American University *of* Armenia

Հայաստանի Ամերիկյան Համալսարան

A US-accredited institution affiliated with the University of California

Capstone project

Perspectives of 3D manufacturing

Instructor: Aleksandr Grigoryan

Supervisor: Samson Avetian

Group members: Mariam Zalumyan, Siranush Sevoyan, ZaruhiMirzoyan,

Ani Hayrapetyan, NairuiKhachatryan,

2017

CONTENT

EXECUTIVE SUMMARY

The goal of this research project is to discuss economic implications of 3D technology and understand the opportunities of 3DP adoption in Armenia. For this purpose, we firstly understand the current position of global 3DP market. Afterwards, we analyze the import structure of Armenia and show which part in the future might be substituted by this technology. Based on this, 6 hypotheses were developed about the integration of 3DP in Armenia. To test the hypotheses, a research of 3DP market of Armenia was done and number of interviews were conducted with 3DP market related companies'. Within each hypothesis research questions have been formed, answers are collected and propositions are made based on answer's analysis. On the final hypothesis an adoption strategy is suggested based on the interview analysis, about the effective implementation of 3DP in Armenian economy. The purpose of the paper is to show the opportunities of import substitution by implementing 3DP technologies. During the analysis areas are identified which have perspectives to lead to export promotion as well.

The research will be conducted on qualitative basis as 3DP market is relatively new and globally in the stage of development. Thus, there is few data available about global 3DP market and no supporting data about the domestic 3DP market.

INTRODUCTION

3DP refers to any manufacturing process which additively builds or forms 3D parts in layers from software data. The technology is significant because it offers direct manufacturing, meaning a design goes directly from you to physical product through a computer and a printer.3D manufacturing has proven to be a disruptive technology that has demonstrated an ability to expedite the speed of innovations and create products that were previously not possible. This technology changes two important economic equations in favor of in sourcing and localization. One of the problems of Armenian economy has poorly developed manufacturing, which leads to higher import proportion in trade account. There are several reasons of less developed manufacturing, such as:

- Inefficient economy of scale: Armenia has small local demand and import of final products in bulk could be more efficient and cost effective than in-house production

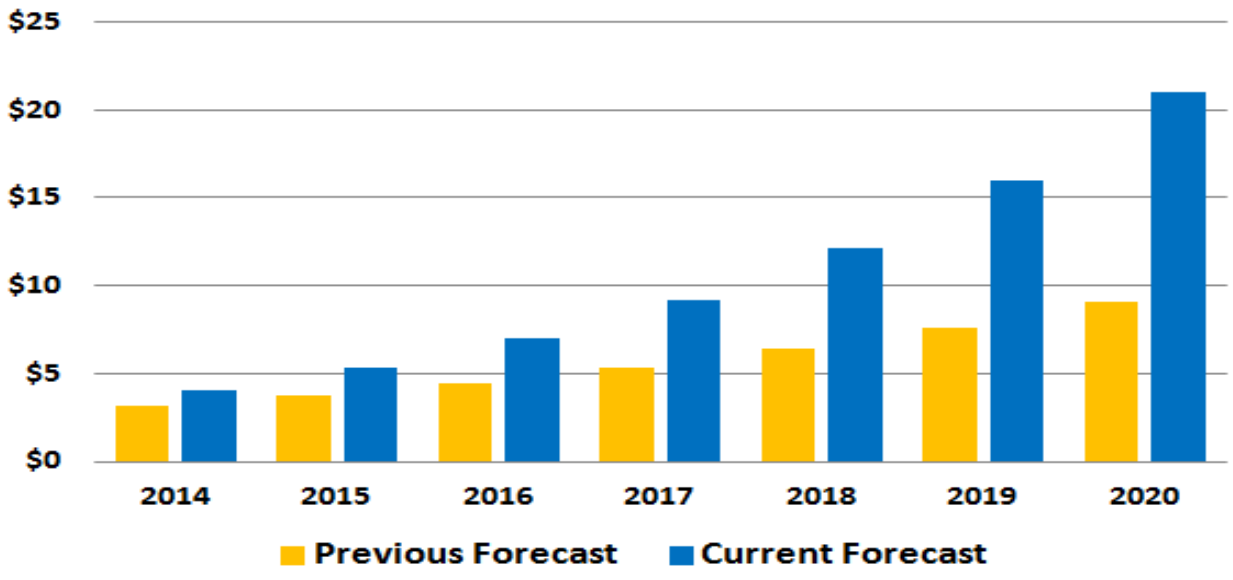
- Weak supply chain: it is away from trade centers, has few trade agreements, might face delay of raw materials, has poor infrastructure
- Inefficient logistics: Armenia has complicated geolocation.

The main objective is to understand whether 3D printers can be used to solve above mentioned problems. Armenia has already stepped in 3DP market as it has mainly privately sponsored educational institutions to develop the necessary labor base. Moreover, there are several companies which produce their own 3D printers. The two 3DP methods, which are applicable for Armenia are Fused Deposition Modeling (FDM), which builds objects layer by layer from the very bottom up by heating and extruding thermoplastic filament and Selective Laser Sintering (SLS), which uses a laser to harden and bond small grains of metal materials into layers in a 3D dimensional structure.

GLOBAL TRENDS OF 3DP

According to Wohler's Report 2015, the worldwide 3DP industry is now expected to grow from $3.07B in revenue in 2014 to $12.8B by 2018, and exceed $21B in worldwide revenue by 2020with compounded annual growth rate (CAGR) of 26.2%.[1]

