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Recycling concrete construction and demolition wastes: a financial feasibility model

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"RECYCLING CONCRETE CONSTRUCTION AND DEMOLITION WASTES: A FINANCIAL FEASIBILITY MODEL"

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Abstract

RECYCLING CONCRETE CONSTRUCTION AND DEMOLITION WASTES IN THE MIDDLE EAST: A FINANCIAL FEASIBILITY MODEL

The construction industry is a very dynamic field. Every day new technologies and methods are invented to speed up the process and increase its efficiency. Efficiency briefly is the measure of the resources used with regards to the actual product being produced. Hence, if a project uses fewer resources it will become more efficient.

This thesis examines the recycling of concrete construction and demolition (C&D) waste to reuse it as aggregates in other structural applications for projects in Egypt. This study focuses on the technical and financial components of concrete recycling plants emphasizing on the three main types of concrete recycling plants; stationary, mobile and traditional plant settings. All plant types are designed and compared for different types of recycling projects. The machinery used in the plant is being analyzed technically and financially according to capacity, production rate, country of origin, etc. All the data is extracted from experts in the field and evaluated by university professors and engineers from relevant disciplines. The data is gathered from national and international sources, through numerous interviews, meetings and site visits. The following visits were conducted to extract information to be used in the model, a site visit to a stationary plant in Madrid, Spain, recycling research center in Madrid, Spain, site visit to a mobile plant in Paris, France, interview with director of recycled aggregates, Paris, France, and traditional plant in 6^{th} of October, Giza, Egypt.

These findings are gathered and grouped to obtain a comprehensive cost-benefit financial model to demonstrate the feasibility of constructing a concrete recycling plant in Egypt. The type currently being implemented is the traditional one, however, according to the calculations of the model presented in this thesis, the mobile type has generated the most profits among the other types, stationary and traditional. Furthermore, a sensitivity analysis is conducted to provide verification on the model. The exercise of the sensitivity analysis is a change in parameters and then the results are logically tested to verify the correctness of the model. Therefore, the sensitivity analysis is conducted on the mobile type by selecting and maneuvering the expense with the highest impact by -20%, -10%, 10% and 20%. The sensitivity analysis showed that administrative, salaries and cost of goods sold expenses had the most impact on the model. Nevertheless, the case study is conducted to validate the model. The case study at hand is the traditional plant of 50 TPH, in 6th of October, Giza, Egypt. The plant's actual revenues, expense and profits are compared with the same result produced from the model. The actual results available are for the first three years. They are close to the forecasted results, more discussion is available in text.

Moreover, a developed user friendly model specialized to forecast revenues, expenses and profits is available in softcopy to be used by any user to help him/her in taking decisions related to his/her investment. In addition, a recommendation is presented to guide investors and contactors when choosing the suitable and most profitable type of equipment based on the project type.

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List of Abbreviations

BEAM	Building Environmental Assessment Method
BCA Green	Mark Singapore Building and Construction Authority Green Mark
BREEAM	Building Research Establishments' Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CDW	Construction and demolition waste
CD&E	Construction Demolition and excavation
CEDEX	Centro De Estudios Y Experimentacion De Obras Publicas
CHPS	Collaborative for High Performance Schools
COGS	Cost of goods sold
GBAS	Green Building Assessment System
GG	GREEN GLOBES
GGHC	Green Guide for Health Care
GRIHA	Green Rating for Integrated Habitat Assessment
GSBC	German Sustainable Building Certification
HQE	Haute Qualite' Environnementale “high Quality Environmental Standard”
LEED	Leadership in Energy and Environmental Design
NABERS	National Australian Built Environment Rating System
NGBS	National Green Building Standard
SBTOOL	Sustainable Building Tool
TPH	Ton per hour
TEC REC	“Technologio Reciclado”

RCA	Recycled concrete aggregates
USGBC	The US Green Building Council

I. Chapter 1: Purpose and Significance of the Study

A. Introduction

1. Concrete as a material

Concrete is the second most consumed material after water and is the basis for the urban environment. It can be roughly estimated that in 2006 between 21 and 31 billion tons of concrete (containing 2.54 billion tons of cement) were consumed globally compared to less than 2 to 2.5 billion tons of concrete in 1950 (200 million tons of cement) as illustrated in Figure I-2 World Cement Production by region .

