg	Hamburg	Wellington	Wellington
Country	Germany	Germany	New Zealand	New Zealand
Date	2014.07.09	2010.07.09	2014.07.09	2010.07.09
Latitude (°)	53.57000	53.57000	-41.33000	-41.33000
Longitude (°)	10.03000	10.03000	174.81000	174.81000
Elevation (m)	50.00	50.00	10.00	10.00
Declination (nT)	2.17529	1.67526	22.27710	22.17603
Declination (nT) SV	7.47890	7.47890	1.52018	1.51345
Inclination (nT)	68.46972	68.46438	-66.47474	-66.48421
Inclination (nT) SV	0.06593	0.06593	0.14316	0.14144
X component (nT)	18196.22153	18159.83092	20694.98948	20755.90510
X component (nT) SV	9.09765	9.09765	-15.22890	-15.22890
Y component (nT)	691.17079	531.12221	8477.97194	8460.20169
Y component (nT) SV	40.01214	40.01214	4.44256	4.44256
Z component (nT)	46155.56864	46037.18069	-51372.25366	-51509.60957
Z component (nT) SV	29.59699	29.59699	34.33898	34.33898
Horizontal Intensity (nT)	18209.34361	18167.59615	22364.22585	22413.89322
Horizontal Intensity (nT) SV	10.65295	10.65295	-12.40594	-12.42337
Total Intensity (nT)	49617.70562	49492.25753	56029.16244	56174.92756
Total Intensity (nT) SV	31.44139	31.44139	-36.43669	-36.44403

XIV. Annex VIII: The MRI controlling in detail

The Raspberry Pi is a single board computer system designed for the teaching of the Python programming language. This easy to learn programming language can be handled by the Raspberry Pi by using an interpreter (therefore the Pi - Python interpreter). The original programming code for the Raspberry Pi is the ARM 32bit instruction set, which is the native language of the ARM central processing unit (CPU). Converter and interpreter for different programming languages are available, whereas Python is the most important language due to its possibility to include subprograms and subroutines written in other programming languages.

With the extension boards and the ATmega based Arduino programming environment there are several possibilities for various projects. Arduino and Raspberry Pi have their own active community, which is developing hobby-projects in their free time. Most software and hardware is licence free, which makes the hardware inexpensive and the software free for downloading. All tools and boards are the result of research work to make electronics become more attractive and understandable for beginners. It is explicitly designed for educational purpose. Researchers discovered the possibilities to combine Arduino technology to develop inexpensive 3D printer, which are able to replicate their own plastic parts. The RepRap project (Replicable Rapid-prototyping) is becoming a famous possibility for creating 3D objects at home. The Michigan Technological University has proven that it is possible to use open-source 3D printer (e.g. from the RepRap project) to develop and build laboratory equipment with low costs [137]

Possibilities for medical applications are possible, as the hardware and software is open-source and well documented. Therefore everyone is free to perform changes and to develop own boards, which can be connected to Arduino and Raspberry Pi. The UCL Centre for Medical Image Computing showed that full scale medical image processing of MRI images is possible with a Raspberry Pi [138] and a e-health sensor platform was developed by Libelium [139]. This platform is shown in figure 49.

"The e-Health Sensor Platform has been designed by Cooking Hacks (the open hardware division of Libelium) in order to help researchers, developers and artists to measure biometric sensor data for experimentation, fun and test purposes. Cooking Hacks provides a cheap and open alternative compared with the proprietary and price prohibitive medical market solutions. However, as the platform does not have medical certifications it can not be used to monitor critical patients who need accurate medical monitoring or those whose conditions must be accurately measured for an ulterior professional diagnosis."

e-Health Sensor Platform V2.0 for Arduino and Raspberry Pi [Biometric / Medical Applications] [139]