Figure 1: Worldwide 3DP industry Forecast



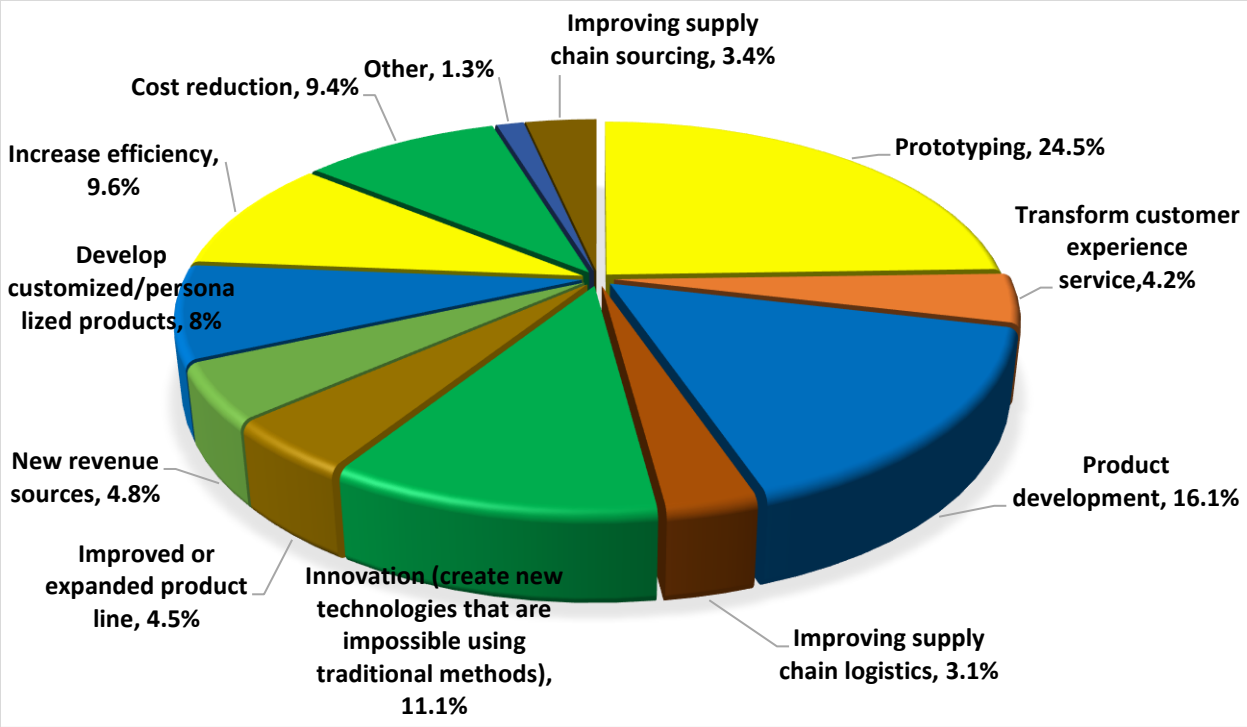
Source: Wohlers associates, Wohlers Report 2015

[1]Wohlers associates, Wohlers Report 2015

According to Figure 2, prototyping (24.5%), product development (16.1%) and innovation (11.1%) are the three most common reasons why companies use 3DP. Of those surveyed in a recent Gartner study, 37% had just one 3D printer within their organizations, with 18% owning 10 or more. The average number of printers per organization was 5.4.[2]

For Armenia3DP, as an innovative solution for economic development, can serve as a useful tool for realizing new business ideas or make traditional ones more efficient. Furthermore, the technology may assist IT companies in easing their prototyping stage and solve more customized issues for communities, thus, improve the country's trade account.

Figure 2: Reasons for Pursuing 3DP



Source: Gartner INC, The results of worldwide survey (November 2015)

PwC estimates 67% of manufacturers are already using 3DP. Of these, 28.9% are experimenting to determine how 3DP can be optimally integrated into their production processes and 24.6% are using 3DP for prototyping.[3]Siemens predicts that 3DP will become 50% cheaper and up to

[2]Gartner INC, The results of worldwide survey (November 2015)

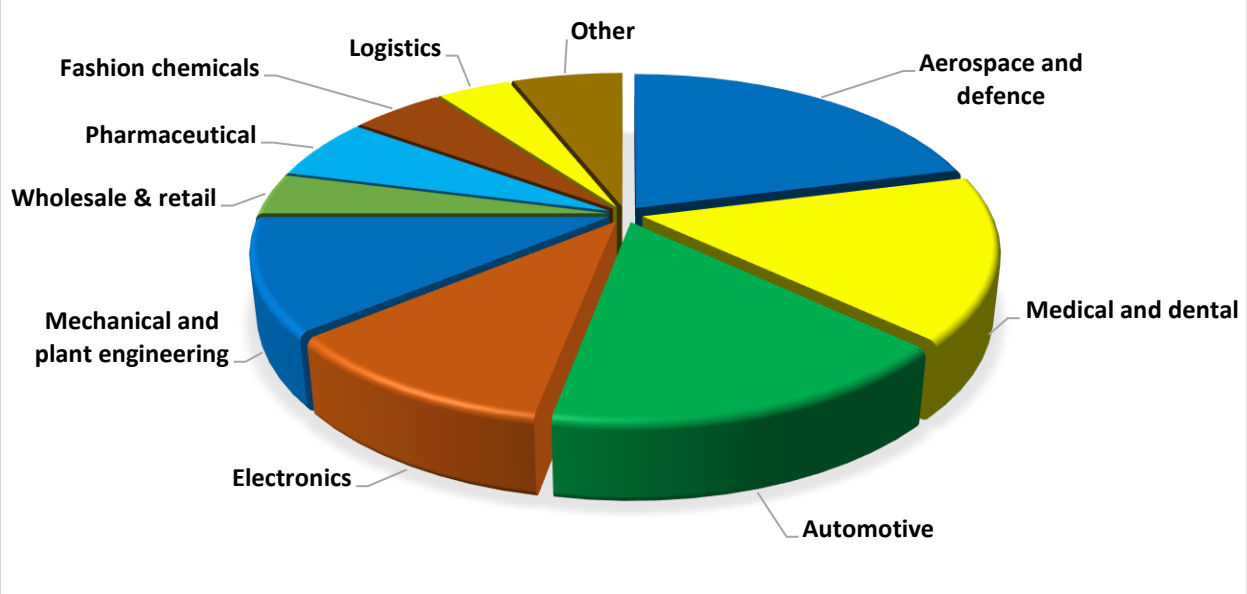
[3]PWC:Next Manufacturing: 3DP comes of age

400%faster in the next five years. Siemens is also predicting that 3DP will have €7.7B ($8.3B) global market value by 2023.[4]

Currently, according to EY analysis (Figure 3), the most developed area in the world which uses 3D printers is aerospace and defense followed by medical and dental, then automotive industry.

When thinking about Armenian market to see the opportunities in these mostly developed industries, it's obvious that the country might largely benefit when implementing 3DP in its activities in defense, as the latter is an industry with high proportion in the budget. Armenia already has a medical tourism, and new technology solutions suggested by 3DP can make this industry more efficient and profitable.

