Advancement Documentation

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1. Week Two

The focus of Week 2:

- What exists already?
- What do we know of the market?
- What are promising and impactful directions?

Main Questions:

1. How (is) are the job(s) from week one currently done?
2. How have other existing products tried to solve the problem that you have identified?
3. How has the technology of these jobs evolved? (timeline for each job)
4. What are available (potential) solutions on the market?
5. What are their strengths and weaknesses?
6. How do they compare to our companies?

1.1 Jobs and the Main Questions

1.1.1 Medicine

Job: Diagnosing (chronic) diseases

Insights: Detection (invasive methods causing pain) takes place mostly when chronic diseases (e.g., cancer, Alzheimer's, diabetes) and microorganisms are already formed and already damaging a human's body.

1.1.1.1 Christensen et al. (2016) and their Jobs to be Done

❖ ***Do we see any nonconsumption?***

➢ General trend where healthcare is not accessible in countries with a bad or expensive healthcare system.

❖ ***What workarounds have people invented?***

➢ Health imaging → MRI scan & CT scan.

- ➢ Microscopes to detect and evaluate samples within medical treatment → are bulky & expensive.
- ➢ Personalized medicine → diagnosing and monitoring of imaging.
- ➢ Microscopes to detect and evaluate samples within the medical treatment.
- ➢ Personalized medicine (diagnosing and monitoring of treatment response)
- ➢ Blood Testing (glucose-CGM system)/Biopsy → invasive methods.
- ➢ Notes from: Health Imaging (2021), Britannica (2022), Genome (2022), TE (2022)

❖ ***What surprising uses have users invented for existing products?***

- ➢ Fluorescence microscopy.
- ➢ Smartwatches to detect specific issues (heart rhythm response).
- ➢ Usage of A.I. to interpret data from medical diagnoses.
- ➢ 3D health imaging.
- ➢ Notes from: Health Imaging (2021), Ford (2022), Genome (2022), TE (2022)

1.1.1.2 Main Questions

1. How (is) are the job(s) from week one currently done?

- Health imaging.
- Blood testing.
- Biological tissues sample analysis.
- Use of microscopes for sample evaluation.
- Personalized devices (smartwatches) to detect inconsistencies (e.g., Diabetes, Heart rhythm, Oxygen level).

2. How have others tried to solve the problem that you have identified?

❖ ***Health imaging***

- ➢ ***Problem:*** Inefficient and expensive health tests (blood pressure measurement, taking cells to investigate etc diseases). Detection takes place mostly when diseases are already formed (e.g., cancer) and already damaging a human's body.

- ➢ Usage of radiation in CT scan (dosage of radiation, can be damaging) & MRI/CT scan not optimal for claustrophobia.
- ➢ Need for highly skilled doctors (optical scientists to calibrate & adjust optics in CT/MRI scan), mostly only available in countries with good healthcare systems.
- ➢ Side effects include physical (ionizing radiation) and emotional stress (psychological and behavioral changes).
  (Meglinski and Da Silva, n.d.).

❖ ***Microscopes to detect and evaluate samples within medical treatment***

- ➢ ***Problem:*** The current microscopes can not identify the full light spectrum, state of art quite expensive and non-affordable Ford (2022).

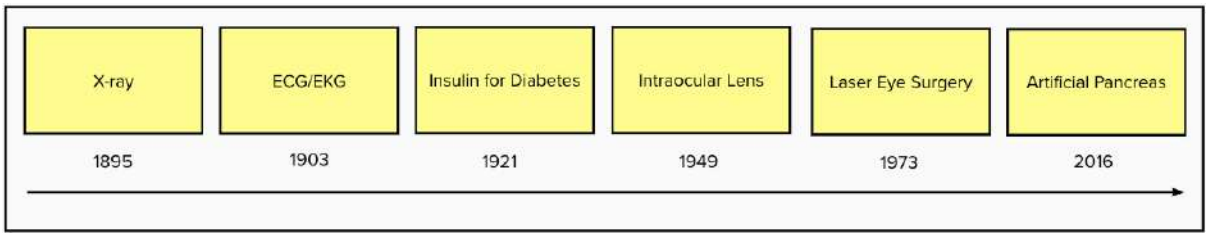
❖ ***Personalized medicine → diagnosing and monitoring of treatment response***

- ➢ ***Problem:*** Complicated and difficult to know how treatments influence patients and what the consequences of these treatments Genome (2022).

❖ ***Blood Testing (glucose-CGM system)/Biopsy***

- ➢ ***Problem:*** The process of measuring blood glucose levels/taking the tissue sample is currently done by using invasive methods.
  (Meglinski and Da Silva, n.d.).

3. How has the technology of these jobs evolved? (timeline for each job)



4. What are available solutions on the market, strengths and weaknesses?

❖ ***Health imaging***

- ➢ Artificial intelligence; 3D medical imaging.

- ➢ ***Strength:*** reduces the probability of human error, improves the accuracy of imaging description, and provides a better way to an examination of images.
- ➢ ***Weakness:*** costly, the equipment could be space consuming.

❖ ***Microscopes to detect and evaluate samples within medical treatment***

- ➢ Fluorescence microscopy, in which fluorescent molecules are used to light up target proteins, cells or cellular components, allows biologists to observe live samples in real-time. But because visible light cannot distinguish between objects closer than 200 nanometres to each other, it is not, on its own, enough to reveal the detailed structures of tiny functional components in cells called organelles. Electron microscopes can achieve much higher resolutions, but require a vacuum and so cannot be used on live samples. In modern science, cell biologists have access to an ever-growing armory of microscopy tools, which can be used either alone or in combination and offer many improvements over the older technique of crystallography (Fleming, 2019) (Nature, 2019)
- ➢ ***Strength:*** It provides a superior clear image over fluorescence microscopy and a composite 3D image of the sample.
- ➢ ***Weakness:*** Prolonged exposure to fluorescent light can result in bleaching and loss of fluorescence intensity, Unable to produce high definition images of SUVs or oligo lamellar liposomes, the addition of probes and dyes can potentially interfere with the properties of the lipid vesicles and cause experimental artifacts which may result in inaccurate data interpretation (Robson et al., 2018).

❖ ***Personalized medicine → diagnosing and monitoring of treatment response***

- ➢ Healthcare providers offer and plan specific care for their patients based on their individual genes and sometimes a device (e.g. Smartwatches) can help on specific issues (heart rhythms)
- ➢ ***Strength:*** more accurate predictor to identify the consequences of certain medications exercises, treatment plans will affect an individual patient
- ➢ ***Weakness:*** high cost, misinterpretation of genetic and health data, access and availability of genetic testing (Musa, 2019).

- ***Biopsy***
  - Liquid biopsy
  - ***Strength:*** less-invasive nature of taking a blood sample, there is significantly less risk to the patient, earlier diagnosis in comparison with the traditional one (Landsdowne, 2018)
  - ***Weakness:*** still uses invasive methods for the test, but are not commonly used.

- ***Blood Testing (glucose)***
  - The sensor directs a beam of light onto the skin, which warms the glucose molecules in your skin very slightly (only around 1/1000˚C.) After a few seconds, the sensor gives a glucose reading based on the absorption and reflection pattern of the light. (Briskin, 2021)
  - Radiofrequency waves measure blood glucose continuously (Briskin, 2021).
  - ***Strength:*** Accuracy
  - ***Weakness:*** Costly and not approved by FDA?

6. How do they compare to our companies (technology)?

- ***Health imaging***
  - ***Solution:*** A central machine (like a photo booth) that provides an accurate evaluation or diagnostic of errors in the forming of cell patterns > resulting in future failed treatment avoidance & efficient detection of early stages of cancer etc., more cost-efficient and better to detect diseases and immediately treat (leading to fewer casualties). Less need for highly skilled individuals, lenses with MEMS metasurfaces do not have a need to be calibrated. Can be used in combination with CRISPR (a way to find specific bits of DNA in a cell and edit those genes). stratification of patients, and generally reducing health care costs. A metamaterial is developing ***MammoWise***, a radio-wave imaging system for breast cancer screening. This technology is not intended to supplant mammograms or MRI imaging, but rather to expand screening procedures to a large pool of younger patients in a cost-effective and reliable manner. Enhanced early detection, without side effects, including physical and emotional stress,

could help revolutionize future breast cancer prevention, detection, and treatment.
(META Team, 2020)

- ***Microscopes to detect and evaluate samples within medical treatment***
  - ***Solution:*** Metamaterials offer super-resolution images → which makes it easier to detect these diseases → metamaterials can observe the full spectrum of light. Also offers a more "price-friendly" price tag. (Meglinski and Da Silva, n.d.).

- ***Personalized medicine → diagnosing and monitoring of treatment response***

  Solution: Relieve professional healthcare by developing better devices for individuals to track their own health status. Would solve the need for accurate and real-time evaluations of personal health (personalized health care system). Usage of smartwatches or implemented chips to detect a person's health. Usage of deep learning and artificial learning, by the usage of the new innovative disease detection or health care check with the help of thin-film MEMS for metasurfaces. Would solve the need for accurate and real-time evaluations of personal health (personalized health care system). Usage of smartwatches or implemented chips to detect a person's health (once again, cheaper to detect diseases earlier rather than actually treating them) → Real-time data from the diagnostics tools (e.g., detections of cancer cells, diabetes, interstitial cystitis = bladder pressure, Alzheimer) could be shared with healthcare providers (A.I. would facilitate this distribution process of the collection of a person's data) (Meglinski and Da Silva, n.d.). In worst-case scenarios, these innovative devices would 'call' for immediate assistance (ambulances) when people are having very critical measurements.

- ***Blood Testing***

  Solution: Taking these samples without any damage to the tissue or any kind of pain. By putting the chip, the chips then identify or measure the results Cleveland Clinic (2021)

- ***Biopsy***

  Solution: use of the technology is clinically relevant in vivo cytological diagnostic capability that could be used in real-time for the detection of cancer, with the potential to revolutionize the present need to take a cancer tissue biopsy for pathology Radiology (2021)

1.1.2 Communication

Job: Communication

Insights: Inefficient communication methods by the usage of radio frequencies. Low radio frequencies travel slowly compared to light, which is therefore inefficient to use over long distances.

1.1.2.1 Christensen et al. (2016) and their Jobs to be Done

- ***Do we see any nonconsumption?***
  - Problem: Non-accessibility to communication in rural areas or overcrowded areas (no communication infrastructure available).
  - Problem: Expensive communication systems in developing countries.
  - With both problems, there is nonconsumption since not all people (inhabitants of countries) can access communication systems in the desired way. As well as nonconsumption due to inefficient communication systems when communication can be done much more effectively (usage of light instead of radiofrequency).

- ***What workarounds have people invented?***
  - Communication over long distances (e.g., Earth to Mars) by using radiofrequency.
  - Communication across the water (e.g., SONAR, Radar).
  - Bandwidth.
  - WIFI.
  - Telecommunication.

- ***What surprising uses have users invented for existing products?***
  - Twisted light beams with OAM.

- LIFI.

1.1.2.2 Main Questions

1. How (is) are the job(s) from week one currently done?

Contemporary communication methods all use wavelengths by using radiofrequency, which can have wavelengths up to 100 km. Applications such as Telecommunication, WiFi, SONAR, and Radar are all practical applications that make use of radio frequencies (RF). An efficient way of communication since radio frequencies can penetrate obstacles (e.g., walls). For short-distance communication, a high frequency (with high bandwidth = amount of data transmitted within a certain time period) is used which requires small antennas. On the contrary, large antennas (up to 500 meters) are used for long-distance communication (low frequency = low bandwidth), which requires the usage of a high amount of resources

Notes from source: (ScienceDirect, n.d.).

2. How have other existing products tried to solve the problem that you have identified?

- ***Communication over long distances (e.g., Earth to Mars) by using radio frequency***
  - Large antenna usage for long-distance communication is efficient to use since it travels through obstacles.
  - ***Problem:*** Difficulty transporting a vast amount of data over large distances. (Mann, 2018) (Willner et al., 2012) → explaining how data can be packed into OAM in twisted light
    (Wogan, 2020) (Buddies and Finio, 2020)→ explanation how data can be packed into OAM in twisted light.

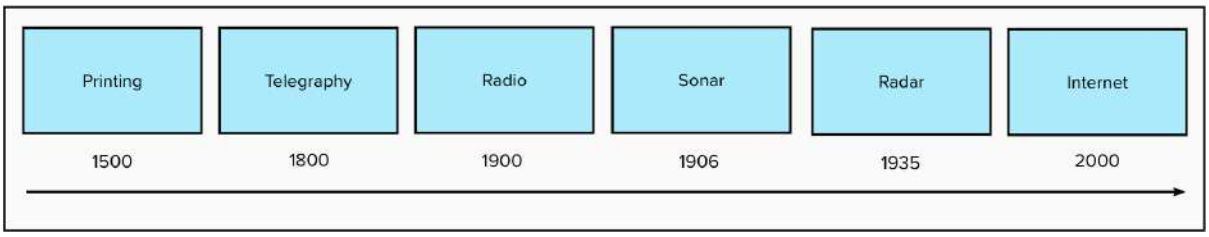
- ***Communication across the water (e.g., SONAR, Radar)***
  - ***Problem:*** not detailed pictures, since today the state of art offers only detection of objects → not actually the figure and shape of the object → (Britannica, n.d.) → information about the characteristics of RADAR.
  - Using the large antenna that demands the physical location for installation, the optical transmission is 90%, expensive and has a low-frequency range.

- ***WIFI***

➢ ***Problem:*** weak security (Xiong and Jamieson, 2013).

- Network latency.