Concrete is made from coarse aggregate (stone and gravel), fine aggregate (sand), cement and water. Primary materials can be replaced by aggregates made from recycled concrete. Fly ash, slag and silica fume can be used as cementious materials reducing the cement content. These materials can be added as a last step in cement production or when the concrete is made as illustrated in Figure I-1 Concrete Making Process .

In the developed world most cement is made industrially into concrete and sold as ready-mix concrete. On a smaller scale, and more commonly in developing countries, individual users make concrete in situ on the construction site.

Figure I-1 Concrete Making Process (The Cement Sustainability Iniative)

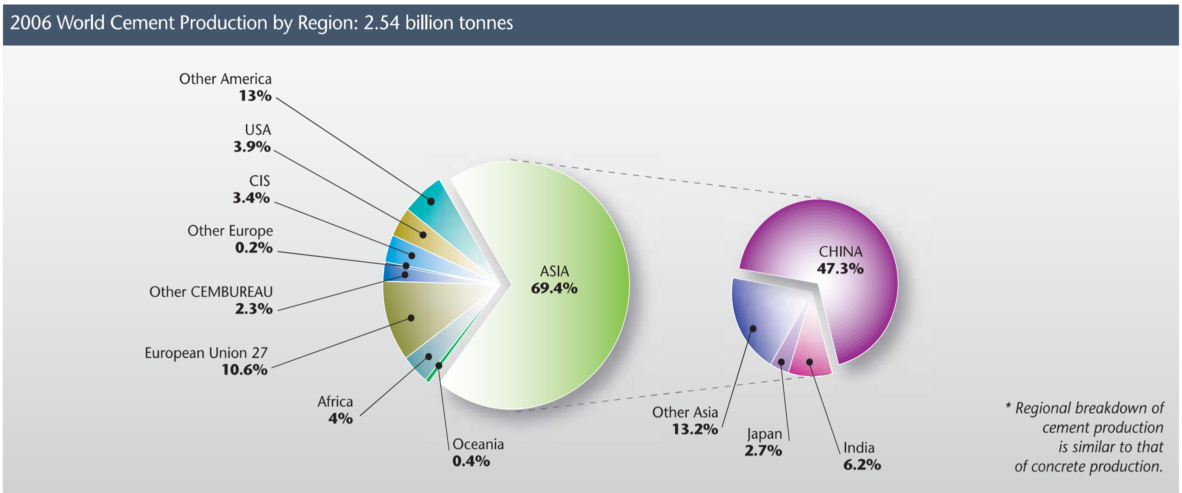


Figure I-2 World Cement Production by region (The Cement Sustainability Iniative)

2. How it is used?

Concrete is one of the most durable materials used in construction and pavement activities for many decades. It is estimated that 25 billion tons of concrete are manufactured globally each year. This figure means that 1.7 billion truckloads each year or about 6.4 million truck loads a day. In other calculations, it means 3.8 tons per person in the world each year. Twice as much concrete is used in construction around the world. The total of all materials used together including wood, steel, plastic and aluminum. About 1,300 million tons of waste is generated in Europe each year, of which about 40% (510 million tons) is in the construction and demolition waste (C&DW). The US produces about 325 million tons of C&DW and japan produces 77 million tons. In addition, china and India are now producing and using over 50% of the world's concrete, therefore their waste generation will also be as significantly high as development countries (Haggar, 2007).

3. Recycling concrete

Many countries have recycling schemes for C&DW concrete and very high levels of recovery are achieved in countries such as the Netherlands, Japan, Belgium and Germany. In other countries concrete waste is usually thrown away in landfills. Variations in calculation methods and availability of data make cross-country comparison difficult in the mean time. Recovered concrete from waste can be used as aggregates again if it was well crushed on such activities as the road sub-base. In other applications, it can be used to pour new fresh concrete, preferred in non-critical structures.

Returned concrete (fresh, wet concrete that is returned to the ready mix plant as surplus) can also be successfully recycled. Recovery facilities to reuse the materials exist on many production sites in the developed world. Over 125 million tones are generated each year (The Cement Sustainability Iniative, 2009).

Recycling or recovering concrete has two main advantages: (1) it reduces the use of new virgin aggregate and the associated environmental costs of exploitation and transportation and (2) it reduces unnecessary landfill of valuable materials that can be recovered and redeployed. There is, however, no appreciable impact on reducing the carbon footprint (apart from emissions reductions from transportation that can sometimes be achieved). The main source of carbon emissions in concrete is in cement production (the cement is then added to aggregates to make concrete). The cement content in concrete cannot be viably separated and reused or recycled into new cement and thus carbon reductions cannot be achieved by recycling concrete (The Cement Sustainability Iniative, 2009).