The Raspberry Pi is not only usable as single system but also can be used as a cluster. The "Iridis Pi" system developed by a team of Stanford researchers with 64 Raspberry Pi boards working together remains relatively cheap in construction, while providing a maximum calculation power of 1.14 Gflops^{-1} without the need of active cooling systems and a minimum of electricity (810 mA in total during normal use, maximum need of 900 mA during high performance benchmarks) [129]. The 64 Graphics Processing Units (GPUs) were not involved in the calculations and could offer additional performance, as a single GPU is designed for up to 24 Gflops^{-1}, which means that a 64 Pi cluster could provide a theoretical calculation power of 1536 Gflops^{-1}. As the publication was submitted in 2013, new revisions of the Raspberry Pi board and its operating systems are likely to increase the performance of the cluster. Revision 1.0 of the model B of Raspberry Pi was used for the cluster, which only had 256 MB random access memory (RAM). The new revision 2.0 of model B or the model B+ introduced in July 2014 could allow better performances of the hardware, while new versions of the operating system increase the specific internal communication.

Clusters of Raspberry Pi systems show their advantages compared with single multi-core workstations in applications, where immediate repairing is not possible due to its location and current situation (e.g. for military purpose, on ships or rural areas). The "Iridis Pi" shows the possibility that damages of single nodes of the system did not mean a failure in calculation but a continuation of the calculation with a lower performance.

"Our 'Iridis-Pi' cluster includes 64 GPUs, giving rise to the possibility of a portable GPU cluster which may provide something that a single high-powered workstation cannot. Its 64 video outputs would allow it to drive video walls, and the GPUs could perform image reconstruction, perhaps in medical or similar applications."

Iridis-pi: a low-cost, compact demonstration cluster [129], page 8

The clusters functionality can be described as robust as there are no moving parts in the system, which makes it possible to run the system in moving environments e.g. cars or airplanes. Taking these properties into account the Raspberry Pi and clusters of Raspberry Pi boards are suitable alternatives to common computer systems and work stations needed for medical equipment. Their low cost, low size and low energy consumption provide possibilities of creating mobile medical devices, which are robust enough to be used by paramedics in ambulance cars or rescue helicopters. Complex medical systems can be changed into mobile systems to be transported between hospitals to allow a technology sharing and therefore a cost-effective implementation of modern medical technologies in rural areas.

Figure 49: e-Health Sensor Platform V2.0 connected with various medical equipment to visualize the possibilities (source: www.cooking-hacks.com, (the open hardware division of Libelium)

XV. Annex IX: Journal article

A paper concerning the Infrastructure of Mongolia will be published in the Mongolian Journal of Health Sciences. A possible design is prepared and shown in this thesis. The Mongolian Journal of Health Sciences is an English language journal about all topics related to health sciences.

Publisher is the Health Sciences University of Mongolia; the first volume was published in 2004.

Information about the journal can be found online at http://www.mongolmed.mn/journal/7

*"The **Mongolian Journal of Health Sciences instructions to authors***

The Mongolian Journal of Health Sciences publishes articles in basic and clinical health sciences. The Editorial Board welcomes contributions in the form of original research reports, review articles, brief communications, case reports, commentaries, clinical practice materials, and letters to the editor, medical memoranda. The Journal also publishes review of books and audiovisual materials, and other (medical) educational materials; socioeconomic, political and legal matters related to medical practice; conference and workshop reports and other categories including medical news."

Instructions to Authors, Mongolian Journal of Health Sciences

As the requirements for the Journal include that the manuscript is not published on another journal before, the design for the journal article is already fit into the shape of typical published articles of the journal (pdf versions of the older volumes are available in internet at the website mentioned above).

"Manuscripts should be prepared in accordance with the "uniform requirements for Manuscripts submitted to Biomedical Journals" issued by the International Committee of Medical Journal Editors (http://www.icmje.org). Manuscripts are considered with the understanding that they have neither been published previously nor are under consideration by another publisher. Publication of preliminary findings elsewhere (in an abstract form) does not exclude consideration by MJHS. All contributions, including those solicited, are subjected to peer review by editors of the Journal and/or invited assessors. The decision of the editors is final. Authors are responsible for all statements contained in their contributions. "

Instructions to Authors, Mongolian Journal of Health Sciences

The author plans to review the prepared text and to use his new position as a teacher at the Mongolian University of Science and Technology (MUST) to increase the impact of the journal article for Mongolian readers.