3. How has the technology of these jobs evolved? (timeline for each job)



4. What are available (potential) solutions on the market, strengths and weaknesses?

❖ ***Twisted light beams with OAM***

➢ By controlling, steering and expanding twisted light beams with OAM (a way to pack data into twisted light and also encrypt the packed data). Better to use twisted light beams since radio frequencies are often ineffective (cannot go through obstacles, but light can). In general, the twisted light beams can be used to accurately transmit data (by the usage of light) from A to B. Can be used to effectively transmit data e.g., to rovers on planetary missions (Mann, 2018, Willner et al., 2012) → explaining how data can be packed into OAM in twisted light (Wogan, 2020) → explanation how data can be packed into OAM in twisted light (Buddies and Finio, 2020).

➢ ***Strength:*** boost data transmission, power-efficient connection and sensing, memory enhancement and human-machine interaction, faster, energy-efficient and cheaper

Notes from source: (Ahmed and Sohal, 2017)

➢ ***Weakness:*** *not easy to adjust for reduced roll stiffness, fatigue*

❖ ***LIFI***

➢ A wireless communication network that uses light to transmit data between devices.

➢ ***Strength:*** security, energy and cost efficiency, availability of high-speed data transmission.

- ***Weakness:*** internet cannot be used without a light source; the signal's range is limited by physical barriers; sunlight will interfere with the signals, resulting in interrupted Internet; new infrastructure is needed.
  Notes from source: (Staff, 2020).

6. How do they compare to our companies (technology)?

- ***WIFI (LIFI)***
  - ***Solution:*** The metamaterial provides the solution to reduce the network latency (the time it takes for data to pass from one point on a network to another). Without reincreases or a network connection, offering a more sustainable and cost-efficient alternative, increasing the quality of life.
    Notes from source: (Halper, 2019).

- ***Communication over long distances (e.g., Earth to Mars)/Communication across the water:***
  - ***Solution:*** Transparent antennas as a substitute for the currently large antennas. The transparent antennas are high conductivity, very transparent to the human eye (windshields & windows), higher optical transmission like up to 98%, excellent radiation performance and better frequency ranges (480MHZ-92GHZ).
  - ***Solution:*** Manipulating light through metamaterials (metalenses) helps in creating more extensive quality pictures/imaging when using SONAR and Radar technology. Because the state of art does not offer this solution, there is a demand for this development of technology.
    (Mann, 2018) (Willner et al., 2012) → explaining how data can be packed into OAM in twisted light
    (Wogan, 2020) (Buddies and Finio, 2020)→ explanation how data can be packed into OAM in twisted light.

1.1.4 Controlling and Analyzing Nature

Job: Controlling and analyzing nature.

Insights: The technology that is used within systems that control and analyze nature is somewhat outdated (e.g., Expensive & bulky systems in satellites and drones).

1.1.4.1 Christensen et al. (2016) and their Jobs to be Done

- ***Do we see any nonconsumption?***
  - Inability to map landscapes (both on earth as well on other planets etc.) correctly → nonconsumption due to inaccurate.
  - Inability to measure the development of landscapes & nature correctly.

- ***What workarounds have people invented?***
  - Satellites to analyze developments of landscapes.
  - Satellites for mapping landscapes in space and earth.
  - Satellites for mapping landscapes during space missions (e.g., vehicles on Mars or the Moon).
  - Telescopes.

- ***What surprising uses have users invented for existing products?***
  - Satellites do detect natural disasters (E.g., wood fires in rural areas such as Siberia, and hurricanes in the US).

- ➢ Satellites for detecting changes in water temperature.
- ➢ Drones (Crop monitoring).

1.1.4.2 Main Questions

1. How (is) are the job(s) from week one currently done?

- ❖ Controlling and analyzing nature with the help of Satellites and telescopes.
- ❖ Controlling and analyzing nature with the help of drones.

2. How have other existing products tried to solve the problem that you have identified?

- ❖ ***Satellites to analyze developments of landscapes***

  Satellites made a huge development throughout the years, from large & expensive applications from the size of a truck to smaller-scale satellites (the size of a shoebox) which can be mass-produced. Still, satellites nowadays cost approximately 1.000.0000 $, which can be seen as rather expensive. Still the size of a shoebox.

  Notes from source: (Davenport, 2021; Harebottle, 2021).

- ❖ ***Satellites for mapping landscapes in space and earth***
  - ➢ Contemporary, LIDAR techniques with lenses in satellites are used to map landscapes, with the usage of three colors of the colour spectrum. These applications can map extraordinarily large landscapes which can provide visibility of remote areas and can increase that e.g., areas with biodiversity are not neglected. Moreover, they help with more accurate detection of wood fires, seeing rural areas which are impacted by drought, rural areas where there are heavy floods, development & movements of ice fields on Greenland, Antarctica etc. (seeing how global warming is impacting the melting of ice). However, LIDAR systems in these satellites are still expensive and heavy.

    Notes from source: (Dwyer, 2021).

- ❖ ***Satellites for mapping landscapes during space missions (e.g., vehicles on Mars or the Moon)***

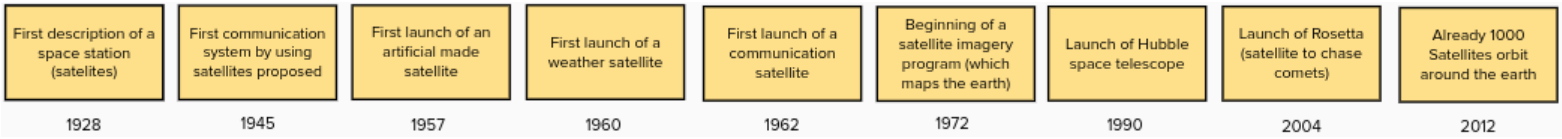
- ➢ LIDAR Lenses in telescopes or satellites for mapping landscapes, the same technology as with the previous topic. Still, these lenses in LIDAR systems are expensive and bulky.

❖ ***Telescopes***

- ➢ Usage of telescopes which can reveal changes in temperature on planets or map landscapes of other planets or asteroids

  Notes from source: (Open Access Government, 2022).

3. How has the technology of these jobs evolved? (timeline for each job)



4. What are available (potential) solutions on the market?

❖ ***Satellites do detect natural disasters (E.g., wood fires in rural areas such as Siberia, and hurricanes in the US).***

- ➢ ***Solution:*** Provides operational capability for disaster warnings and search-and-rescue efforts.
- ➢ ***Strengths:***
  - Data combined with AI and properly quantifies physical geographic phenomena associated with the movements of the earth's surface (e.g. earthquakes, mass movements), water (e.g. floods, tsunamis, storms), and fire (wildfires), produce up-to-date macro information on vast geographical locations.
  - An efficient way to detect on a large scale (mapping large water areas) as well as a small scale (individual coral reefs in the waters of Australia) natural disasters.
  - Improving weather forecasting abilities, which improves the protection of life and property.
  - Higher-resolution imaging and more accurate measurements of potential natural disasters.

- Ability to use nighttime images, essential for areas with a low amount of sunlight during winter months (e.g., Alaska, Siberia, Scandinavia etc.) **Notes from source:** (Morgan, 2020) (ICEYE, n.d.) → Satellite project for flood warning

➢ ***Weaknesses:***

- Expensive, somewhat unreliable signal, propagation delay
- Cannot measure the whole light spectrum.
- For wood fires, there is a weakness in using satellites since there are the following issues: determination of a fixed threshold for potential fire pixels, ignoring the sensitivity difference of test conditions, and spectral difference of small fire.

  Notes from source: (Zang et al., 2021)

❖ ***Satellites for detecting changes in water temperature***

➢ The contemporary increase in water temperature (due to global warming) leads to a decrease in Koral formation (decrease of O2) needed for oxygen (through photosynthesis). The VIIRS (Visible Infrared Imaging Radiometer Suite) on a NASA satellite is currently mapping these changes.

➢ ***Strength:***

- An efficient way to detect the change in water temperature, both on a large scale (mapping large water areas) as well as a small scale (individual coral reefs in the waters of Australia).
- Improving weather forecasting abilities, which improves the protection of life.
- Higher-resolution imaging and more accurate measurements of sea surface temperature. As well as the increase of the capability to observe (change in) ocean colors, which is an indicator of the quality of the sea life.
- Ability to use nighttime images, essential for areas with a low amount of sunlight during winter months (e.g., Alaska, Siberia, Scandinavia etc.).

➢ ***Weakness:***

- Cannot measure the whole light spectrum. E.g., the VIIRS satellite is missing some channels in the red [wavelength of light] and without them, it can't measure the phytoplankton chlorophyll fluorescence signal, which is a valuable indicator of phytoplankton health and nutrient stress.

Notes from source: (Bashkatov and Genina, 2003) (Maconochie, 2017) (National Ocean Service, n.d.)

6. How do they compare to our companies (technology)?

- ***Satellites do detect natural disasters (E.g., seeing wood fires in rural areas such as Siberia)***
  - ***Solution:*** Cheap to use and very light & flat because you don't need several lenses in satellites. Leads to smaller satellites and to cheaper production of satellites (economy of scale). Furthermore, it would enhance competition on the production of satellites market since more companies could make use of this technique. Furthermore, an increase in usage of colors in MEMS for metasurfaces can lead to better and more accurate detection of wood fires, seeing rural areas which are impacted by drought, rural areas where there are heavy floods, development & movements of ice fields on Greenland, Antarctica etc. (seeing how global warming is impacting the melting of ice).
    Notes from source: (SLU, 2021) (University of Cambridge, 2021)

- ***Satellites for mapping landscapes in space and earth***
  - ***Solution:*** Adding the combination of MEMS for metasurfaces to LIDAR would lead to smaller lenses and increase usage of color spectrum > leading to more efficient usage of satellites to map other planets and asteroids. Same usages can be used to map effectively landscapes on earth.
    Notes from source: (Mlekuž, 2013)

- ***Satellites for mapping landscapes during space missions (e.g., vehicles on Mars or the Moon)***
  - ***Solution:*** Usage of metalenses in LIDAR systems would reduce bulky systems and would lead to cheaper satellites systems.
    Notes from source: (Szotak et al., 2021)

- ***Satellites for detecting changes in water temperature***
  - ***Solution:*** Cheaper usage of lenses (MEMS for metasurfaces) leads to an increase in usage to detect the increase of water temperature and better ability of widely distributed devices to detect so.

Notes from source: (Bashkatov and Genina, 2003) (Maconochie, 2017) (National Ocean Service, n.d.)

- Drones (Crop monitoring)
  - *Solution*: Better to use a fleet of A.I. powered drones to automatically send data to a crop management system which responds to the sent data and sprays pesticides on damaged crops or irrigates water in dry areas > actual real-time monitoring system. Efficient to use with metalenses since they can 'see' more colors rather than the standard 3 colors in normal lenses. > Also smaller & less heavy lenses, so better usage in drones.
    (Fly Guys, n.d.)

1.1.5 Transportation

Job: Transportation
Insights: The main issue with transportation is that it is quite analogue and outdated, and the demand to find a more simple way of transportation is arising. As well as a more efficient transportation network and usage of surface areas for roads etc.

1.1.5.1 Christensen et al. and their Jobs to be Done

- ***Do we see any nonconsumption?***

- Nonconsumption due to transportation over the land surface
- Nonconsumption due to inefficient transportation methods (traffic in densely populated areas, usage of fossil fuels in transportation vehicles etc.)

❖ ***What workarounds have people invented?***

- Tunnels (due to Inefficient transportation systems in crowded areas) → Roads must go 3D (tunneling networks)
- Application in cars which measures distances to other cars

❖ ***What surprising uses have users invented for existing products?***

- Self-driving cars & trucks
- People with a handicap (blind or deaf) → system which measures the distance
- Drones → use of alternative ways of product delivery

1.1.5.2 Main questions

1. How (is) are the job(s) from week one being currently done?

➢ Cars

➢ Bicycles

➢ Trucks

2. How have other existing products tried to solve the problem that you have identified?, 4. What are available (potential) solutions on the market? & 5. Strengths and Weaknesses?

✣ ***Tunnels (due to Inefficient transportation systems in crowded areas)***

➢ ***Problems:*** Contemporary big cities e.g Sao Paulo & Los Angeles face major traffic issues due to densely populated cities. City density will highly increase in these cities since people tend to move in the past decades to the city (especially with the Hispanic population moving to Los Angeles).

➢ ***Solution:*** Therefore, need for alternative transportation methods. Therefore, roads must go 3D. Surface roads today incorporate 3D model-like elevated highways and cloverleaf interchanges that are expensive and disruptive to build.

Notes from source: (Boring company, n.d.)

➢ ***Strengths:***

- Tunneling networks are 3D and provide high-throughput transportation in an economically viable way.

- Traffic and congestion will be a thing of the past. There is an unlimited capacity (unlimited layers of tunnels) to build it.
- Weatherproof operation (no effect of snow, rain and wind) on transportation systems.
- Future expectations are easier done than extending roads (which are limited in crowded areas due to houses etc.).

➢ ***Weakness:***

- Expensive and time-consuming to dig tunnels (more expensive & time-consuming than making roads on the surface).
- Excavated dirt from this process is time-consuming, noisy and expensive.

Notes from source: (Boring company, n.d.)

✣ ***Application in cars which measures distances to other cars***

➢ ***Problem:*** Contemporary, human errors are leading to traffic accidents and people falling asleep while driving.

➢ ***Solution:*** Lenses to detect obstacles around the car in cars to help people navigate more safely and detection when cars come too close to the side of the roads.