Figure 3: Most developed industries



Source: EY analysis based on 3DP survey

The automotive industry's adoption of 3DP is projected to increase from $365.4M in 2015 to $1.8B in 2023, attaining a 19.51% CAGR. The aerospace industry's adoption of 3DP solutions is projected to increase from $723M in 2015 to $3.45B in 2023, attaining an 18.97% CAGR. The medical industry's adoption of 3DP solutions is projected to increase from $721M in 2015 to $4.31B in 2023, attaining a 21.53% CAGR.[5] It is obvious that medical industry has the highest growth rate.

Among the numerous companies using 3DP to ramp up production are GE (jet engines, medical devices, and home appliance parts), Materialize NV (3DP software, medical, and industrial

[4]Siemens: Pictures of the Future (The Magazine for Research and Innovation): Additive Manufacturing Facts & Forecasts

[5]EY analysis based on 3DP survey

production), Lockheed Martin and Boeing (aerospace and defense), Aurora Flight Sciences (unmanned aerial vehicles), Stratasys (aerospace, dental, medical and automotive), Invisalign (dental devices), Google (consumer electronics), and the Dutch company LUXeXcel (lenses for light-emitting diodes, or LEDs). 3D Systems Corporation (multi-jet printing, color jet printing, direct metal printing and plastic jet printing).

IMPORT STRUCTURE IN ARMENIA AND POSSIBILITIES OF IMPORT SUBSTITUTION

When a country persistently experiences a trade deficit there are predictable negative consequences that can affect economic growth and stability.

- **Employment**: Domestic jobs, especially in manufacturing, are lost to those abroad.
- **Currency Value:** Trade deficit is an indication that a nation's currency is desired in the world market and the value of a currency should decline. If Trade deficit becomes structural there are risks of abrupt adjustments.
- **Interest Rates:** A sustaineddownward pressure on a country's currency devalues it, which can lead to inflation and is thus counteracted by restrictive monetary policy the central bank increase interest rate which can put a damper on economic growth.
- **Foreign Liabilities:**Deficit nations experience a greater degree of foreign ownership of government debt and in some cases, suboptimal foreign investment. The large proportion of the Armenia's assets and resources become owned by foreigners who can then control and influence how those assets and resources are used.

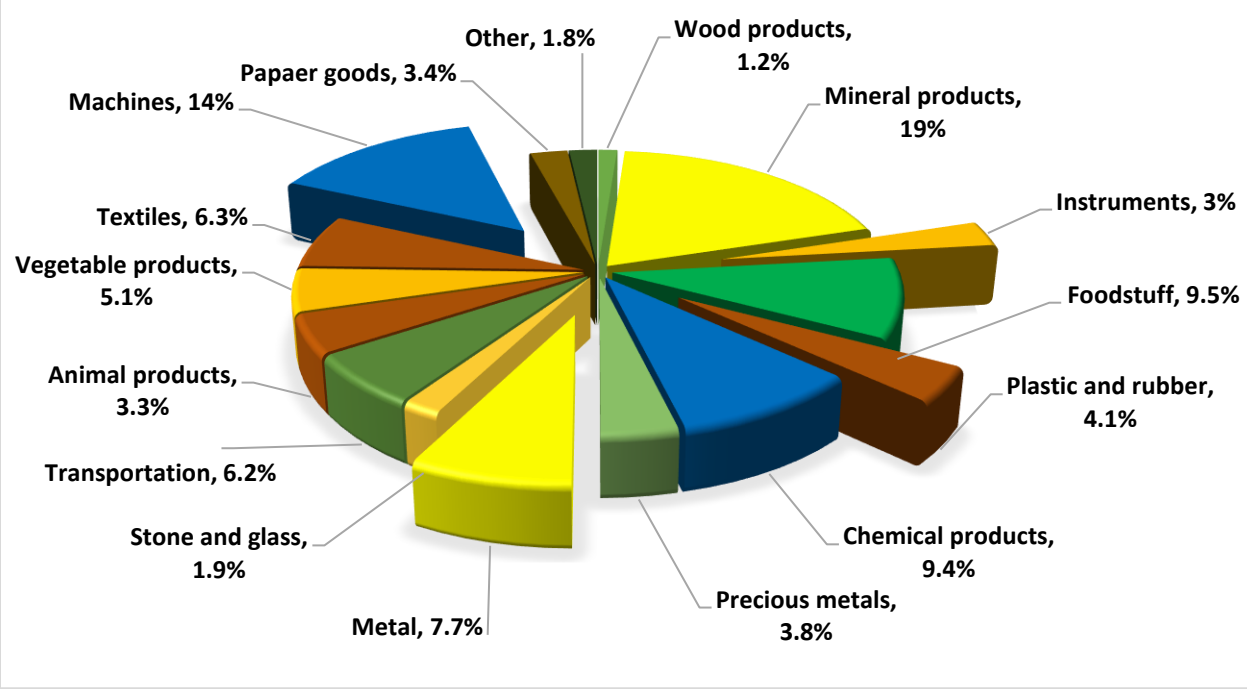
To have deeper understanding about perspectives of import substitution strategy the Armenian import structure has beenanalyzed. During the last 5 years Armenia have had average trade deficit of $2,456,616,667. It has a descending trend over those years, reaching its minimum in 2016. With export value of $1,782,900,000 compared to $3,292,400,000 of import value, trade deficit was $1,509,500,000in 2016.The trade balance as a percentage of GDP over the last 5 years is -17.2%, compared to Georgia (-19.8%), Turkey (-2.8%), Kazakhstan (3.8%), etc.[6]

After conducting and analysing the interviews with Armenian 3DP market key players, the list of imported commodities has been analysed and the products that can be 3D printed have been identified. These include mainly accessories and parts of machines, instruments from plastic and metal.

[6] armstat.am

In Armenian import structure the largest proportion compile mineral products with 19% proportion, followed by machines (14%), foodstuff (9.5%), chemical products (9.4%). While 3D printable products regard to the machines (14%), metal (7.7%), instruments (3%)and plastic and rubber (4.1%)(Figure 4).[7]

Figure 4: Import structure of Armenia in 2016



Source: atlas.media.mit.edu

3DPmight have the potential of decreasing import volume in Armenia. In Appendix 1 it is estimated that approximately the products and particles with value of $167,544,900 may have the capacity to be in-house printed. This will decrease the import by 5% leading to the decline of trade deficit by 11%. Thus, there is an opportunity of applying 3DP in these industries, which in their turn will boost local production, and decrease import by replacing with 3D printable portion.