Medical health care problems and possible solutions for developing countries:
Case study Mongolia

Mongolian Journal of Health Sciences

Strengthening infrastructure for strengthening the healthcare

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ABSTRACT

Second hand and aging medical equipment are in use throughout the Mongolian country. Projects from the Mongolian Ministry of Health, the Asian Development Bank, the World Health Organization or the Mongolian Emergency Service Hospital Hygiene Project (MeshHp) try to improve the medical situation by offering education, suggestions and modern medical technology. But experiences with modern equipment e.g. computed tomography (CT) and magnetic resonance imaging (MRI) in Ulaanbaatar and Aimag areas demonstrate several problems including damages of the devices and irregularities with the functionality of the devices. While medical equipment developed 20 years ago tend to consist of robust hardware components, which are relatively unaffected by changing environmental and infrastructure conditions, modern medical technology consists of extremely sensitive and damageable components, which are likely to be seriously affected by slightly and severe changes in the infrastructure. Investments into modern medical technology can be seen as a waste of money, when requirements of that technology are not fulfilled or cannot be ensured and the technology fails or gets damaged. Protective measures for electricity and water supply can stabilize the infrastructure and improve the quality, what leads to safer and more accurate operation of modern medical devices. Repairing and Maintenance services could concentrate on safety- and functionality- related checks instead of trying to repair damages caused by voltage spikes or over-current. Quality- and risk- management could ensure the correct functionality and calibration of medical devices and therefore strengthen the healthcare. (238 words)

Key words: Medical technology; Medical infrastructure; Quality management; Risk management; Maintenance.

INTRODUCTION

Medical technology is mostly running with electrical energy coming from 110 V or 220 V electricity networks. In most of the Eurasian continent only one of these two networks is chosen; mainly the 220 V network. Medical devices are designed to use electricity with a certain voltage tolerance range effectively and without damages. However unstable and unprotected electrical infrastructure can cause overvoltage, over-current or voltage spikes outside these tolerance ranges, which are likely to damage all kinds of technical devices. Especially electrical components do not age during the time but only can get damaged by mechanical impacts or damages due to currents and voltages above or below of the tolerance ranges.

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Depending on the probability of unstable events in the electricity network and the time, where the device is connected to the network, the probability of electricity related damages rises during the time, which is often seen as aging effects. Reducing the number of unstable events and therefore the probability of these events to occur can increase the average lifetime of technical and medical devices in hospitals as well as in residences and industry. Several national and international standards in the world describe requirements on electrical installations in medical locations [1, 2] to provide an environment which is safe for medical doctors, staff, third persons and also the medical equipment.

Medical technology also needs trained and experienced personnel to be used in a safe and appropriate way and to ensure a diagnosis and treatment which prevents unnecessary harm to patients. Educational infrastructure therefore is the second cornerstone for an efficient use of medical technology. Personnel need to understand the specifications of used medical devices and that 220 V will shorten the lifetime of 110 V devices extremely. Properly used medical technology provides efficient functionality and reliable outcome which is strengthening the healthcare situation.

Also water quality and hygiene are cornerstones of an efficient healthcare system, because it can increase the lifetime of medical devices and reduce infectious diseases. Medical devices using water or reusable medical equipment which needs to get cleaned in central sterile service departments (CSSDs) benefit from high water quality and high hygiene standards.

MATERIALS AND METHODS

Materials for this publication are international- , German- and Mongolian standards to understand and compare the different situations. International publications concerning the Mongolian healthcare system or infrastructure are reviewed for a better understanding of the Mongolian situation. International reports (World Health Organization, United Nations Development Programme) as well as Mongolian reports (Mongolian Census 2010, Health Indicators 2012, National Human Development Report 2011, Fifths National Progress Report 2013 on Millennium Development Goals) give hints and suggestions about the current situation and possible improvements. German reports provide ideas and solutions on how to implement Germany's high level requirements.