➢ ***Strengths:*** Currently the state art offers a functioning solution to how the distance is measured to the vehicle "ahead"

➢ ***Weaknesses:*** It still lacks in the way the technology perceives the information → lenses and substituting with metamaterial might contribute to the new solution which may derive better tracking of distance measurements.

(Universe optics, n.d)

✣ ***Self Driving cars***

➢ ***Problem:*** Contemporary, human errors are leading to traffic accidents and people falling asleep while driving.

➢ ***Solution:*** Self-driving cars where A.I. makes better decisions than humans, leading to fewer accidents. However, contemporary lidar systems are currently big & expensive, metalenses can make them smaller & more compact.

- ***Strengths:*** Offers a new way of transportation without the need for a human driver.
- ***Weaknesses:*** Since there is no driver present, there might be a risk of technical failure deriving unwanted incidents.

  Notes from source: (Universe optics, n.d.)

✣ ***Self-driving trucks***

- ***Problem:*** Human error during long-distance truck drives (e.g., chauffeurs falling asleep). In the future, this would lead to an increase in human casualties with human-driven trucks. Truck drivers also need to rest (sleep) after a period of driving.
- ***Solution:*** Self-driving trucks for long distances (e.g., long straight roads in Arizona, Australia etc.), which will increase the efficiency of usage of trucks (no need for rest). Fleet managers can manage a bunch of trucks and might interfere when there is a need to.
- ***Strengths:*** Just as self-driving cars, self-driving trucks offer the transportation industry a new way of delivering goods etc. and assists the drivers when driving for long hours.
- ***Weaknesses:*** Complexity in designing the technology to function flawlessly, without any incidents and-/or accidents.

  Notes from source: (Brove, 2022)

✣ ***Rovers (Mars rovers)***

- ***Problem:*** Contemporary such rovers on planetary expeditions of NASA etc. are using CCD (charge-coupled device) sensors to map landscapes in order to drive around obstacles. However, this usage is expensive (due to many lenses in the sensors and the need to have multiple lenses in sensors).
- ***Solution:*** Decrease usage of sensor systems (smaller lenses), which decreases costs and bulkiness of rovers.
- ***Strengths:*** The rovers offer a solution to transportation when the terrain is not always beneficial for other means of transportation.

- ***Weaknesses:*** The rovers are still dependent on receiving commands since they do not possess artificial intelligence, which makes the controlling of the rovers insufficient.

  Notes from source: (NASA, n.d.) (Tech Brief, n.d.)

- ***People with a handicap (blind or deaf)***
  - ***Problem:*** Contemporary, blind people are rather not taking part in public life due to uncertainty about their handicap.
  - ***Solution:*** Usage of a combination of walking sticks and sensors (same type of application as with sensors which measure the distance to other cars). However, walking sticks are not an inefficient way since it doesn't detect all obstacles (do not warn of incoming cars, obstacles etc.).
  - ***Strength*:** for now one of the most effective ways to move around for blind or deaf people.
  - ***Weakness*:** Sticks cant detect the obstacles by which the handicapped one may encounter danger and it is outdated compared with their importance of use.

    (Medline Plus, n.d.) (Super Lidar, n.d.)

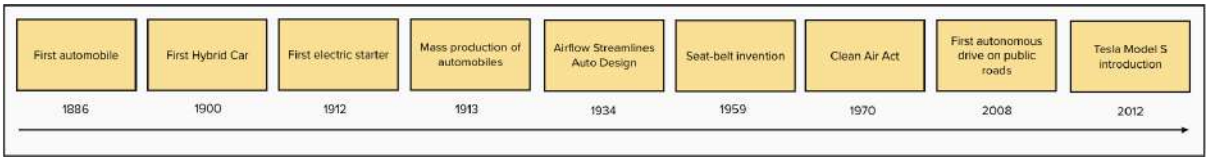
- ***Robots:***
  - ***Problem:*** Contemporary expensive to produce robots (mass production is not possible) since lenses are expensive, big and have no ability to be mass-produced.
  - ***Solution*:** Usage of alternative lenses and scale-down technologies
  - ***Strength*:** More efficient management of traffic, provides more accurate results than humans and can work 24/7. Also more reliable as it provides few mistakes and can save time.
  - ***Weakness*:** More expensive, some operational downtime as the staff is trained and robots are implemented as per the programmed to do, inflexibility in operations as it works according to preset systems and processes, which can make rapid change difficult.

    Notes from source: (Benevides, 2020)

- ***Drones:***
  - ***Problem*:** major traffic issues due to densely populated cities which slows down the time of delivery services
  - ***Solution*:** use of alternative ways of product delivery
  - ***Strength*:** speedy movement of goods, can reach inaccessible areas.
  - ***Weakness*:** Risk for the general public, not being allowed in certain areas, pose a danger to aircraft.

    (Fly Guys, n.d.)

3. How has the technology of these jobs evolved? (timeline for each job)



6. How do they compare to our companies (technology)?

- ***Self-Driving cars***
  - ***Solution:*** Lidar system in self-driving cars (based on A.I.) which accurately measures the distance (e.g., usage in self-driving cars and drones = so they don't crash).

    Notes from source: (Universe optics, n.d*)*

- ***Flying cars (hop on-hop off the system)***
  - ***Solution:*** Same technique as self-driving cars (cheaper way of production → cheaper lenses). Based on Uber elevate. To solve traffic problems in big cities like Los Angeles → Future of Urban mobility

    Notes from source: (Inverse, 2017) (Uber, n.d.)

- ***Self-driving trucks***
  - ***Solution*:** Same technique as self-driving cars: Based on assisted autonomous self-driving system → fleet manager system who can step in (fleet managers sitting in a room and managing several trucks).

    Notes from source: (Crosbie, 2016) (Toobin, 2016)

- ***Application in cars which measures distances to other cars***
  - ***Solution:*** MEMS for metasurfaces could reduce the size of LIDAR lenses since they are more compact and cheaper in production.

- ***People with a handicap (blind or deaf)***
  - ***Solution*:** Device in their skin that measures the distance to walls, objects or obstacles → no need for walking sticks. For blind people, the device would produce high or low voice frequencies to measure distances to obstacles. For deaf people, the same can be done with vibrations on watches or chips attached to the skin or clothes. Through this, a safer environment can be ensured, since both groups of people with a handicap are often still highly unsecured to take part in public life (e.g., walking on crowded streets, crossing streets etc.)
    Notes from source: (Medline Plus, n.d.) (Super Lidar, n.d.)

- ***Robots***
  - ***Solution:*** Same technique as in self-driving cars. MEMS for metasurfaces can reduce lens sizes
- ***Rovers (Mars rovers)***
  - ***Solution:*** Usage of LIDAR lenses with twisted light and MEMS for metasurfaces will make the lenses less compact & less expensive.
    Notes from source: (NASA, n.d.) (Tech Brief, n.d.)
- ***Environment***
  - ***Solution:*** Smoother and more predictable brakes, will help in producing the lower emissions, so it is more toward the environment setting or environmental sustainability.
- ***Tunnels***
  - ***Solution:*** Subway system instead of roads

1.6.1 Energy

Job: Produce energy / Consume energy

Job: Store Energy

Insights: Lack of safe, low-carbon, and cheap large-scale energy alternatives to fossil fuels. Energy production and consumption imply issues regarding air pollution, climate change, water pollution, thermal pollution and solid waste disposal. Low efficiency. The motion that can be harvested is narrow and drops fast.

1.6.1.1 Christensen et al. and their Jobs to be Done

- ❖ ***Do we see any nonconsumption?***
- ➢ Inability to store energy
- ➢ Still usage of fossil fuels > unsustainable > need for alternatives
- ❖ ***What workarounds have people invented?***
- ➢ Lithium batteries: Batteries designed with kinetic electromagnetic or thermal energy.
- ➢ Solar panels: Renewable energy using the sun as a power source.
- ➢ Hydropower: Turbines, dams or other water infused sources.
- ➢ Windcraft: Mechanical energy generated from wind
- ❖ ***What surprising uses have users invented for existing products?***
- ➢ Creation of energy through gravity
- ➢ Floating wind turbines
- ➢ Geothermal energy production
- ➢ **Notes from:** (Murray, 2019) (Nature, 2021) (Lane, 2021) (Solarreviews, 2021)(Lane, 2021) (Solarreviews, 2021)

1.6.1.2 Main questions

1. How (is) are the job(s) from week one being currently done?

- ➢ Batteries
- ➢ Fossil fuels
- ➢ Nuclear
- ➢ Solar panels
- ➢ Hydropower
- ➢ Windcraft

2. How have other existing products tried to solve the problem that you have identified? & 5. Strengths and Weaknesses

- ***Lithium batteries:*** Batteries designed with kinetic electromagnetic or thermal energy. Lithium batteries have a higher overall charge per unit mass and unit volume than peers. They are rechargeable and do not need frequent maintenance in the form of battery watering, equalization, cool-down time, or acid adjustments.
  - ***Problem:*** Extracting the raw materials, mainly lithium and cobalt, requires large quantities of energy and water. Moreover, the work takes place in mines where workers often face unsafe conditions. Batteries do eventually run out of power.
  - ***Strength:*** Needed to help power the world's electric grids, because renewable sources, such as solar and wind energy, still cannot provide energy 24 hours a day. The aforementioned high energy density, relative light-weight, and compactness make them perfect for these uses
  - ***Weaknesses*****:** toxic chemicals are needed to process lithium. The release of such chemicals through leaching, spills or air emissions can harm communities, ecosystems and food production. Moreover, lithium extraction inevitably harms the soil and also causes air contamination.

    Notes from source: (Murray, 2019) (Nature, 2021)

- ***Fossil fuels:*** Cheap and reliable energy source. Can be stored and transported easily and for an indefinite period of time.
  - ***Problem:*** Irresponsible use can be dangerous (for humans and nature). Contributors to global warming → biggest threats to humanity. We will run out of oil eventually = we need another energy source. Fossils fuels like coal and oil must be burned to generate power and replenish very slowly = they are not a long term energy solution.
  - ***Strengths:*** Can provide energy to the masses since it is relatively cheap in comparison to other energy sources (National Geographic 2021)

- ***Nuclear:*** When uranium or plutonium atoms are split through nuclear fission, the energy released during the reaction is used to heat water into steam. The steam turns a turbine and creates usable nuclear electricity. Controversial energy source. Some argue

the potential risk associated with the power source is too great, others mean it is the answer to a zero-carbon future. the "holy grail of harnessing the energy". If we learn to control atomic fusion → unlimited energy.

- ➢ ***Problem:*** Non-renewable. Safety risk (nuclear plants), water-intensive, environmental impact. Radioactive waste → The waste created by nuclear power plants remains dangerously radioactive for thousands of years after it is created. Many issues arise when trying to figure out how to store this radioactive waste.
- ➢ ***Strengths*:** Low-cost, zero carbon emissions, Promising energy future, high energy density.
- ➢ ***Weakness:*** Environmental impact, water-intensive, the risk for accidents, radioactive waste, non-renewable energy source.
  Notes from sources: (Lane, 2021) (Solarreviews, 2021)

❖ ***Solar panels:*** Renewable energy using the sun as a power source.

- ➢ ***Problem:*** Hard to collect more than a fraction of this energy. Not a reliable energy source since it is hard to predict whether precisely.
- ➢ ***Strengths:*** Harnessing power by installing solar panels. Expensive in the short run, but beneficial in the long run for both the environment and private economy. Low maintenance costs.
- ➢ ***Weakness:*** Takes up a lot of space, weather dependent (Energypedia, 2021)

❖ ***Hydropower:*** Turbines, dams or other water infused sources. It is a clean and renewable energy source that pairs well with other renewable energy technologies.

- ➢ ***Problem:*** Hydropower installations adversely impact the physical environment around them and are expensive to build. Limited places remain that are suitable for reservoirs and hydroelectric plants.
- ➢ ***Strength hydropower:*** Storage hydropower and pumped storage hydropower facilities have the ability to generate electricity on-demand, making hydroelectric plants dispatchable resources. Allows hydroelectricity plants to replace traditional dispatchable generation

methods like coal and gas peaker plants. It is clean and renewable. Hydropower will always be a viable way to generate electricity.

- ➢ ***Weakness:*** Aside from being affected by drought, hydro energy production can cause drought conditions downstream if they don't allow sufficient water to pass through

  Notes from source: (Energysage, 2022)

- ❖ ***Windcraft:*** Mechanical energy generated from wind or some other naturally occurring airflow.
  - ➢ ***Problem:*** Noisy and unappealing aesthetically. Impact the physical environment around them. Turbines and generation sites may be located quite far from the population centers where electricity is needed. Therefore, transmission lines are an additional piece of infrastructure that must be built for this form of energy generation to be successful.
  - ➢ ***Weakness:*** Reliant on weather and not capable of generating electricity 24/7. Difficult to predict how much electricity a wind turbine will generate over time. A wind turbine's blades are very large and rotate at very high speeds. Unfortunately, their blades can harm and kill species that fly into them, like birds and bats. The construction of wind farms can also disrupt the natural habitats of local species if not conducted in a sustainable manner. However, these problems can be solved to some extent with technological advancements and properly-siting wind farms
  - ➢ ***Strengths:*** Operating costs are relatively low, and the turbines don't require too much maintenance over the course of their lifetime.

    Notes from source: (Energysage, 2022) (Bambhaniya, n.d.)

3. How has the technology of these jobs evolved? (timeline for each job)

4. What are available (potential) solutions on the market?

- Renewable energy still remains unused in most countries = Enhance the technology behind renewable energy to make it cheaper, more reliant and accessible.