On the other hand, 3DP might contribute in increasing the export volume in Armenia. Medical industry is one of the fields that will benefit from the 3DP implementation, thus boosting the export of medical services by developing 3D printed prosthesis, implants, stents, etc. through medical tourism. 3DP technology can promote hardware production, as well, thus resulting in increase of exports in trade balance.

[7] atlas.media.mit.edu/en/profile/country/arm/#Imports

HYPOTHESES AND ANALYSIS

As a result of our research of this industry we identified that there is already 3DP market in Armenia which is operating for 2years. There are companies which use 3D printers in their activities. Moreover, understanding the importance and the trend of the technology, there are companies which are engaged in the production of 3D printers, and companies which use them for educational purposes, such as Armath engineering labs, which provides free technological education to schoolchildren. As the market is newly established with limited number of participants who are aware of all the insights and nuances of the technology, all of them have been interviewed to get profound comprehension of the industry.

Hypothesis 1: Can 3DP lead to import substitution?

Answers

By the view of Vahagn Poghosyan, the CTO of Instigate, 3DP can be a good fit to promote the internal manufacturing development. This can be manufacturing of particles of broken equipment or defective products not to throw them away and import new ones or to visualize new and customized ideas.

Artur Khojabakhyan the CEO of Augmentar mentioned that "Armath" students already have useful and practical achievements with the help of 3D printers, which further can lead to domestic printing of more and more products:

- Truck door handle, which is hard to find tool in the market,
- Bullet containers to be used in army,
- Beehive ventilation system,
- Intellectual 3D printed games, which are already being sold in a store opened in Goris.

According to him these kind of small steps can become a trigger to bigger breakthroughs and might lead to import substitution.

In the opinion of Hrachya Khachatryan, the CEO of Symotec LLC, their company is already experimenting with printing robotics particles in-house with the help of "Armath" labs, instead of buying them from China as they did in the past. For example, "Armath" children3D printed different parts of "SeRob" robot, e.g. the sensors, which reduced the costs more than 5 times (from $40 dollars to $8). Another example was the 3DP of the frame of the controller of "SeRob" robot. These robots are already being exported moreover.

Analysis

Based on these observations the following factors are inferred, which will lead Armenia to trade deficit reduction:

- Students of "Armath" labs, which afterwards will become necessary engineering specialists and will spur the spread of domestic production of 3D printable products.
- 3D printers can be viewed as means to develop start-ups, which will be base for future business ideas development.

As it is concluded from the interviews that "Armath" itself may locally print both:

- hardware products, e.g. robot particles,
- basic, routine products and selling them in shops of their neighborhood.

On the other hand, it's not right to focus on specific industry to find the opportunity of manufacturing with 3D printers for import substitution. The technology itself can make a firm ground for future manufacturing in Armenia and will help to reveal exciting problems and provide customized solutions. Another supporting factor might be increasing global trend of 3DP usage and development, which will lead to the availability and affordability of global experience. Based on these the country can get a chance to shorten import and increase self-sufficiency in the long run, thus, the hypothesis is accepted.

Hypothesis 2: Can 3DPbring opportunities for Armenia in high technology manufacturing?

Purpose: find out the possibilities of prototyping by 3DP and the economic benefits it can bring in high technology manufacturing and in start-up idea realization.

Answer

Vahagn Poghosyan, the CTO of "Instigate" responded that 3DP a prototype is often more affordable than contracting a manufacturer to do it. Particularly with low quantities of production, producers or inventors of start-up projects can rapidly design, print and test a product. Vahagn mentioned 3DP as a new solution for the ICT sector, which can become a beneficial tool to address problems of visualising innovative ideas which may stay on paper because of being costly or not having a chance to be produced as of being complex. In this way, the producer will get a chance to manufacture in very small scales both to check the quality of the product and to estimate the market demand. Moreover, this can help in investment attraction process as the potential investors can not only listen about the idea but also try it in practice. 3DP can serve a ground to be used in engineering laboratories in printing equipment and particles. "Instigate" already has an experience of using 3DP in the creation of particles for robotics and drones.

Another representative of IT market in Armenia "Van technologies" has already an experience of utilizing 3DP in their business of automation systems development The company makes 3D printers in-house and uses them in the testing and production process of the particles of its automation system equipment.

3DP can become beneficial for start-ups too, as it allows ideas to develop faster than ever, thus reducing the time to market and costs. The Armenian start-up ideas presented in Global Cleantech Innovation program mainly addresses renewable energy issues. The teams invented diverse innovative technologies to reduce energy and water waste, solar systems to get or renew energy. These start- ups responded that 3DP technology can be efficiently utilized in their projects.

Analysis

From the points discussed above, it can be derived that 3DP for prototyping in high technology manufacturing enables entrepreneurs to verify, test the design for fit and function, detect costly errors, understand market demand before it goes to mass manufacturing. Prototyping by 3DP at

the same day it was designed, shrinks high technology manufacturing from what might have been months to a matter of days. This helps IT companies stay one step ahead of the competition. Bringing rapid prototyping to the 'masses' will most likely have a large effect on creativity and innovation as well. So, potentially, rapid prototyping can also lead to more value creation in IT. As 3D printed prototype's costs are small, even negligible and the technology eases the prototyping process, the number of IT start-ups in Armenia can be boosted. All the ideas have a potential to become revolutions both for local and global markets. In bringing the ideas to life, 3DP can serve a useful tool for all the start-ups to both prototype the parts or make complex particles. Thus, 3DP plays a significant role by saving time and a lot of resources for the companies. IT sector has an immense export potential and may have significant contribution in the growth and development of the economy of Armenia. As a conclusion, the hypothesis is accepted, as the value captured from 3DP integration in high technology manufacturing can be economically substantial.

Hypothesis 3: Can 3DP integration in education system throughout "Armath" labs and "Real" schools be beneficial for Armenia's future?

Purpose: The purpose of the research over the importance of the education on 3DP and vice versa is to reveal if 3DP can become a promising and ground-breaking innovation that will assist in the fulfilment of a productive educational experience and to see how the education can boost 3DPculture in Armenia.