In all initiatives to recover concrete, a full life cycle analysis is needed. Often the drive is to achieve complete recycling; however, the overall impact and best use of the materials should always be considered. Refining the recovery may result in high-grade product but at an environmental processing cost. In the mean time, most recovered concrete is used for road sub-base and civil engineering projects. From a sustainability viewpoint, these relatively low-grade uses currently provide the optimal outcome.

To summarize this part the concrete can be recycled from:

- Returned concrete which is fresh (wet) from ready-mix trucks
- Production waste at a pre-cast production facility
- Waste from construction and demolition

4. Some key benefits of recycling concrete include:

- Reduction of waste, landfill or dumping and associated site degradation
- Substitution for virgin resources and reduction in associated environmental costs of natural resource exploitation
- Reduced transportation costs: concrete can often be recycled on demolition or construction sites or close to an urban area where it will be reused
- Reduced disposal costs as landfill taxes and tip fees can be avoided
- Good performance for some applications due to good compaction and density properties (for example, as road sub-base)
- In some instances, employment opportunities arise in the recycling industry that would not otherwise exist in other sectors.

B. Problem Statement

The main objective of this research is to advance the research in the field of recycling concrete wastes in Egypt. The problem in Egypt is that a huge quantity of concrete waste is produced. The waste management techniques are very poor. The knowledge and knowhow of waste management is minimal at this time. There have been many attempts by academic researchers and experts in engineering to address this problem; however, no study to date has comprehensively addressed efficient sustainable applications. Moreover, it was proven that concrete could be recycled and reused in many applications. Hence, the focus of this study is to present a technical and financial model that can handle the multiple variables associated with this problem and present them in an easy-to-use decision support system.

C. Significance of study

This thesis examines the financial and technical feasibility of recycling concrete waste as aggregates for new concrete in Egypt. The significance of the study is to help engineers and other decision makers with a complete feasibility and technical plan for implementing and operating a concrete recycling plant. Hence, the model is created to aid them in choosing the best type of plant for their project. The model is presented in details in chapter 4.

Although many users may have object at utilizing recycled aggregates into their concrete mixes, however, this has a huge impact on the cost of the project (Marie and Quiasrawi, 2012). Many researches were done in this field of comparison between recycled concrete aggregates (RCA) and normal aggregates (NA). Research showed that when replacing 20-30% of the NA by RCA in the concrete mix, minor changes were noticed in the compressive strength (Batayneh, 2007). Moreover, availability of natural resources is a problem that exists in other countries such as Bahrain. The limited availibility in bahrain forces the contractors to import aggratged from Saudi Arabia, however, if the recycling technique is applied it be add more value to the project and the enviroment.

D. Objective of the research

As the resources of the world are getting more limited every day, engineers and researchers should start thinking of many ways to acquire new resources, use their old or efficiently use the current resources. The average annual consumption for each human being is 1 cubic meter of concrete in the modern world (Marie and Quiasrawi, 2012). The consumption of aggregates is rapidly increasing as the population increases, thus building more shelters.

In fact, concepts like cradle to cradle are now very important in the understanding of suitability and the concrete life cycle. Cradle to cradle is basically designing the materials to acquire many life cycles. In other words, the product is reused over and over again (Haggar, 2007) as illustrated in Figure I-3 Cradle to Cradle approach . For example the construction debris can be recycled to be used again as concrete aggregates; similar materials can be reused in the same way as well.

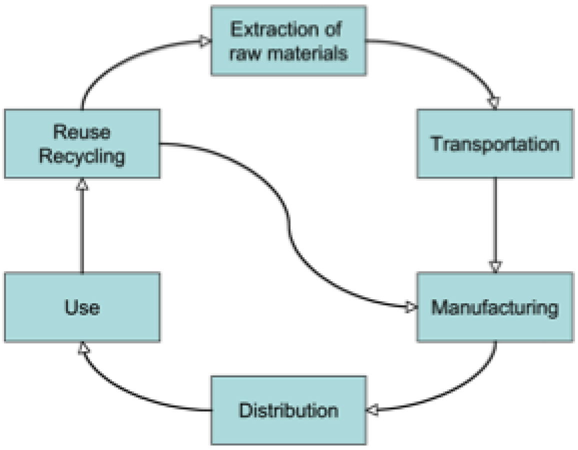


Figure I-3 Cradle to Cradle approach (Haggar, 2007)