- Reduce wastage of energy → Improve batteries vs reduce energy consumption on devices.
- Nuclear → Critical in reducing our greenhouse gas emissions, but it has a significant environmental impact since it is water-intensive, risk of nuclear accidents, management of radioactive waste is problematic and it is non-renewable.
- Notes from: (Nature, 2021) (Lane, 2021) (Solarreviews, 2021)(Lane, 2021) (Solarreviews, 2021)

6. How do they compare to our companies?

- Magnetic fields can be manipulated with metamaterials. One magnet connects to another without the other connecting back → Power only flows one way. Efficiently convert kinetic electromagnetic or thermal energy into electrical energy = ditch conventional batteries due to the fact that devices offer radio frequencies across cell networks, Bluetooth and wifi etc → excess electromagnetic emissions that can be collected and harvested energy = New energy source. Based on the theory that metamaterials can reverse physical energy. Instead of improving batteries → power consumption can be reduced.
- Fuel production: Encourage cleaner ignition where fuel can mix better with air in the ignition process and lead to fewer polluting emissions. It can also enhance the efficiency of fuel production using better catalysts and may reduce running costs.
- Harvest Energy from the air → Metasurface based antenna uses radio waves to create energy (electric power).

  Notes from source: (Sci Tech daily, 2022)

<u>Question to be covered after two weeks</u>

1. Where are these new technologies necessary or more impactful?

- Health care
- Energy
- Transportation

2. Can we see new markets for this technology?

- Health imaging & individual health care
- Transportation systems (tunnels, self-drive cars)
- Storage and creation of energy

3. Are there jobs that can be performed that are not done today with the existing technology?

- Energy stored, is currently not able to absorb and store energy without the usage of metasurfaces
- Smaller lenses → Enhancing of lenses with metasurfaces in LIDAR systems in autonomous vehicles (less bulky and cheaper)
- Usage of the full light spectrum in satellites & drones
- Non-invasive tissue sampling/biopsy
- Metasurfaces chips for personalized medicines (alternative for smartwatches)

Week Three

After the feedback from Meta Highlight representatives, we have decided to move forward with two fields: Transportation and Medicine. The area within transportation will be our main focus since the team experience interesting opportunities and are excited to explore the field more in depth. When it comes to the Medicine field we see most opportunities in detecting and diagnosing chronic diseases. We will therefore focus our work towards these directions and see what our research and elaborations will take us.

Job: Diagnosing (chronic) diseases

2.1 Personalized medicine → diagnosing and monitoring of treatment response

Portable devices or electrical sensors to detect diseases in real-time (patients can respond very differently to any given medical treatment; portable devices or electrical sensors for diagnosis and monitoring of treatment response will improve patient stratification and treatment efficiency, which may save significant costs by the avoidance of failed treatments).
Products: portable device with a sensor for non-invasive measuring glucose in the blood.

2.1.1 Who are the main users

Direct role

Healthcare payers

➢ Patients (payers)

- ➢ Patients relatives (family & friends)

Healthcare producer

- ➢ Startup IT healthcare company > with expertise from researchers and doctors

Influential role

Healthcare providers

- ➢ Hospitals & clinics
- ➢ Diagnostic centres
- ➢ Pharmacy
- ➢ Personnel (doctors & nurses)
- ➢ First-aid responders

Healthcare payors

- ➢ Private insurance provider

Healthcare policy

- ➢ Policymakers (Governmental)
- ➢ Policy advisors
- ➢ Regulatory authority (FDA)

Investors & collaborations (for-profit firms)

- ➢ Healthcare start-ups (born-digitals)
- ➢ MNEs (Apple & Google)
- ➢ Pharmaceuticals

2.1.2 What drives them and how do they influence one another?

2.1.2.1 What drives them?

Direct role

Healthcare payers

- ➢ Problems with health, the need of getting tested regularly.
- ➢ The trend toward being healthy and doing regular check-ups.
- ➢ The willingness of relatives/friends of the patient to make him aware of his health status.

- ➢ Not being affected by human errors of the healthcare provider, can lead to affecting the health of the healthcare payer.
    - **Notes from:** (Better Health, 2020)

Healthcare producers

- ➢ Innovative features and technologies (finding new products & treatments) in the healthcare industry makes the treatment process efficient.
- ➢ Enhancing existing products or treatments.
- ➢ The opportunity of earning profit in the fast-developing industry within diabetes treatment.
- ➢ Ability to detect diseases in a preliminary stage.
- ➢ Healthcare products are produced in such a way, so their costs of sale are not that expensive.
- ➢ Creating systems or devices that can monitor the health of the healthcare payer in an efficient way.
- ➢ Possibility to mass-produce the designed healthcare products
- ➢ Ability to sell their mass-produced products globally in various markets.
- ➢ Usage of a minimum amount of resources or minerals (e.g., steels, chromium, graphite) in the production of healthcare products.
- ➢ Usage of sustainable elements that do not affect global warming (not the usage of resources where the mining process is damaging eco climates).
- ➢ To develop new approaches to diabetes tracking and detection.
- ➢ To enhance the quality of life of people suffering from the disease by applying a non-invasive method of glucose measuring.
- ➢ Developing healthcare treatments that can be spread across the globe (by the usage of various sample groups in the research process, to create treatments for people on different continents).
- ➢ Ability to create healthcare treatments or healthcare products that can be.

Influential role

Healthcare providers

- ➢ Primary health care.
- ➢ Ability to detect diseases in a preliminary stage.
- ➢ A reliable method of healthcare, which is effective for all users of the product.

- ➢ A safe method of healthcare, equipped with safety devices and features that withheld accidents in healthcare.
- ➢ Possibility to apply healthcare that can also be done without the usage of extremely specialized doctors.

Healthcare Payors

- ➢ To attract more customers by providing coverage of the disease treatment/monitoring.
- ➢ Being able to create healthcare programs that are accessible for the main part of the public (or target group), in terms of costs.

Healthcare Policy

- ➢ Healthcare policies are designed in such a way that it is not affected. healthcare payers through human errors by healthcare providers or producers.
- ➢ A safe design of healthcare producers, which are in line with set healthcare policies.
- ➢ Designing efficient healthcare policies that are affecting all healthcare payers.

Investors & collaborations (for-profit firms)

- ➢ The possibility to launch and develop new companies/business areas for future profits.
- ➢ Being included in developing vital technologies for people with diabetes > attract more funding for other operational activities.
- ➢ The possibility to expand in the new markets by using networks of other firms.

- **Notes from:** Health Imaging (2021), Ford (2022), Genome (2022), TE (2022)

2.1.2.2 How do they influence one another?

Healthcare payers

- ➢ Healthcare payers are influential stakeholders since they demand:
- ➢ Fast diagnosing processes > Producers, Providers
- ➢ Cost-efficient processes > Providers, Policy
- ➢ Participative healthcare (= understandable communication) > Providers, Payors

Healthcare producer

- ➢ Increase patient recovery > Patient, Policy, Providers
- ➢ Precise healthcare > Producers, Policy, Investors and collaborations, payors

- ➢ Reduce cost and time consumption > Patient, Providers, Policy
- ➢ Regulation > Policy, Providers, Investors and collaboration.

Healthcare providers

- ➢ Increase patient satisfaction > Patient, Producers, Policy
- ➢ Less time-consuming processes > Patient, Producers
- ➢ Less costly processes > Producers, Patients, Policy
- ➢ Safe health care processes > Patient
- ➢ Regulation > Policy, Producers, Investors and collaborations

Healthcare payors

- ➢ Increased customer satisfaction > Patients

Healthcare policy

- ➢ Precis diagnoses > Producers, Providers, Patient
- ➢ Safe healthcare > Patients, Providers, Producers
- ➢ Precise and timely healthcare > Patient, Providers, Producers, Investors, Collaborations
- ➢ Cost-effective healthcare > Providers, Producers, Investors and collaborations

Investors & collaborations (for-profit firms)

- ➢ Regulation> Policy, Providers, Producers
- ➢ Safe healthcare > Policy, Providers, Producers, Patients
- ➢ Enhanced healthcare > Policy, Providers, Producers, Patients
- ➢ Effective healthcare > Policy, Providers, Producers, Patients

2.1.3 What kind of processes are involved?

Healthcare payers

- ➢ Buying the device
- ➢ Using the device/installing necessary applications
- ➢ Service the device in case of defects/malfunctions
- ➢ Interpretation of the measurement results
- ➢ Visiting doctor if needed

Healthcare producer

- ➢ The production of the devices.
    - What suppliers to use.

- How should they be manufactured?
- The process of delivering the product to the market.

➢ The continued service of the devices.

- Where to service the devices.
- Details that need to be delivered.
- The interaction with the consumer/user.

➢ The storage of the devices, both at the manufacturing plant, but also the general storage process amongst the public.

➢ Collaboration with researchers of the technology

➢ Assisting further development of the technology

➢ Conducting the trials of technology

Healthcare payors

➢ Developing the healthcare programs for people with diabetes

Healthcare providers

➢ Promoting the use of the new non-invasive technologies

➢ Monitoring the glucose level among diabetes patients

➢ Providing necessary medical treatments

Healthcare policy

➢ Policymakers and their action toward the developments within the healthcare industry:

➢ New policies to be more applicable to the new technology of non-invasive methods of glucose level monitoring.

➢ <u>Regulations</u>

Old and new regulations that derive the healthcare industry in one direction or another.

Investors & collaborations (for-profit firms)

➢ How do investors and companies in collaborations identify themselves with the way of healthcare?

- Consequences of moving towards non-invasive technology
- Costs of moving towards non-invasive technology

- Benefits of moving towards non-invasive technology

2.1.4 What do people do, and what kind of tools and technology do they use?

The standard of measuring glucose in blood now is using invasive methods: "by applying a drop of blood to a chemically treated, disposable 'test-strip', which is then inserted into an electronic blood glucose meter." There are many electronic blood glucose meters on the market, however, they all are based on invasive principles of procedure. This can usually cause pain, especially for the patients who need to do the measurements regularly.
(Pickering and Marsden, 2014) (Meta Go Beyond, n.d.)

2.1.5 What are the main challenges, problems and pains that these users experience in existing solutions and processes (i.e. in what way do they do a poor job?)?

➢ ***Heart rate measurement***

Problem:

Electric waves cause your muscles to squeeze and pump blood, electrodes are attached to the user's body.

If you want to measure heart rate without wires or chest straps, photoplethysmography (PPG) is much less invasive. The pulse causes your arteries to alternate between swelling and contracting (News Medical, 2019)

Solution:

A heart rate monitor (HRM) is a personal monitoring device that allows one to measure/display heart rate in real-time or record the heart rate for later study (Live science, 2019)

➢ ***Expensive***

Problem:

The process and procedure in the healthcare centre are expensive and not everyone can have the capacity to pay for it.

Solution:

A report from Science Direct states that investment in IT healthcare such as different software has been proven to reduce the operational cost

- Notes from: (News Medical, 2019) (Live science, 2019)

➢ ***Blood testing***

Problem:

The process of measuring blood glucose levels/taking the tissue sample is currently done by using invasive methods (CDC, 2021).

Solution:

Glucose Meters that don't need finger pricks.

➢ ***Microscopes to detect and evaluate samples within medical treatment***

Problem:

The current microscopes can not identify the full light spectrum, the state of art is quite expensive and non-affordable.

Solution:

Fluorescence microscopy, in which fluorescent molecules are used to light up target proteins, cells or cellular components, allows biologists to observe live samples in real-time.

- Notes from: (Britannica, 2022)

➢ ***Personalized medicine***

Problem:

Complicated and difficult to know how treatments influence patients and what the consequences of this treatment are. Moreover, patients with diabetes must test glucose levels several times a day and more than half of patients don't test often enough, in part because of the pain and inconvenience of the needle prick (need for alternative solution), (Genome, 2022)

2.5.1 Current solutions on market with non-invasive methods to measure diabetes (competitors)

Countless companies worldwide aim to form the lives of millions of diabetes patients easier by establishing non-invasive methods of glucose monitoring. Developing these methods as accurate as standard test strips is a hard undertaking. Hence, one high-profile example is the Google Contact Lens, whose establishing was cancelled in 2018 since its method of scanning glucose standings in tears wasn't accurate and consistent enough.

➢ DBase is a glucose meter (shoebox-sized) established by the German company DiaMonTech. This tool measures glucose standards by irradiating an infrared laser across the tissue of the finger and inducing the glucose of the skin to transform the light becoming heat. The device then calculates the blood sugar level based on how much

the heat on the tissue of the skin rises, but the rise in temperature is too miniscule for the user to notice. The firm is also working on wearable devices with small sensors.

- ➢ Eversense is a percutaneous implant established by US based firm Senseonics, that continually screens blood sugar standards. The doctor must first install it under the skin, but the sensor can last up to 3 months before it needs to be replaced. Eversense uses a polymer that fluoresces in response to glucose standards based on the measurement of glucose in the interstitial fluid below the tissue of the upper arm. The data is then transferred to a transmitter that shows real-time blood sugar standards.
- ➢ Established by the Israeli-US firm Integrity Applications, the GlucoTrack can scan blood glucose standards using a combination of heat waves, electromagnetic waves and ultrasound. The sensor is clipped to the ear for display, to show an accurate measurement. This device is for adults with type 2 diabetes and is sold in Europe. Integrity Applications is currently looking to expand into the United States and is establishing a GlucoTrack (second generation) consisting of a wireless ear attachment sensor combined with a smartphone.
- ➢ GlucoWise is a sensor under establishing that can scan blood sugar standards by simply positioning it on the skin between the index finger and thumb. The device then sends measurements (real-time) straightly to a smartphone app. Developers believe that their device is more accurate than other wireless blood sugar measures since its scans blood sugar standards using radio waves of a specific frequency.
- ➢ As an eye-focused blood sugar measurement device, Occuity Indigo literally takes the phrase "eyes are windows to the soul." Instead of measuring tears like Google's contact lenses, UK developer Ocuity examines the eyeballs since it's a clear, stable setting where glucose standards correlate with blood levels. Occuity Indigo sends low light rays to the eyeball and scans the light reflected back to the device. It works based on a technology that measures the level of glucose in the eye based on the refraction of the return light.