Answer

The interview with co-founder of UITE Karen Vardanyan shows that a huge work has already been done in the sphere of technological education to make a firm ground for future development and integration of 3DP in Armenian economy. In his opinion this type of manufacturing is to become an innovative solution for diverse industries and it's the exact time to enter into the development cycle of 3DP technologies. Karen Vardanyan thinks, it's not right to focus on specific industry to find the opportunity of manufacturing with 3D printers, but address the global problem, which is the research and development of the technology and stay compatible globally. In his view the inclination towards education through educational labs and programs is a favourable ground to get ready for 3D printer market revolution. With the ongoing efforts of UITE, Armenia already has more than 200 specialized "Armath" labs, to be involved in engineering research and development process to get skills required to use 3DP technology for the benefit of their communities. These engineering labs with about 5,000 students provide free technological education to schoolchildren. Laboratories are equipped with the high-quality 3D printers, mini-computers, robotics kits and other devices produced in Armenia. The computer programs and systems are "armenianized" to the extension possible, as the priority is given to the local producers. By 2019 the number of labs is expected to surge to 1200 all over the country and special attention is given to the engagement of cross border communities of Armenia. The main goal of this project is to assist young generation in their early interest emergence in modern high technology in order to promote the development of engineering state of mind from early ages and to prepare competent students who can practically apply gained knowledge and skills for revealing and communicating more specific issues in these communities.

Instigate also, with UITE, now establishes "Real Schools" in Armenia to make it possible for young generation not only to become aware of technology usage but to create it from scrap,

which will help to boost 3DP and engineering sector by having prepared human capital base for future development.

Moreover, Entrepreneurship and Product Innovation Center (EPIC), which aims to develop knowledgeable and efficient entrepreneurs to address global and local needs, has established 3DP laboratory in AUA for R&D and educational purposes.

Analysis

The development of engineering labs and having tech savvy individuals mostly in rural areas, is a serious investment for future to be able to face and solve every day local problems with the help of 3D printers**.** The educational skills that are gained now will boost engineers to make or import 3D printers for establishing their businesses, thus developing the 3DP market, e.g., there are no specialized shops for parts, particles, tools in villages and those can be locally printed to make the business process and overall life easier. In future, this young generation will be enough experienced to utilize their knowledge in making customized staff and open 3DP shops or centers to support local needs. These shops will ascertain the availability of important components for diverse fields which will lead to ongoing productivity in communities. The 3DP market development through the engineering education will bring to establishment of new and innovative businesses in IT. These new businesses, that create most employment and productivity, may put Armenia on more compatible level, will move employment from unproductive sectors in regions to more productive via the new tech savvy generation – and thus will increase employment in the country. In addition, the productivity increase of IT sector can bring to the development of education, agriculture, manufacturing and later result in the creation of workplaces.

The hypothesis is accepted, as the primary driver behind innovation and development in the 3DPindustry is coming from education. The strength and effectiveness of the links created between existing educational centres and business sector can later create new economic opportunities.

Hypothesis 4: Can 3D metal printing bring benefits to Armenia?

Purpose: understand to what ends can 3DP reach in Armenia besides plastic products, identify sectors where it can bring the most benefit and what economically beneficial perspectives can it reach, in order to diminish the trade deficit.

Recently Lt Pyrkal, a Greek-Armenian company, was in a process of building a 3D metal printer working by laser, with a Canadian 3D printer producer Zecotek. These paved a groud for this research project to meet and understand the potential of this company.Lt Pyrkal is R&D and production company, specialized in crystal growth, laser accessories and components, lasers and systems.

Answer

During the interview Lt Pyrkal company identified the perspective of metal 3DP for Armenia in prosthetics and dental industries. By the view of the company the 3D metal printers are not designed to substitute traditional manufacturing, they are only to print complex parts in aerospace, auto or medical industries in place. In the opinion of the company's CEO Gagik Buniatyan and General Engineer Tigran Sargsyan the possible strategy of 3DP integration into Armenia is through importing 3D metal printer, which can print implants and prosthesis. On the initial stage importing printer might be beneficial, because local low volume production of printers will be expensive, requiring huge investments. At first one printer can be imported, which will help to spread the culture of 3DP, by showing the benefits of high quality, efficient customization and the reduction of time per client to the doctors. Afterwards it will become obvious weather there is a demand for 3D printed implants and prosthesis. Besides local demand, the company foresees that this technology integration will foster medical tourism in Armenia as well.

By having solid experience in working with laser the company estimates several scenarios after initial purchase in case of metal 3DP development in medical industry in Armenia:

- Start producing printers locally,
- Buy parts and build printers locally,
- Provide supporting services: produce printer parts, supply printer raw materials, provide laser parts.

Analysis

As a result of the interview, these are the main factors, which indicate 3D metal printing implementation to be successful in Armenia:

- For medical procedures Armenia has competitive pricing and services actually are more affordable compared to European countries.
- Besides traditionally manufactured prosthesis having high costs caused by the need for each device to be custom made for the patient, the 3D printed prosthesis can reach significant cost reductions.
- In case of implants, 3D printed tooth implants can reach precise individual customization via 3D scanning technology, which is currently common in Armenia.
- The presence of this company in our country, specialized in this technology, is also perceived to be another advantage. The company can bring benefits, as it is familiar with the technology and can support the integration process.
- Another factor is the vast availability of inputs (metals) in Armenia.

Besides Lt Pyrkal's suggested implementation of 3DP to print implant and limb prosthesis, there has been analyzed by our Capstone Group that metal 3D printers are excellent in printing heart stents. The printed stents are flexible, can be customized for patient’s specific anatomy, while nowadays ill-fitting stents are failing frequently. Today Armenia is distinguished with its heart surgery services and the implementation of 3DP can add competitive value to this sector.

Based on the interviews and growing number of medical tourists, it can be concluded that 3DP is a decisive strategy in this sphere, because it might promote medical, mainly dental and heart surgery, tourism in Armenia. As a conclusion, the hypothesis is accepted, meaning that the implementation might be visible. As a consequence, 3D metal printing might become an important factor in contributing to the development of the country’s economy.

Hypothesis 5: Can Armenia have perspectives to become 3D printer producer?

Purpose: estimate the consequences of producing domestic 3D printers. It is to show that by having a local producer, Armenians will stand more close to the technology, which will foster local production of routine products and at the end bring to import substitution.