E. Summary of Objective

The objective of this thesis is to present a complete technical plan and financial feasibility study for operating a ZERO construction waste traditional, mobile or stationary plant specialized in recycling concrete aggregates. In addition, the plant will manage all other kinds of waste and outsource their recycling process to other specialized plants

F. Summary of the Methodology

The research methodology is considered the backbone of any scientific or engineering study. The methodology sets the flow of the research and how it is conducted. It also states the kind of results that are expected from the research. The methodology of this research consists of seven main phases as follows in this order, as shown in Figure I-4:

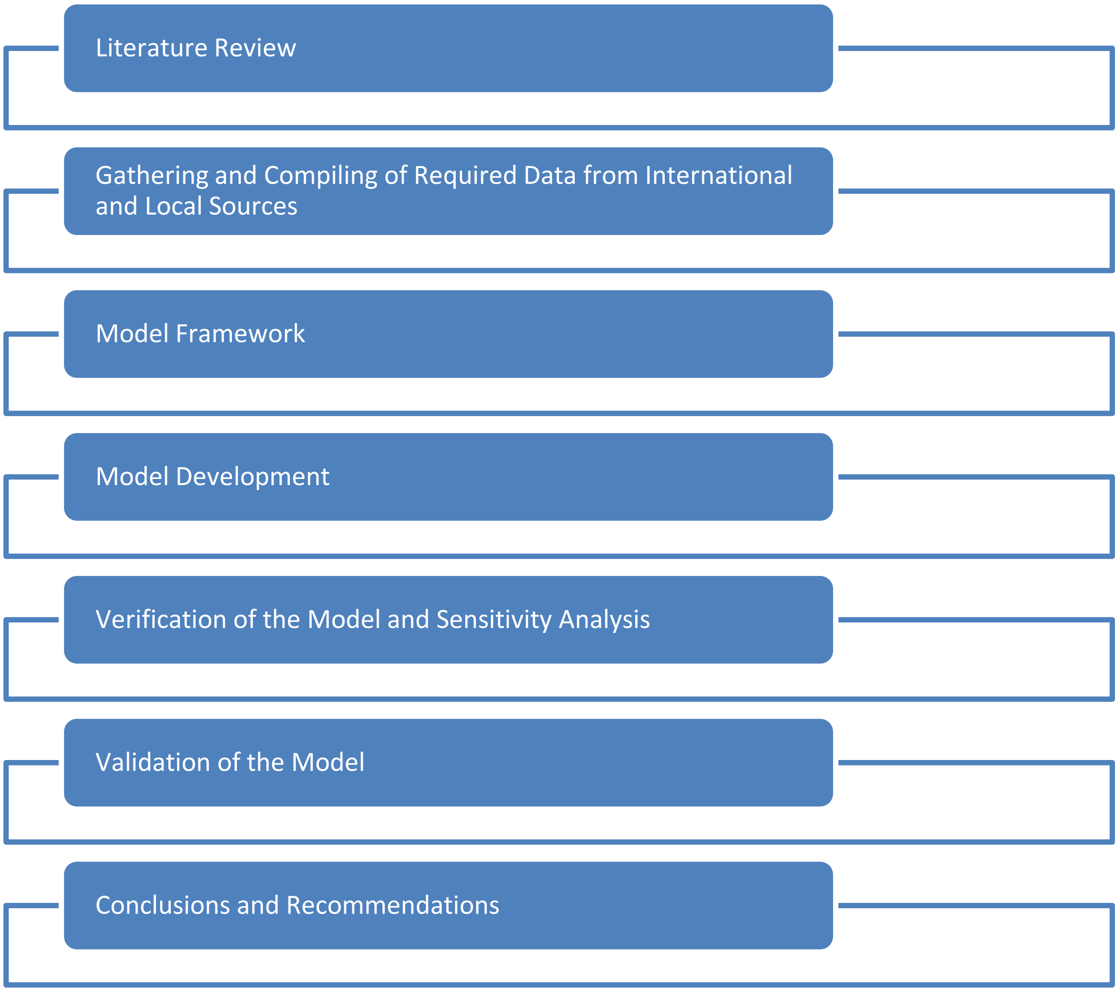


Figure I-4 Phases of the methodology summarized

These simple steps, described in Figure I-4 Phases of the methodology summarized, will be the flow of the thesis research to lead the reader to the results and conclusions. The literature review will be collecting all the previous work or research done in the field of recycling concrete. The research and work is conducted by experts, researchers, professors, engineers and entrepreneurs. This methodology is used to gather as much diverse data as possible. Afterwards, the next step taken will be gathering and compiling enough data to proceed with the plan design. The data includes plant technical specifications, prices, techniques of recycling, labor and equipment to be used, etc.