  (Fernandez Rodriguez, 2021)

2.5.1 Issues with current non-invasive methods with infrared usage

Spectroscopy absorption and emission of light can only penetrate a few millimeters into tissue. Glucose measurements from the fluid that bathes skin cells, known as interstitial fluid, to blood glucose levels. The signal that is measuring the glucose leans to get dampened out by numerous

other skin tissue components. When measuring the signal coming from the tissue, there are additional solid components (collagen, lipids & proteins) which provide a strong signal compared to glucose. Hence, due to the different skin tissue components, it is tough to distinguish the glucose signal from other solid components signals.
(Crotti, 2020) (Bahareh et al., 2018) (Badawi, 2019)

2.5.2 Solution for metasurfaces

Healthcare providers offer and plan specific care for their patients based on their individual genes and sometimes a device (e.g. Smartwatches) can help on specific issues. Focused on diabetes, A wristband (inexpensive in production, mass production, highly accessible to mass-market globally) with MetaHiLight technology lenses shines a beam of light through your skin, which is then reflected and scattered by the glucose in your blood. The sensor then detects signals from the light that is reflected back. Glucose exhibits a unique reflection pattern that differs from the other components of your blood; the difference in signals is how the sensor could determine your glucose level (Zhang et al. 2021).

2.1.6 What are things that are difficult to do?

Over the past few years, advanced technology, especially imaging and light rays, has become essential for healthcare. The more detailed and concise an image is, the easier it is to determine and implement the best possible decisions for patient care. Good imaging can help detect early symptoms of an emerging medical condition - and early detection is often important. Electric waves, microscopes, glucose-CGM systems, biopsy, MRI, ultrasound and other technologies have worked great in healthcare, especially AI and 3D vision. However, each of these technologies has its own limitations. 3D images created using multiple cameras have begun to appear throughout the medical field, reducing the likelihood of human error, improving the accuracy of imaging descriptions, and providing a better way to test images. This type of technology mimics human stereoscopic vision and creates appearance. Even traditional imaging methods can be combined with 3D displays for increased clarity. The development and application of 3D imaging technology in general is challenging because of its high cost and the equipment it can take up space. Electrical waves compress the muscles and pump blood, attaching electrodes to the user's body. Photoplastismography (PPG) is much less invasive in this case but the process and method of this technology is expensive and not everyone can

afford it. Also, existing microscopes used in healthcare cannot detect the full spectrum of light, the state of the art of this technology is quite expensive and not cost effective, and it is complex and difficult to know how personalized drugs affect patients and what the consequences of these treatments are. In addition, an MRI scan produces hundreds of images that must be diligently reviewed. Specialists must be careful that all angles are represented and that the images meet the needs of referring physicians and radiologists. However, it has become a great challenge to overcome the issues and to bring out revolutionary changes in medical technology (Niddk, 2017)

To measure heart rate, Heart Rate Monitor (HRM) is a personal monitoring device that allows one to measure or display heart rate in real time or record heart rate for further study. In blood tests, a glucose meter is used which does not require a fingernail. Fluorescence microscopy, in which fluorescent molecules are used to illuminate target proteins, cells or cellular components, allows biologists to observe real-time live samples to identify and evaluate samples in medical treatment. Smart watches have recently been used to measure heart rate and as personalized medicine instruments. However, 3D imaging has the potential to improve medical collaboration and help physicians explore the mysteries of the human body. As healthcare technology advances rapidly, many of its triumphs will depend on efficient and state-of-the-art imaging, and metamaterial technology can be an effective solution for providing clear images to detect chronic disease as well as other health-related issues. Metamaterials offer super-resolution images that make these diseases easier to detect, and metamaterials can observe the full spectrum of light. Also offers a cheaper price compared to other existing devices due to the smaller size. A central machine (such as a photo booth) uses metamaterial technology that provides an accurate assessment or diagnostics of defects in cell pattern formation resulting in avoiding future failed treatments and efficient detection of early stages of cancer, etc .; which is more cost-efficient and better to detect diseases and immediately to treat. A metamaterial is developing MammoWise, a radio-wave imaging system for breast cancer screening. The technology is not intended to replace mammograms or MRI imaging, but to extend the screening method to a large pool of young patients in a cost-effective and reliable manner. Increased early detection, without side effects, including physical and emotional stress, can help revolutionize breast cancer prevention, detection and treatment in the future using metasurface technology (Niddk, 2017)

Questions to Juan Tuesday 19th:

- ➢ What markets to focus on regarding each job (only one, or a broader overview of all)

Feedback from Paul

- ➢ He mentions that there is potential within the energy section.
- ➢ Think of the competing technologies.
    - Take price and performance into consideration.
- ➢ Small electronic devices that do not have room for batteries → lasers as a powersource.
- ➢ Solar panels
    - However, difficulties when absorbing the full spectrum of light.
    - Uncertain if the increase in efficiency actually will be more with the help of metamaterials.
- ➢ Transportation
    - 3D vision = relevant.
- ➢ Health care
    - Sensors to observe and keep the patients in check (through our SmartWatch?)
- ➢ The most prominent job(s)
    - 3D vision → multiple fields of application

2.2. Secondary Idea: 3D vision

Job: Transportation

Topic: Autonomous driving (Computer Vision)

Details about the idea: Enhancing the state of art within transportation, e.g., 3D imaging systems, with the assistance of metamaterials and Meta HiLight.

Questions to ask ourselves:

- How can we scale down the current technology?
- How can the current technology be redefined in the existing market?
- What will it cost?
- Who is the current competitor?

2.2.1 Who are the main users?

Direct role

The user (the driver etc.)

- ➢ Drivers (e.g., car, truck, bus) > Semi-autonomous

- ➢ A.I. → autonomous
- ➢ The elderly and the disabled (driverless cars)

Bystanders (being affected by users' actions)

- ➢ Passengers
- ➢ Pedestrians

Influential role

Transportation companies

- ➢ Freight transportation / Third-Party (Trucking companies, container shipping lines, railway operators and bus companies)
- ➢ The transport user group (Association, LaborLabour Unions and Forum)
- ➢ Logistics providers (UPS, FedEx, DHL, etc.)

Transportation production

- ➢ Vehicle Services
- ➢ Vehicle Factories
- ➢ Vehicle Energy production (e.g., electricity)
- ➢ Vehicle warehousing
- ➢ Road design/constructors

Transportation policy

- ➢ Vehicle policymakers (Governmental)
- ➢ Vehicle policy advisors
- ➢ Regulatory authority
- ➢ City planners (e.g., go 3D instead of land surface)

2.2.2 What drives them and how do they influence one another?

2.2.2.1 What drives them

The user (the driver etc.)

- ➢ Willingness to get a fully working vehicle which is designed in an effective and cost-efficient way.
- ➢ Driving the vehicle of the brand that they like the most (brand loyalty = emotional connection to one car brand).
- ➢ Residual value of the car shouldn't depreciate that quickly.

- Costs of ownership of the car (e.g., costs for insurance, low fuel consumption costs for powering the car through either electricity or fossil fuels and low costs to maintain and service the vehicle).
- Innovative features and technologies in the car design that enrich the car driving experience.
- Electric Fuel efficiency, with electric cars the users focus is on what the range is that the car can drive with one battery charge.
- A sustainable driving method, should not pollute due to a low fuel consumption. (Ucars, 2020)
- A safe and reliable method of transportation, equipped with safety devices and features that withheld a car crash.
  (Protective Agency, 2018)

Bystanders (being affected by users' actions)

- A safe and reliable method of transportation, equipped with safety devices and features that withheld a car crash.
- Being a passenger in the safe environment of a vehicle due to a car design based on ensuring the safety of their passengers.
- Not being affected by human errors from a vehicle driver, which can lead to accidents affecting the health of the bystander (responsibility of the driver) (Vouch for me, 2018) (RMA group, 2018)

Transportation companies

- Transportation vehicles that are produced in such a way, so their purchase is not that expensive.
- Possibility to apply a fleet management system in their fleet of vehicles (e.g., ability to have an overview of real time data where their vehicles are at the moment.
- Usage of vehicles which can transport goods over a long distance in an effective way, without damaging or loss of value of the transported goods.
- System that can monitor if drivers of the transportation vehicles are staying sharp (focused on the road) as well as awake.

- Costs of ownership of the transportation vehicle (e.g., costs for insurance, low fuel consumption costs for powering the car through either electricity or fossil fuels and low costs to maintain and service the vehicle).
- Electric Fuel efficiency, with electric cars the users focus is on what the range is that the car can drive with one battery charge.
  (Oster, V., n.d.)

Transportation production

- Efficient working vehicle, which is designed in such a way that it is an easy selling item for the mass market.
- Possibility to mass produce the vehicles and having a fast production cycle.
- Possibility to purchase mass produced vehicle parts used in the mass production of the vehicles (e.g., tires, windows, lenses for 3D imaging systems).
- Possibility to produce cars in countries with lower labor wages leading to less costs in the production of vehicles.
- Usage of a minimum amount of resources or minerals (e.g., steels, chromium, graphite) in the production of cars.
- Usage of sustainable elements that do not affect global warming (not usage of resources where the mining process is damaging eco climates).
- Ability to effectively sell their cars through car dealers to the public.
- Ability to sell their vehicles globally in various markets.
  (Chase, 2020) (Grüntges et al., 2021)

Transportation policy

- A safe and reliable method of transportation, equipped with safety devices and features that withheld a car crash.
- Vehicle policies that are designed in such a way that it is not affecting bystanders through human errors from a vehicle driver, which can lead to accidents affecting the health of the bystander (responsibility of the driver).
- Designing roads in such a way that the roads do not use an excessive amount of land surfaces.
- Safe design of roads, roundabouts etc. (leading to less accidents).

- Finding alternative solutions for traditional roads due to the increase of densely populated areas (e.g., traffic in Los Angeles).
- Decreasing noise from vehicles

(OECD, n.d.) (Baldwin and Shuttleworth, 2021)

2.2.2.2 How do they influence one another

The user (the driver etc.)

Users are the most influential stakeholder because they insist :

- Less Fuel consumption > Transportation Production
- Environment friendly transportation system > Transportation policy
- Cost effective > Transportation companies
- Secured and comfortable > Bystanders

Transportation companies

- Building more cost effective vehicles > Transportation Production
- Business friendly policy > Transportation policy
- Safe driving capacity > Users
- Customer preference > Bystanders

Transportation Production

- Production cost > Transportation companies
- Approving Innovating product > Transportation policy
- Incorporating new features > Users
- Safety Guideline > Bystanders

Transportation policy

- Follow transportation policies > Bystanders
- Maintain driving guidelines > Users
- Follow public transportation guideline > Transportation companies
- Sustainability > Transportation Production

Bystanders

- ➢ Public rights > Transportation Policy
- ➢ Safety > Users
- ➢ Cost Effective > Transportation companies
- ➢ Luxury atmosphere > Transportation Production

2.2.3 What kind of processes are involved?

The user (the driver etc.)

The process of managing a vehicle:

- ➢ Purchasing the vehicle and its technology from the producer.
- ➢ Driving the vehicle, both through semi-autonomy and manually.
- ➢ Servicing the vehicle.
- ➢ Purchasing insurances.
- ➢ Difficulties to avoid human error, 1.3 million deaths worldwide, where roughly 50% are related to the drivers solely being injured or killed.

Bystanders (being affected by users' actions)

Consequences to bystanders of the actions made by the driver:

- ➢ Accidents due to human error.
  - 1.3 million deaths worldwide, 50% related to pedestrians etc.
  - Passengers of vehicles are also affected by the actions of the driver and how they operate the vehicle.
  - Bystanders' requirement to adapt depends on the drivers' actions. (World Health Organisation, 2021)

Transportation companies

Third parties are dependent on the vehicle's functionality

- ➢ How are the parties going to conduct the transportation from A to B?
- ➢ The importance of defining the most prominent way of transportation, e.g., the driver, the vehicle, the route, etc.

Associations, Labour Unions, Forums, and how these identify themselves towards the way of transportation. Dependent on the choice of either executing the transportation manually or through semi-/full autonomy.

- ➢ Consequences of moving towards semi-/full autonomy
- ➢ Costs of moving towards semi-/full autonomy
- ➢ Benefits of moving towards semi-/full autonomy

Transportation production

Vehicle factories and service centers:

- ➢ The production of the vehicles.
  - What suppliers to use.
  - How should they be manufactured?
  - The process of delivering the product to the market.
- ➢ The continued service of the vehicle.
  - Where to service the vehicles.
  - Spare parts that need to be delivered.
  - The interaction with the consumer/user.
- ➢ The storage of the vehicles, both at the manufacturing plant, but also the general storage process amongst the public.
- ➢ Infrastructure
  - The network of roads and how it should be built and maintained.
  - The future development and evolution of roads. How to construct them to best suit the technology of semi/fully autonomous vehicles?

Transportation policy

- ➢ Policymakers and their action towards the developments within the vehicle industry:
  - New policies to be more applicable to new technology of semi/fully autonomous vehicles.
- ➢ Constructors of the planning of the road network:
  - Architectural planning.
  - Acquiring material for road-construction.

- The actual construction of the roads.