Answer – Augmentar CJSC

Augmentar is Armenian company which is engaged in the production of 3D printers and designing of other digital managing devices in Goris. The main goals of its establishment are to support the development of IT sector in Syunik region, to participate in educational initiatives and to organize training courses for the field specialists.

The company's perspective is to become international 3D printer producer, as their printers have quality similar to Europe, with much lower prices comparing with European and Russian analogs. However, annually only 80 printers are produced, while having current annual capacity of producing 350 printers. The main customers are "Armath" engineering laboratories and a few number of 3D printers are sold to IT companies which use them to develop engineering way of thinking of their employees, individuals who buy them for educating purposes of their children and fanatics who are inspired by this new trend. From the company's point of view, the factor, which hinders the evolvement of Armenia as a 3D printer producer is low local demand, which is not sufficient for reducing the costs and making printers more affordable. The company believes that idle capacity usage solutions can be found by:

- **Boosting local demand.** The founder of Augmentar noted that for this purpose it is crucial to increase awareness about 3DP technologies in the society and to show the opportunities offered by the usage of the technology. Currently steps are already taken, such as in 2016 the company participated in Digitec Expo and World Vision exhibitions in Kapan and Goris where people demonstrated huge interest and were surprised to see the 3D printer's working process and results. Another step was the introduction of extensive warranty period of 2 years to promote the purchase of local brand. Moreover, company decided to create educational videos to show all details of better printing, which will improve effectiveness of printing, resulting the better integration of technology.
- **Foreign markets penetration.** Besides its competitive advantage in terms of price and quality, the company recently made a major adjustment to its production part to reach higher efficiency and enhance the existing standards.

Another goal which the company has is to increase awareness about the printers especially in business sphere by introducing details which can be printed by 3D printers and by selling printed parts.

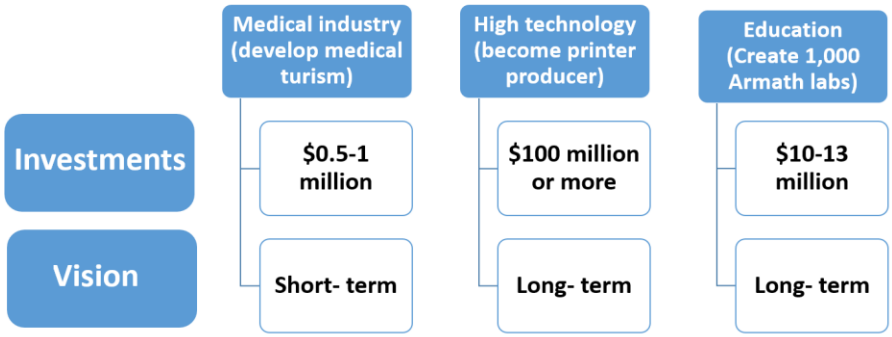
Answer – Lt Pyrkal CJSC

During the interview Lt Pyrkal CJSC highlighted that in the long run Armenia has a perspective to become 3D metal printer producer. In the opinion of the company's CEO GagikBuniatyan and General Engineer Tigran Sargsyan the company needs to mass produce printers in order to become metal printer producer. By the view of the company Lt Pyrkal has the potential of entering the market with innovations, lower prices and attract market shares. The company knows how to efficiently work with laser, given its experience of decades. Recently they have investigated the features of titanium, which allows them to come with new ideas of improving raw materials used in 3DP. Thus, the company has solutions of process enhancement and innovation of 3D metal printing, but the problem within the company is that it lacks investments to put the printers into mass production.

Analysis

After conducting these interviews, we came to the conclusion that Armenia may have significant unrealized potential to become one of the producers and exporters of 3D printers to offer new and comprehensive solutions in this technology environment and introduce to the world its innovative engineering ideas. Moreover, in-house production of 3D printers will change local's perception, as they will start to recognize that these kind of technologies are made in Armenia. Further to foster the process, it is necessary to take steps towards right positioning and awareness enhancement through all information sources. This will become a trigger to spread the 3DP culture, leading also to an increase of local demand towards domestic printers. It is anticipated that by getting known to these technology people will implement their ideas. Thus, based on these observations the hypothesis is accepted**.**

Figure 5: Perspective and investments needed for 3DP integration



Hypothesis 6: Can 3DP be integrated in Armenia via joint use of printers in communities?

Purpose: is to understand the ways 3DP can be integrated in Armenia.

Answer

From the opinion of Augmentar CJSC CEO, the integration of 3D printers in communities to solve the routine problems is a valuable idea. To facilitate the implementation process, CEO suggested to use the network of "Armath" engineering labs and the skills of instructorsworking there.

Karen Vardanyan stated that the aim of "Armath" lab itself is to promote the technological advancement in diverse communities to make professionals who will later address the local, customized problems with the help of 3D printing, thus, revealing and communicating more specific issues in these communities.

In the opinion of both of them this network itself is sufficient at the beginning stage of 3DP community establishment, without a need to create a separate association giving printers for mutual use.

Analysis

The suggested strategy is to promote broad adoption of 3D printers. This is to show that 3DP for development is a bottom-up contribution, so the perspectives of the technology via community action project are demonstrated. The idea is to put team printers in communities, which users can share. The aim is to show that founding 3DP job shops in communities across all regions will be a crucial step to integrate this technology into Armenia, as it will support integration of 3DP into their daily lives. People will unite in communities to 3D print broken parts of their everyday objects (e.g. handle of a refrigerator or a chair) and/or visualize their new ideas in niche markets. The goal is to force 3DP to interface even more closely with routine problems and find spontaneous solutions to fix them. It is anticipated that these job shops will reverse society's norms of importing particles, products from foreign countries by having the possibility to print objects locally through these communities. As a result, people will have the ability to create and sell printed parts and products that were once out of reach or out of range. Moreover, this platform's aim will be to create a house for start-ups, accelerator programs, hackathons and other tech events to boost innovative ideas created with 3D printers.

Principles and steps of 3DP integration via raising awareness of 3DP throughout Armenia are:

1. Create communities across regions in Armenia, which will unite innovation and technology driven people in all regions.
2. Give computers, 3D printer and open source software to each community.
3. Inform and educate the groups in those communities by providing useful content.
4. Share created ideas across communities.
5. Organize competitions to promote innovation and reward the best ideas.

Creating small 3D printer job shops is a common practice in Global South. Thus, with community job shops 3DP will be integrated into Armenia's culture. Moreover, there can be organized some competitions for the innovators who will be rewarded for the most feasible development projects in their communities. Later the most successful ideas can be mass produced through traditional manufacturing.