The author prepared case studies at different private and public hospitals in Ulaanbaatar to observe their general healthcare situation and to detect causes of problems. Interviews with healthcare workers, public health scientists, technicians, medical doctors, hospital management professionals, students and university teachers allowed connecting the information from the literature with experiences from professionals. All information was gathered together in the authors Master-thesis [3].

RESULTS

The electrical infrastructure can be improved by using surge protective devices (SPDs), which detect overvoltage and lead the remaining voltage to an earth electrode, which needs to be regularly maintained and checked. Protection from electric shock is provided by residual current devices (RCDs), which compare the current running in one part of the circuit with the current running in the other part. Whenever current gets lost e.g. due to cable damages or electric shocks, the device shuts down the circuit to prevent damage on body and building. Over-current devices shut down circuits in case high current could damage the cables. RCDs and over-current devices are sometimes constructed together to residual current breakers with over-current protection (RCBOs).

Medical locations providing life-supporting care or surgical operations are classified as Level 2 medical locations and require medical IT-networks (IT from isolation terra). Isolation transformers separate the circuit from the hospitals electricity network and all metal parts and devices must be electrical isolated from other parts of the hospital. This allows an international standard protection for critically ill patients, where medical devices still can operate safely in case of electrical failures (where normally a RCD or RCBO would shut down the electricity).

According to the Mongolian standards catalogue 2011 there are no Mongolian standards concerning requirements on medical facilities or medical equipment [4]. For residential buildings there are standards concerning the distribution boards, which include different earthing arrangements (TN-S, TN-C, TN-C-S, TT and IT [5, 6]). But because there is no regulation about necessary upgrades of old construction, several public hospitals remain on having two phase power sockets without protection measures (figure 1a).

Figure 1: *Power sockets in old hospitals in Mongolia (a) and "Schuko" power sockets with protection measures recommended for 220 V hospital networks (b).*

"Schuko" power sockets (from the German "Schutzkontakt") have additional pins in the orifice of the socket to establish a connection with the protective earth (PE). Also the deeper orifice protects from touching the metal pins (figure 1b).

Improvement of water quality can be reached by regularly controlling and cleaning of water filters and by creating facilities to clean water in an appropriate way. Water quality in German water infrastructure is ensured by higher restrictions than mineral water, which leads to the situation that hot and cold water from the water infrastructure can be drunken without filtering or boiling. Especially for medical applications (cleaning, sterilization, laboratory diagnostics and treatment of patients) high quality water is necessary to increase the lifetime of devices and reduce risks of infections [7, 8].

DISCUSSION

Separating the technical- from the organizational-infrastructure it is possible to say that technical infrastructure can be improved within a short time period in case of financial investments and sufficient knowledge. Improved electrical infra-structure not only protects expensive medical devices from getting damaged but also protects patients, staff and medical doctors from being harmed. Water quality and hygienic infrastructure are important to protect patients, staff and medical doctors from getting infections and increases the lifetime of medical equipment. Especially outside of Ulaanbaatar these infrastructures are getting worse. Water supply in these areas cannot be ensured [9]. Organizational infrastructure concerning education, quality- and risk management requires long-time planning before adequately trained personnel can start working in positions mainly concerned with effectiveness and efficiency of healthcare. Related to this, also health technology assessment (HTA) is a possible job position for strengthening the Mongolian healthcare system by creating and observing standards for medical diagnosis and treatment of diseases.

CONCLUSION

While improving the educational infrastructure is a long term project due to the fact that its outcome can be only measured by the knowledge gain of graduated students, the basic infrastructures for electricity, water supply and hygiene can be improved easily. It can be assumed that investing money into the hospital infrastructure can be a long term cost effective method to strengthen the healthcare system of Mongolia. Quality- and risk-management, which observe the infrastructure as well as the functionality and adequate operation of medical devices, can help to improve the medical situation of the country and to solve small problems before they develop to big problems.

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