➢ Regulations:

- Old and new regulations that derive the vehicle industry in one direction or another.

2.2.4 What do people do, what kind of tools and technology do they use?

➢ Majority of the cars found in the street have no driving automation which is known as manual driving cars.

➢ The primary level of vehicle autonomy is to have some sort of driving assistance which can be done by controlling steering, accelerating or speed. These types of vehicles are also common in the streets.

➢ The third level of the vehicle that exists in the market is partially autonomous which has driver assistance systems. This type of vehicle can control both steering and acceleration. A driver must need a seat to operate or monitor the car. At present Tesla Autopilot and Cadillac are found on the street.

➢ This type of vehicle has environmental detection capabilities and can take decisions such as accelerating and crossing a slow-moving vehicle. But it still requires human presence. Researchers forecast that around 8 million autonomous or semi-autonomous vehicles will be on the road by 2025. (Synopsys, n.d.) (ABI research, 2018)

2.2.5 What are the main challenges, problems and pains that these users experience in existing solutions and processes (i.e. in what way do they do a poor job?)?

- **3D Scene Analysis**

  Problems

  Accuracy – in 3D scene analysis even the slightest inaccuracies tend to stack into a larger mistake and result in a drift. What appears to be harmless at low speeds can become visible when velocity rises.

Multiple unpredictable objects – what is fairly straightforward on a highway gets complicated in urban traffic, where the street network grows more complex as well as the intentions of the other actors on the road.

Solution

They are using the Lidar and Radar for the effectiveness of 3D scene analysis.

- **Notes from:** Velodyne 2022

- **Human errors lead to traffic accidents**

  Problem

  Contemporary human errors are leading to traffic accidents and people falling asleep while driving. Human error during long-distance truck drives (e.g., chauffeurs falling asleep). In the future, this would lead to an increase in human casualties with human-driven trucks. Truck drivers also need to rest (sleep) after a period of driving. (Toobin, 2016)

  Solution

  Self-driving cars where A.I. makes better decisions than humans, leading to fewer accidents. However, contemporary lidar systems are currently big & expensive, metalenses can make them smaller & more compact

  Self-driving trucks for long distances will increase the efficiency of usage of trucks (no need for rest). Fleet managers can manage a bunch of trucks and might interfere when there is a need to.

  (Toobin, 2016)

- **Major Traffic issue**

  Problem

  Contemporary big cities face major traffic issues due to densely populated cities. City density will highly increase in these cities since people tend to move in the past decades to the city.

  Solution

  Therefore, there is a need for alternative transportation methods. Therefore, roads must go 3D. Surface roads today incorporate 3D model-like elevated highways and cloverleaf interchanges that are expensive and disruptive to build.

(Boring company, n.d.)

- **Expensive**

  Problem

  Contemporary such rovers on planetary expeditions of NASA etc. are using CCD (charge-coupled device) sensors to map landscapes in order to drive around obstacles. However, this usage is expensive (due to many lenses in the sensors and the need to have multiple lenses in sensors).

  Solution

  Decrease of usage of sensor systems (smaller lenses), which decreases costs and bulkiness of rovers.

  (NASA, n.d.) (Tech Brief, n.d.)

- **Outdated navigation systems**

  Problem

  The actual GPS receiver in your car almost certainly works as well as it ever did. It might be "outdated" compared to newer models that track more satellite systems or get an initial fix faster, but the system itself has not been changed in any way that would make older receivers stop working.

  Solution

  Cars that include a cellular data connection could update maps automatically.

  - (NASA, n.d.) (Tech Brief, n.d.)

- **Object Recognition**

  Problem

  Object recognition needs to be done in a real-time environment. When it comes to input from a camera, it is sometimes based on a set of lines that are constantly flowing from the sensor and are used to refresh an ever-changing image on a screen, rather than on a series of complete and whole images. Thus, there is a need to recognize objects without actually seeing them.

  There are multiple elements in an environment that can be confusing for an autonomous system – a truck trailer in front of a car can be a good example.

  Solution

This first challenge can be solved by training a model on the data delivered by the sensor as an output, practically switching the model toward signal analysis rather than image recognition.

The second challenge is an example of a typical problem of AI being unable to generalize and having no prior knowledge of a subject. An interesting solution comes from enriching image recognition with partial evidence – a technique that enables the neural network to use a piece of additional information (for example context) to exclude the least probable outcome **Notes from:** Velodyne 2022.

- **Hike in fuel cost**

  Problem

  The inflation in fuel prices results in an increase in transportation costs to the shippers. The rise in fuel prices constantly increases the surcharges added to freight rates. This naturally cuts down the revenue and earnings of truckers, as fuel prices increase (Riksbank, 2022)

  Solution

  Hybrid technology uses Stop-Start, regenerative braking, and larger electric motors and batteries to reduce fuel use, especially in stop-and-go driving.

- **Environmental issues**

  Problem

  Through the emissions from the combustion of fossil-derived fuels, transportation systems contribute to degraded air quality, as well as a changing climate. Transportation also leads to noise pollution, and water pollution, and affects ecosystems through multiple direct and indirect interactions.

  Solution

  Electric (battery-powered) vehicles and trains, hydrogen-fuelled vehicles.

  (Murray, 2019) (Nature, 2021)

2.2.6 What are things that are difficult to do?

With the development of technological advancement, the transportation sector is in the urge of development combined with AI, Automation and 3D vision which can provide accurate information on speed, fuel state, navigation guidance and environmental settings. Also can assist in danger free driving of the cars on roads where the driver's eyes do not have to adjust

to different brightness and focal plane conditions when changing their vision from the road (bright and distant) to an object cluster (dark and near). The contemporary technologies in transportation are not efficient enough to provide effective results and danger free driving and all of these are problematic. Thus the contemporary transportation systems are facing challenges all over the world and therefore, they need modern and updated solutions combined with the new technology (e.g. AI, Automation, 3D vision) to alleviate the challenges. If we look at the current challenges with the existing technology it has been observed that when analyzing 3D Scenes to detect the multiple unpredictable objects it can't provide accurate results and the contemporary CCD (charge-coupled device) sensors (e. g. Rovers) to map landscapes in order to drive around obstacles invented by NASA are more expensive to use by the general people. Additionally, human errors (falling asleep while driving), outdated navigation systems, major traffic issues on the road, and increasing fuel prices also have made the transportation system more challenging to cope with in the modern era, especially in developing countries which leads to modern technology to look for automation. To have sustainable and efficient transportation; introducing self-driving cars & trucks, flying cars, automated tunnels combined with 3D vision, AI and Automation can help in minimizing the challenges existing in the transportation industry. **Notes from:** Velodyne 2022

Lidar systems in self-driving cars based on A.I. which can accurately measure the distance can solve the issues raised in transportation systems but the contemporary LIDAR systems are big and expensive whereas metalenses can help to make it smaller and cheaper increasing affordability to the mass of people. To solve traffic problems in big cities surface roads incorporate 3D model-like elevated highways and cloverleaf interchanges replacing with metalenses which will make it cheaper in terms of cost with its existing technology since metasurfaces could reduce the size of LIDAR lenses since they are more compact and cheaper in production. Also, Rovers to drive around obstacles can be improved by using metamaterial technology in it which will decrease the usage of sensor systems (smaller lenses) and can decrease the cost and bulkiness. Additionally, the challenge with detecting the object accurately, enriching image recognition with partial evidence with 3D vision by using metalenses in it which the typical AI technology is unable to generalize and having no prior knowledge on a subject, can be solved. However, to deal with the transportation challenges replaced with metamaterial can be the effective solution in future considering the cost and updated technology but how effective it will be depends on how the metamaterial technology

can compete with the existing technology and its affordability to the mass people. **Notes from:** Velodyne 2022

2.3 Questions for interview

The questions in paragraph 2.3 are developed in week 3 after answering the questions 1 until 6.

- ➢ Current way of detecting diabetes (healthcare provider perspective): How is diabetes currently detected?
- ➢ Current way of treating diabetes (healthcare provider perspective): How is diabetes currently treated?
- ➢ Is healthcare accessible in Bangladesh? Is healthcare for diabetes patients accessible?
- ➢ How can healthcare be made more accessible for diabetes patients?
- ➢ How many people are diagnosed with diabetes? Is this increasing or decreasing?
- ➢ Issues/problems: What is currently going wrong in the treatment process of diabetes?
- ➢ Which possibilities do you see how diabetes can be better detected?
- ➢ Which possibilities do you see how diabetes can be better treated?
- ➢ We thought about a wristband (metasurfaces lenses) which can detect diabetes by using light. What do you think about this? Do you think this will work?

Influential role

Healthcare payors (insurance)

Questions

- ➢ How is healthcare currently funded?
- ➢ How expensive is basic healthcare in Bangladesh?
- ➢ How expensive is treatment of diabetes in the insurance package that you are offering?
- ➢ What are the issues with the current method of funding healthcare?

Healthcare policy

- Sharmin knows somebody in Bangladesh

Questions

- ➢ What are the current healthcare policies regarding diabetes in Bangladesh?Which issues or problems are currently in the healthcare policies regarding diabetes?
- ➢
- ➢ If there are issues or problems, how can these be improved?
- ➢ Which policy areas can be improved to increase the accessibility of diabetes detection in Bangladesh?
- ➢ Which policy areas can be improved to increase the accessibility of diabetes treatment in Bangladesh?

Healthcare research

- Contacted LIU researchers working in the area of invasive methods

Questions

- ➢ Focus on our idea for the wristband non-invasive method: Would this be a good idea to make healthcare more accessible for people living in a country with bad healthcare?
- ➢ Would this idea be realistic for implementation?
- ➢ Which areas can be improved in the current non-invasive method of detection of diabetes?

Investors & collaborations (for-profit firms)

Questions

- ➢ Would you consider purchasing this innovative idea?
- ➢ What are the characteristics of companies that you are currently purchasing?
- ➢ Transport > Metasurfaces for 3D Imaging

The user (the driver etc.)

- Interview with Stepfather of Luca

Questions

- ➢ How can transportation be made more safe?
- ➢ What are the current issues in a semi automation car?
- ➢ In which areas do you see improvement by semi automation vehicles?
- ➢ Which elements can enhance the safety in a semi automation car?

- ➢ Would you consider buying a fully automated car?
- ➢ Would you consider being a passenger in a car driven by an A.I. system?
- ➢ Would you feel safe in a car driven by an A.I.?
- ➢ Would you think that in an A.I. driven vehicle that still needs to be a function where humans can interfere (when they feel unsafe)?
- ➢ What innovation and features would an automated car need in your opinion?
- ➢ How much would you consider to pay for a fully automated car?
- ➢ How much would you pay for the costs of ownership?

Bystanders (being affected by users' actions)

- Interview with father of Valeriia

Questions

- ➢ How can transportation be made more safe?
- ➢ Would you consider being a passenger in a car driven by an A.I. system?
- ➢ Would you feel safe in a car driven by an A.I.?
- ➢ Would you think that in A.I. driven vehicle that still needs to be a function where humans can interfere (when they feel unsafe)?
- ➢ In which areas do you see improvement by semi automation vehicles?
- ➢ Which elements can enhance the safety in a semi automation car?
- ➢ What innovation and features would an automated car need in your opinion?
- ➢ Would you think that automation of vehicles would decrease human errors from people that drive vehicles?

Transportation companies

Questions

- ➢ How automated vehicles can influence the business of transportation companies?
- ➢ Would you think that automation of vehicles would decrease/increase the cost of services provided?
- ➢ Would you consider purchasing an A.I. driven vehicle to transport goods?
- ➢ Would you consider purchasing a whole fleet of A.I. driven vehicles to decrease payroll costs (no need anymore for human drivers)?

Transportation production

- ➢ Uncle of Paula (working in energy management)
- ➢ Pedro asked two people working at Mercedes Benz & Audi
- ➢ Pedro asked a researcher working with automation of vehicle

Transportation policy

- https://www.transportstyrelsen.se/sv/kontakta-oss/ > Swedish transportation agency

Questions:

- ➢ What are the current transportation policies applied in Sweden?
- ➢ How the transportation policies can differ depends on the type of the vehicle?
- ➢ Which issues or problems are currently in the transportation policies regarding semi-autonomous vehicles?
- ➢ If there are issues or problems, how can these be improved?
- ➢ Which policy areas can be improved or influenced by the spread of vehicle automation?
- ➢ Which changes have to be made currently in the transportation policy to include vehicles which use A.I. to 'drive' the vehicle?
- ➢ Would an increase of A.I. driven cars also mean that roads have to be changed or adapted to A.I. driven vehicles?