Preconditions of 3DP technology integration through communities

The supportive part in this process is the existence of the well- established online networks that include hosts of worldwide amateurs and experts all sharing their know-how. Open source projects from thingiverse.com and programs from ardoino.com can be supportive for communities. Thingiverse is the biggest social network devoted to 3DP technologies. It is created for the purpose of discovering, creating and sharing free of charge 3D modeled products which can be downloaded and printed no matter what experience do the person have. Ardoino is a peer-to peer platforms, which offers open source and extensible software and hardware. Thus, this can eliminate difficulties regarding finding necessary part designs and significantly ease the process of printing.

Benefits of community 3DP

Community 3DP can result to:

- Reduction of imports by the proportion of 3D printed products
- Rapid prototyping in small quantities
- Promotion of new ideas and innovations
- Protection of business ideas. Innovative ideas will not flow out of the borders of Armenia
- Equal development across the regions, by spreading innovations across communities, as a result of peer–to–peer contribution
- Possibility to trade the works of the innovators in Armenia and to export them as well.

Difficulties in 3DP technology integration through communities

The two main obstacles to employing 3DP through communities are:

- The cost of printers,
- The culture of people. The difficult part will be to change the perception of Armenians towards domestically produced products. It will take time driving people to local production.

3DPopportunities

3DP perspectives in Armenia for the near future are:

- 3D printed tiny motors that can harvest sunlight, in other words custom solar trackers which can be angled to match the sun's path, with the help of 3D printed mechanism,
- 3D printed support systems (from plastic) for orchards in agriculture,
- 3D printed vents or cooling fans of different sizes,
- Bicycles.

The innovation of community 3D printers, which users will share, might be a primary candidate to foster mass adoption. This would lead to 3DP ecosystem development in Armenia and later could meaningfully set the grounds and contribute to import substitution in the future. Thus, the hypothesis is accepted.

As a conclusion in the short term "Armath" network can be used for creating a 3DP community, while later, the graduates of "Armath" labs will buy/build more sophisticated printers and build community job shops. Again there are no future cost estimations for establishing the communities, as the technology changes rapidly changing the prices in parallel.

CONCLUSION

This report shed light on some interesting trends in 3D printing and reveals how this technological innovation can impact the economic development in Armenia. In conclusion, the emergence of 3D printers has been making a large impact on the world today and inevitably on the future, world changing applications for 3D printers are being developed, and Armenia is in great need to start getting ready to step in this new era of technological advancements. When thinking forward about the readiness of Armenia to technology revolution, it's derived that the establishment of engineering and technology schools are a fundament for future success. This approach will enhance the knowledge and prepare a tech savvy generation for solving both local and global problems.

Rapid prototyping, as a process of making models and prototypes from 3D data using 3D printing technologies is another benefit Armenia will get form 3DP. The 3DP technology is fast, cost efficient and offers, at the same, a good quality to build the first working prototype of a future product, which will help to test form, fit and function to make the parts of an assembly, put them together and see if they fit properly.

When looking for real application to apply 3DP as a solution for Armenian economy, it is observed that agriculture and rural areas are the main aspects to be considered and the creation of technologically advanced communities will help to address local and customized problems which in their turn will benefit in stepping a level up in the development process of this rather undeveloped areas.

The research shows the possibility to have the consumer products printed with prevailing low-cost Armenian 3D printers. The expansion and adoption of the 3DP culture across communities will later help both businesses and consumers address printing requirements and performance needs. Moreover, adoption of 3D printers might be subjected to the realization of new innovations and ideas. As printers and products are proven successful in specific markets, the cumulative impact might expand when the technologies will be brought to scale. Given the domestic, low-cost production of 3D printers and the business conditions in Armenia, widespread market penetration of 3D printers and 3D printed parts in Armenia is estimated to be applicable in the near future. As the technology matures, market acceptance will determine if 3D printers and 3D printed products will become valued.

3DP can improve trade deficit both by reducing 5% of imports and promoting export. These supporting factors have been identified during the research:

- ✓ Having necessary engineering base
- ✓ Using 3DP for prototyping in IT companies
- ✓ Using 3DP to develop IT start- ups
- ✓ Having in-house production of 3D printers (plastic and metal)
- ✓ Using 3DP to develop medical industry (printing stents, implants)
- ✓ Creating communities who may locally print routine products.

Thus, 3DP can be perceived as trade deficit reducing mechanism.

BIBLIOGRAPHY

[1]Wohlers associates, Wohlers Report 2015

[2]Gartner INC, The results of worldwide survey (November 2015)

[3]PWC:Next Manufacturing: 3DP comes of age

[4]Siemens: Pictures of the Future (The Magazine for Research and Innovation): Additive Manufacturing Facts & Forecasts