Feedforward from Friday 22/4

Transportation

- Good thing for next week, see the specific problem, where does it happen etc.
- Journey map of a person driving an autonomous cars, steps that they are taken in the driving process from A to B. With different obstacles (animal crashing, car crashing) > why can't it be changed now, what is this thing and where do we place metasurface lenses in this process (interview people that drove a semi-autonomous car in a car accident). > steps for both passengers as well as drivers.
- Steps that happen in recognizing obstacles: recognition, identification, processing and taking action. > both for manual, semi-automatic and automatic cars.
- When how are we seeing people in cars (earlier detection)

- Turn the problem “inside-out”
- Map scenarios and extremely detailed → for instance, map a crash → the full process from point A to B → assists in identifying the issue
- Compare with / learn from manual cars → What does that journey look like?
- Get down to the level where things actually happens → leave the abstract level and move towards the concrete level, be more specific
- **For the interviews:** the process of driving, where do the driver look through the windshield, how does it function, what goes on in the vehicle, rearview mirror
- Change questions, make it very practical and really focus on practical understanding what is going on in the braking process & recognition of obstacles (user & passenger). And for transportation companies, how to design vehicles.
- The real level: what is happening? How can the real level help us understand the abstract level? What is the concrete level?
- Zoom in/out perspectives
- Journey maps for traffic system, for passenger, for driver
- Daniel might be able to give us information about the use of vehicles
- Difference between vehicles (trucks and cars)
- Start from the specific

Healthcare

- Once again describe the process, when, how, where?
- Step for step process in current detection, monitoring and
- What is it like to be a person with diabetes? Steps that are additionally need to be taken as a diabetes patients (several moments per day to take insulin, always need to eat something)
- What do you want to pretend with your product?
- What exactly can the metamaterial (Meta HiLight) measure?
- Blood sugar too high or two low, the process, the symptoms, etc. > on the way to coma.
- Different types of diabetes → Where/when is our technology necessary? Where is it limited?
- In the stakeholder map, be more specific → maybe put the patient in the center…
- What is exactly happening in the various processes?
- Journey maps of the real problem we are trying to solve: detailed and in depth

- The movie perspective: we see the result and then find out exactly what and when things went wrong.
- How can our technology prevent the end result from happening but still make sure that the "job" gets done?

Feedback from coaches:

- More than one persona → one for type 1 diabetes and one for type 2, also worth considering making different persona based on age.
- Don't focus too much on technology

Week 4

The team realized that the Transportation field was characterized by many obstacles that we struggled to overcome with our technology, why we decided to change our primary focus towards medicine where we had gathered insightful information the week before. The decision to change focus was not difficult to make since we all agreed on the limitations and the opportunities for Meta Highlights within the medical field. During this week we tried to gain more understanding for our problem space and the user within it. This weeks research contained of understanding how the existing non-invasive technologies work and the limitations they face. From that we could build an understanding and create a storybraid for the problem space. The visualizations of week 4 show the creation of the persona (user), the needs of the persona and the journey map of the persona.

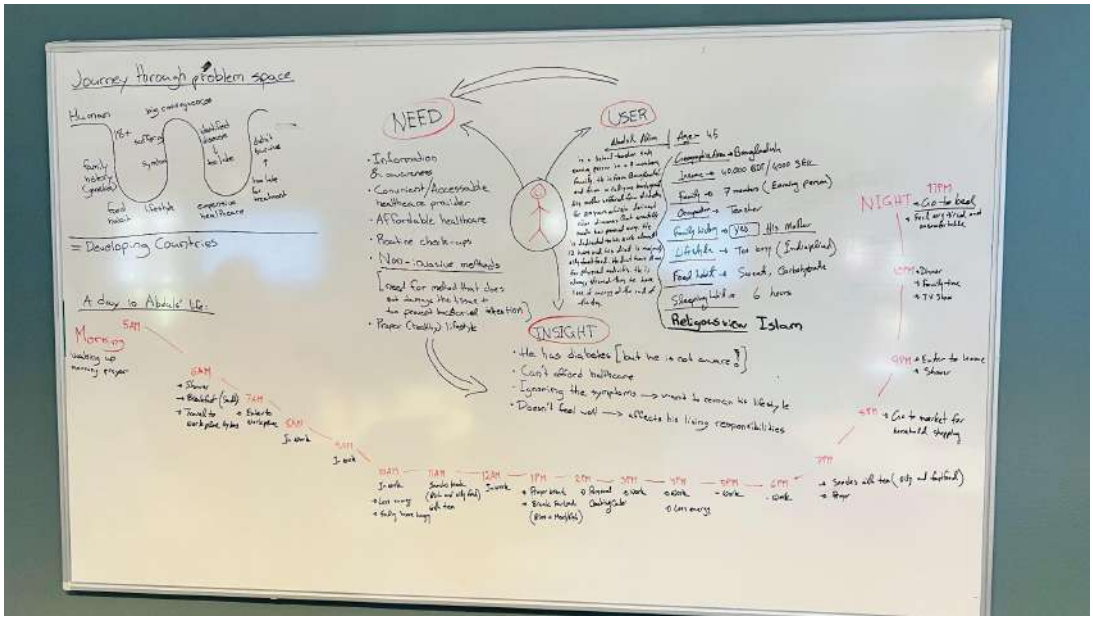


Figure 1. Workshop 25/4

During the workshop, Team Kepler made a first draft of how our visualizations for the problem space could be illustrated. By identifying the user, we could create a journey map of our (first drafted) persona's daily activities.

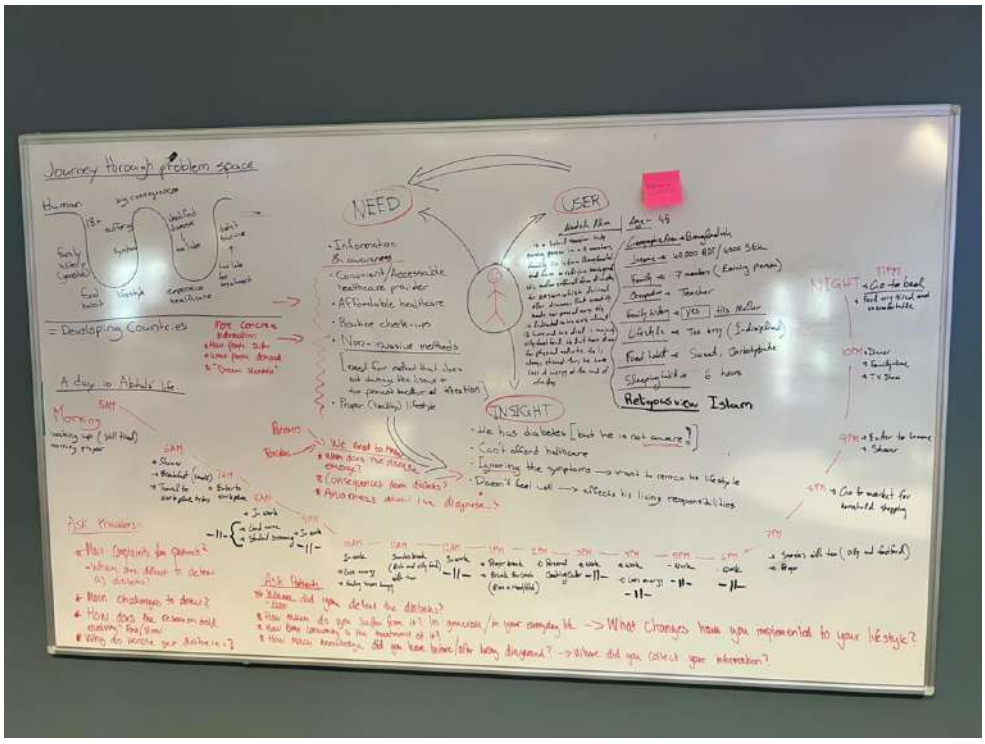


Figure 2. Insights from workshop 24/4

From our visualizations we got insights regarding which activities are the most relevant and which stakeholders to contact for interviews. The illustrations helped us come up with essential questions that we needed answers to in order to collect as much understanding for our problem space as possible. We learned about the loop User→ Need → Insight.

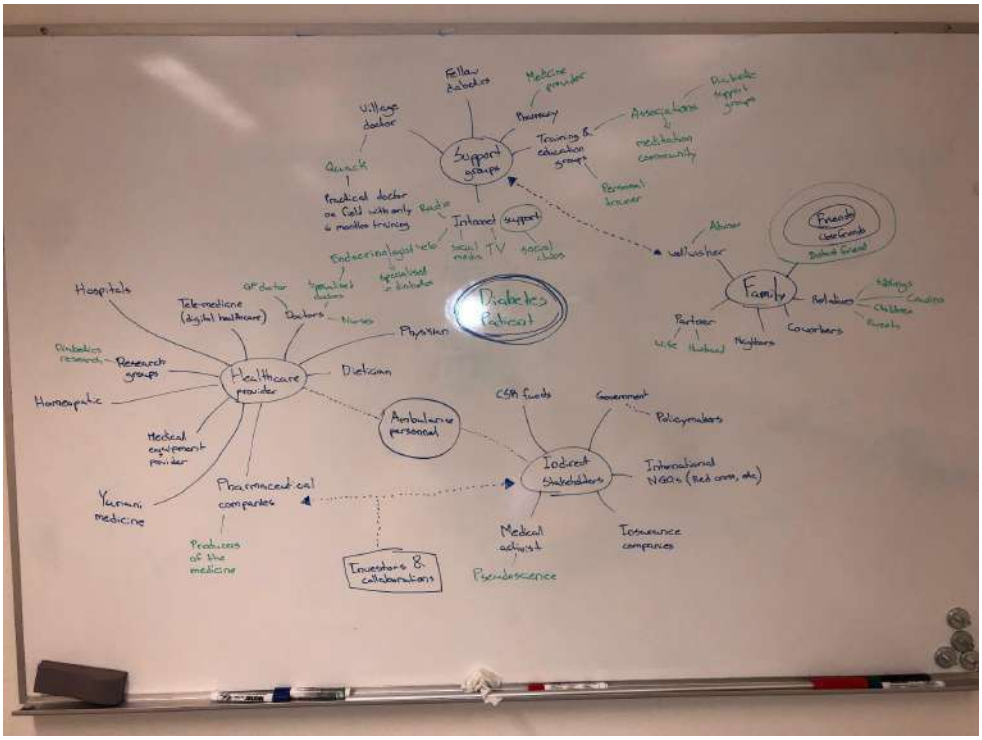


Figure 3. Draft visualization of the stakeholders

Above is the stakeholder map in which we have categorized important parties and sorted out the network a diabetic patient is involved in. The visualization also illustrates how different stakeholders are interconnected.

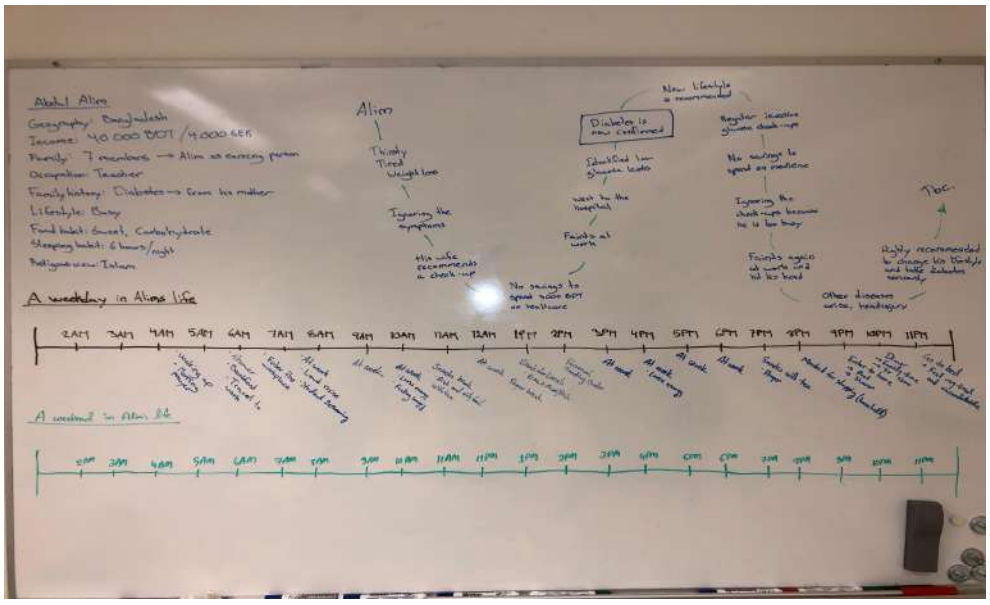


Figure 4. Persona and Journey through problem space

Second draft of our persona and the journey through the problem space. This was drafted as we had collected more information from our interviewees in order to get a more detailed understanding for diabetic patients.

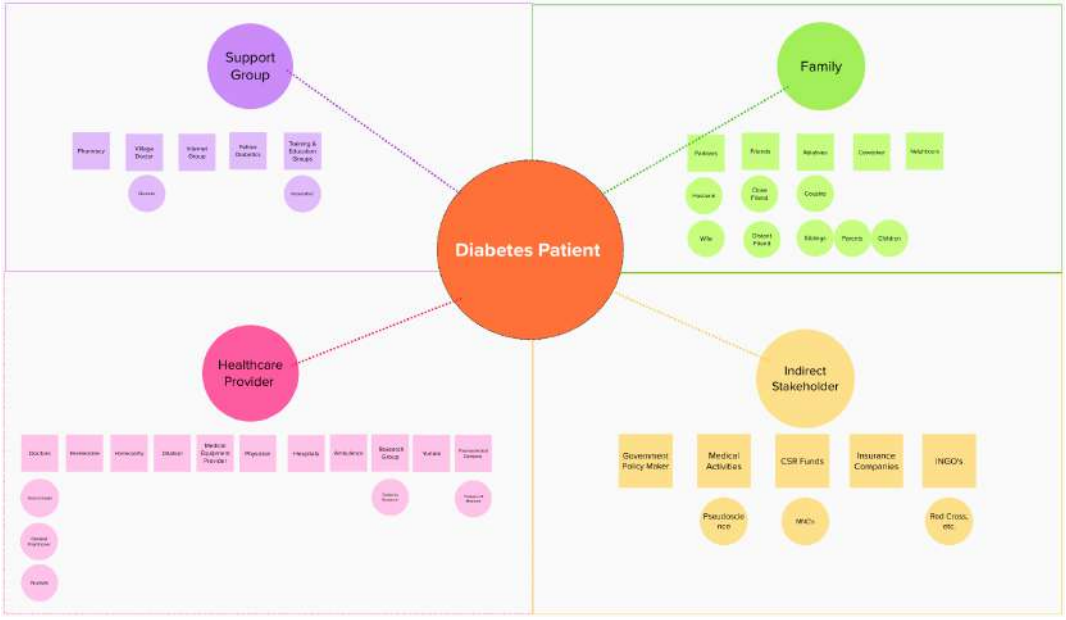


Figure 5. Digital Stakeholder Map

Second draft of how the different stakeholders are connected to the diabetic patient and how they are categorized. From the SGM feedback we learned that it is possible to improve the visualization by illustrating more clearly how the different parties are connected with each other.

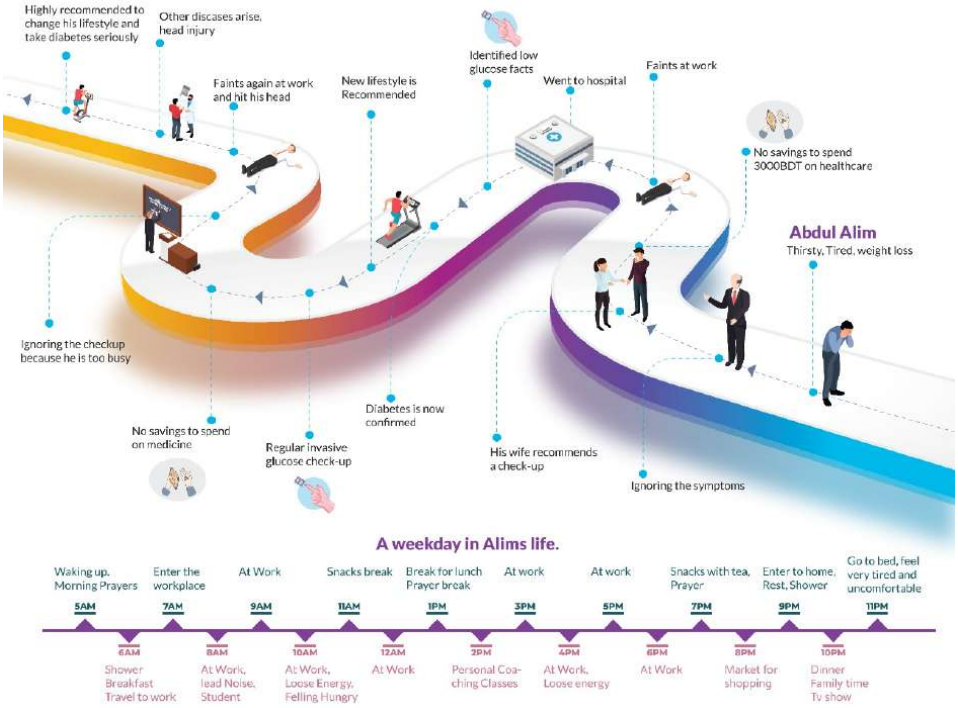


Figure 6. Digital journey map

The third journey map tries to illustrate more clearly how a day in our persona's day looks like. The viewer is guided in Alim's life from the moment he wakes up → when he goes to sleep. The journey through the problem space does also involve more detail than earlier and the

illustrations symbolizes activities in a more distinct manner to increase the viewer's understanding of the problem space.

3.1 Diabetes

Diabetes is a chronic (long-lasting) health condition that causes our bodies to convert the food we eat into sugar, called glucose. In response, the pancreas produces a hormone, called insulin, that delivers the glucose to our cells to give us energy. When you have diabetes, this process gets disrupted.

Type 1		**Type 2**
Your body is no longer able to produce insulin	**Reason**	Your body still produces insulin, but it doesn't make enough of it, or it doesn't use it efficiently
Usually develops during childhood, but can develop at any age	**Age**	Can develop at any age but is most common in adults over 45
Family history	**Risk Factor**	Overweight and/or inactive, family history, high blood pressure
Bedwetting, blurry vision, frequent urination, increased appetite and/or thirst, mood changes, irritability, tiredness and weakness, weight loss	**Symptoms**	Blurred vision, dark patches on armpits and neck, frequent urination, increased appetite and/or thirst, slow-healing sores or frequent infections, tiredness and weakness, unexplained weight loss
No known prevention methods	**Prevention**	Healthy lifestyle
Insulin injection, healthy lifestyle	**Treatmen**	Healthy lifestyle, possible insulin support

3.2 Interview questions: Healthcare

3.2.1 Healthcare Payers

Patient: Mohammad Ishaque Bhuiyn
Age:62
Former Private employee

- ➢ When did you realize that you have diabetes?
  - at the age of 55
- ➢ What were the symptoms?
  - Pressure,Chest pain
- ➢ When did you decide to approach the doctors?
  - After High Pressure, Chest pain
- ➢ What kind of diabetes do you suffer from?

- Type 2

➢ How much do you suffer from diabetes in general?
- Moderate

➢ How much do you suffer from diabetes in your everyday life?
- Moderate

➢ How affected do you feel by the disease?
- Moderate

➢ How did you get diabetes? (Genetics or lifestyle)
- Lifestyle

➢ What changes have you implemented to your lifestyle?
- Moderate food taking

➢ How much knowledge did you have before/after being diagnosed?
- Not that much knowledge

➢ Where do you collect your information about your diagnose?
- Hospital (Popular)

➢ How often do you have to measure your glucose level?
- Once in a month

➢ How often do you *actually* measure your glucose level?
- Once in a month

➢ Would you measure more often if the process was not invasive?
- Yes

➢ Do you follow the doctor's recommendations?
- Not that much

➢ How do you experience the routine for regular checkups?
- I have been adjusted to it.

➢ Do you experience Issues/problems with your treatment?
- I haven't faced any problem.

➢ What do you think could be improved in the field of diabetes?
- Reasonable medical cost

➢ How much do you spend on costs for your testing and drugs per month?
- 2-2.5 thousand BDT

➢ How much could you afford to spend?
- 5 Thousand BDT

➢ Do you have any gadgets or tools to measure the glucose level from home?
- Accu check

3.2.2 Healthcare Providers

Why we are approaching you for this interview:

We are working with a technology which aims to be a non-invasive device and with a sensor technology allowing us to monitor blood glucose at the capillary level without the need to pierce the skin. This is done by transmitting low-power light waves through the wrist, where the skin is thin enough for the waves to pass through the tissue. The signals are then received by a sensor in a wristband where the data about the blood characteristics within the tissue are collected and analyzed. The aim is to reduce the pain and cost and improve the convenience of testing the glucose level of people with diabetes.

Notes from interview with: a doctor and professor at Federico II University: Napoli.

- ➢ How has the research field for detecting diabetes enhanced during your career? Slow/fast?
  - The diabetes field is moving forwards every day with new innovations - many opportunities on the market and the recent focus has been on artificial solutions where the patient don't have to interact with the technology in the glucose measurement or the insulin injection process (automation/closed loop systems).
- ➢ Do you see any possibilities to improve the detecting processes for diabetes?
  - CGM is the most prominent current technology, with lots of opportunities for development. Basically a sensor to measure glucose level continuously and inject insulin when necessary (closing the loop).
  - Current methods for measuring glucose levels can be made more accurate/precise by measuring the hormone on the capillary level without piercing the skin —> and make sure that the insulin is then injected into the blood immediately (now there is a delay of 10-20 minutes when it comes to the effect of the CGM).
- ➢ Why don't people search for help?
  - The awareness of diabetes is weak (both before and after diagnosis) and patients tend to avoid/ignore implementing changes to their lifestyle (diet, physical activity).
  - Healthy lifestyle can solve the issue with type 2 diabetes, even if you are prone to get it due to genetics. Type 1 diabetes is an autoimmune disease and the same conclusions can not be made for that sort.
- ➢ What are the major challenges with detecting diabetes?
  - Diabetes is a very common and emerging disease all over the world. The problem has increased a lot in developing countries in the last decades.
- ➢ From your perspective, what is necessary to overcome these challenges?
  - A big problem is "hidden statistics": The amount of diagnosed patients could be doubled to get a better perspective of how many diabetes cases there are in the world.

- Major competing technology is the CGM and developments within that → however it can be seen as expensive methods for developing countries why other inventions are also welcomed.

3.2.3 Healthcare policy

(This interview was conducted with Chief consultant in Bangladesh institute of research and rehabilitation in diabetes, endocrine and metabolic disorders)

➢ What are the current healthcare policies regarding diabetes in Bangladesh?
- There are multiple health policies existing in Bangladesh. The major policy is the Non Communicable Disease Control Plan.
(World Bank, 2019) (Novonodirsk, 2012)

➢ Which issues or problems are currently in the healthcare policies regarding diabetes?
- The multi-sectoral approach is lagging a bit, the government and Diabetes Association of Bangladesh are taking the major role. The treatment burden to the patients is quite high due to out of pocket market (67%).

➢ If there are issues or problems, how can these be improved?
- The partnership efforts can help the problems get solved. Also the universal health coverage by 2030 is a big commitment to solve major portion of the problems.

➢ Which policy areas can be improved to increase the accessibility of diabetes detection in Bangladesh?
- Screening, diagnosis and referral system can be improved! The Upazila/Thana Health Complex and Community Clinics can have a role here. The paramedics and the associated stuffs at the rural level can be trained.

➢ Which policy areas can be improved to increase the accessibility of diabetes treatment in Bangladesh?
- The referral systems, screening as mandatory at the Thana Health Complex can help the diagnosis part. The reimbursement of insulin and digitization of the consultation could also help.
-

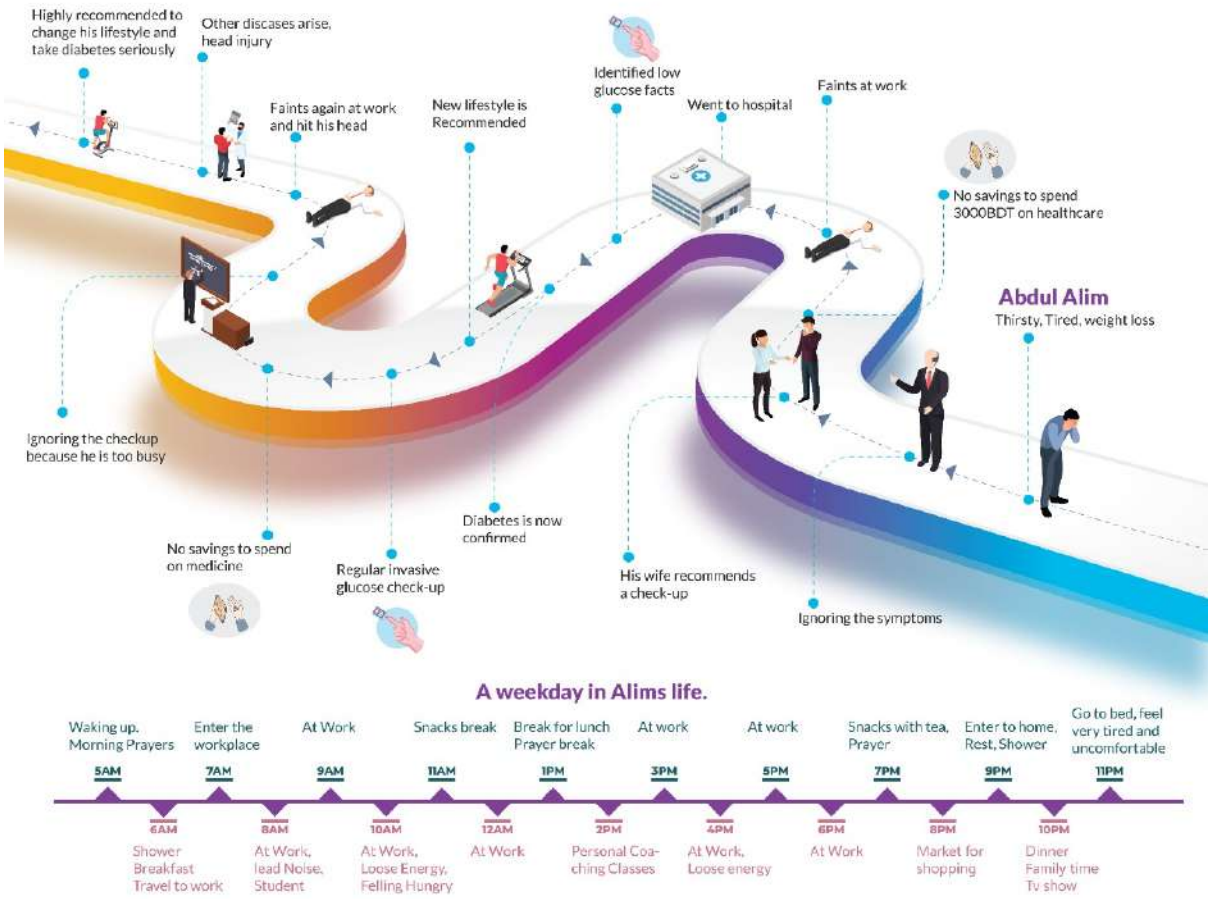
3.2.4 Technical Engineer

(Interview was done with Electrical engineer)

- ➢ Is this technology able to work by kinetic energy?
  - Yes, it's possible but it requires a battery to restore the energy.
- ➢ Which other devices require it to make it work?
  - Foldable Solar cell
- ➢ How will the micro controller work to measure the diabetic level?
  - Through fabrication of the microcontroller
- ➢ How will all the technologies work all together?
  - Integrated sensor will connect the micro controller and the sensor
- ➢ How can historical data be figured out?
  - High generation bluetooth connecting with mobile phone

3.3 Final Journey map

Based on the input from the interviewees, the final journey map was created.



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