[5]EY analysis based on 3DP survey

[6]armstat.am

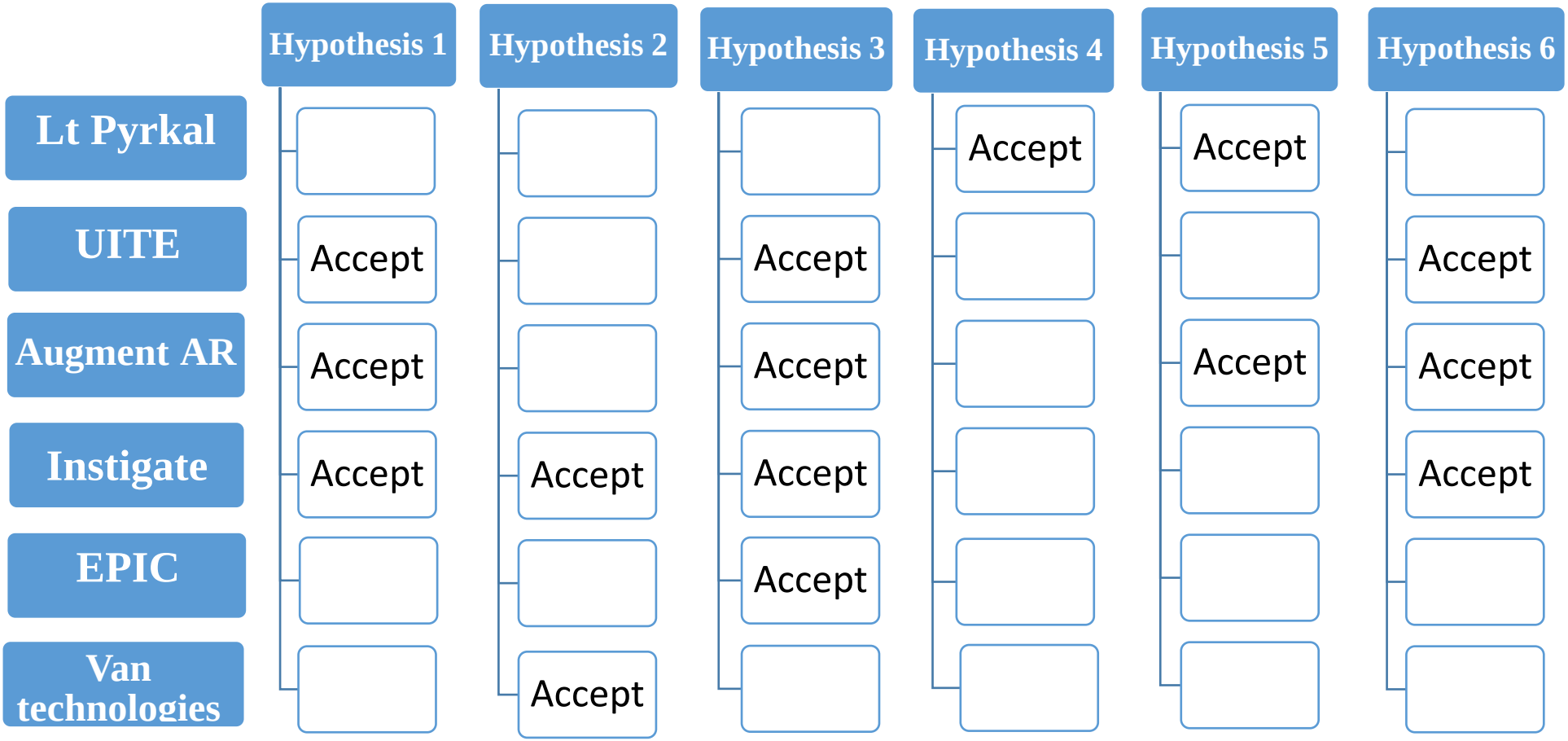
[7]atlas.media.mit.edu/en/profile/country/arm/#Imports

Appendix 1

3D printable commodities in 2016	in tones	in 1000$
Monofilament (>1mm), rods, etc, of plastics	963.8	2096.3
Plastic tube, pipe, hose and fittings	1790.2	5596.4
Plastic floor, wall or ceiling covering, roll or tiles	472.9	906.1
Self-adhesive plates, sheets, film etc of plastic	837	2545.5
Plastic plate, sheet, film not cellular, reinforced	5292.4	11406.3
Plastic plate, sheet, film, foil, strip, cellular,	1612.1	3439.8
Bathroom wares, of plastics	401.5	1472.9
Containers, bobbins and packages, of plastics	3518	7704.2
Plastic table, kitchen, household, toilet particles	1639.3	3411.9
Plastic particles for use in construction	459.5	2050.4
Plastic particles	1864.4	7796.4
Rubber plate, sheet, strip, rod etc,	381.9	1193.7
Waterproof footwear, rubber, plastic (Wellingtons etc)	265.9	288.7
Hot rolled bar, rod of iron/steel, in irregular coils	5203	2234.8
Iron/steel bar, only forged hotrolled drawn, extruded	31735.1	13490.3
Bar and rod of iron or nonalloy steel	1730.4	1040.1
Angles, shapes and sections of iron or nonalloy steel	4785.6	3187.2
Wire of iron or nonalloy steel	4105.8	2562.9
Bar, rod, stainless steel, angles, shapes/sections	16.9	36.9
Base metal fittings for furniture, doors, cars/etc.	1966.6	6015.4
Office staples, binder fittings, paper clips etc.	96.2	215.8
Base metal bells, ornaments, pictures, mirror frames	38.5	252.2
Flexible tubing of base metal	40.9	319.9
Clasp, buckle, eye, etc for clothing, footwear, bags	57.3	1100.4
Stoppers, caps, lids, crown corks, etc off base metal	866.2	3180.2
Air conditioning equipment, machinery	895.1	6250
Refrigerators, freezers and heat pumps	5572.7	4000
Machinery, nondomestic, involving heating or cooling	700.3	7145.3
Harvesting, produce cleaning and grading machinery parts	1333.9	2300.4
Milking machines and dairy machinery parts	38.7	519.9
Feedstuffs, poultry, beekeeping machinery particles	370.4	1231
Clean, sort, mill seed, grain, dry legumes machinery particles	16.5	147.7
Machinery, apparatus, equipment for print preparation	85.3	884.7
Weaving machines (looms) particles	2.6	5
Parts and accessories for machine tools	84.5	351.2
Parts, accessories, except covers, for office machines	82	1392.5
Parts for electrical switches, protectors, connectors	75.8	1187.1

Parts and accessories for motor vehicles	4832	15455.6
Baby carriages and parts thereof	610.8	696.8
Parts of aircraft, spacecraft, etc	285.2	172.7
Parts, accessories for optoelectric instruments	0.7	103.6
Seats (except dentist, barber, etc chairs)	1841.9	7648.5
Medical, dental, surgical, veterinary furniture, parts	99.3	587.9
Other furniture and parts thereof	4795.8	16222.7
Lamps and lighting fittings, illuminated signs, etc	1614.8	7043.2
Othertoys, scalemodels, puzzles, etc	1574.5	4853.5
Articles for funfairs, table and parlour games	159.7	954.2
Buttons, press and snap fasteners, etc	36.4	979.9
Slide fasteners and parts thereof	88.9	3504.9
Smoking pipes, cigar and cigarette holders, parts	19	41.6
Combs, hair slides, pins and similar ornaments	55	225.6
Vacuum flasks etc, parts thereof except inner	75.3	94.7
TOTAL	**95,489**	**167,544,900**
Total import in 2016		**3,290,000,000**

Appendix 2


Hypothesis 1
Hypothesis 2
Hypothesis 3
Hypothesis 4
Hypothesis 5
Hypothesis 6
Lt Pyrkal
UITE
Augment AR
Instigate
EPIC
Van technologies
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept
Accept