The thesis structure will be composed of several chapters that will meet the methodology proposed. The chapters, in this order, are described the diagram of Figure II-5.

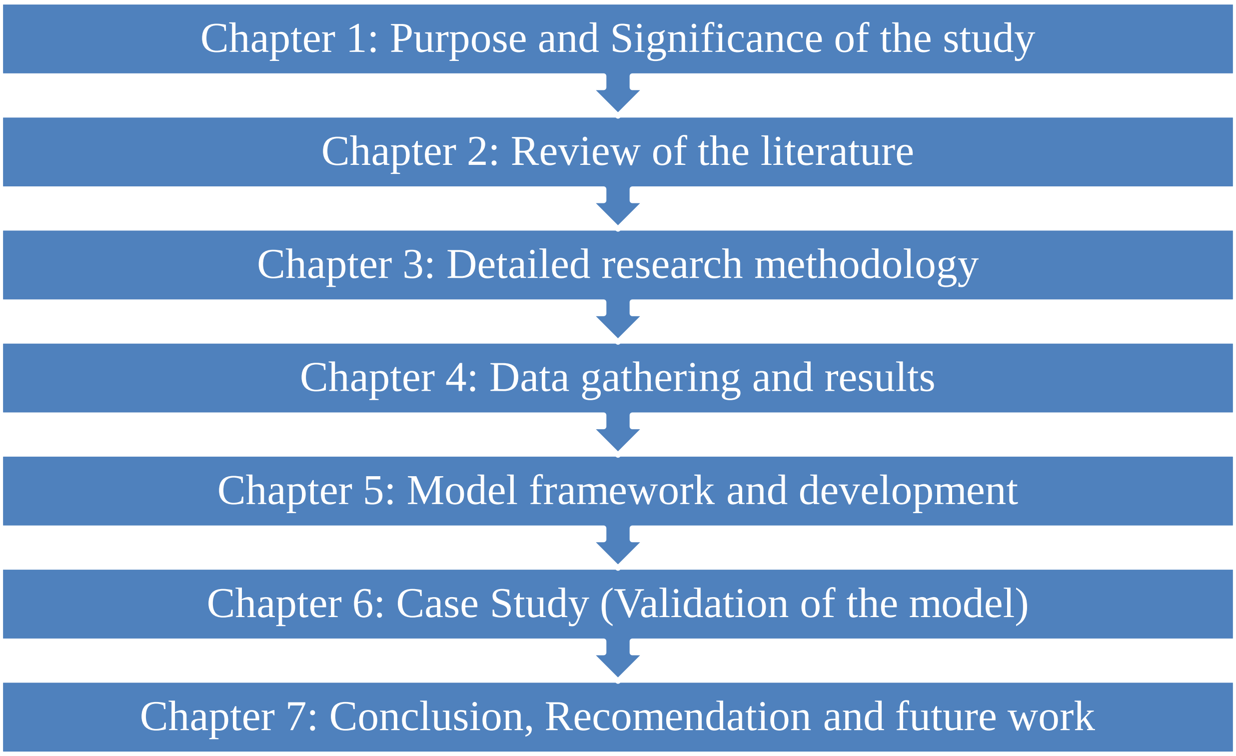


Figure I-5 Chapters of this thesis

After having the sufficient information to design a plant, many steps are introduced afterwards. The proposal of the plant will be ready to be presented in full and accurate details, and up to date with the recent technologies and techniques. Subsequently, the final design and sensitivity analysis is fully presented in details. This is the closing part of the research as it combines all the previous parts together. In this section, the data gathered from the literature review and from other sources are integrated with the proposed plant. The final design should include how the plant will operate, technically and financially. It will also include the sensitivity analysis of all the major variables in the plant design.

II. Chapter 2: Review of the Literature Review

In order to proceed with the research, the background, history and recent studies should be considered first. This will aid us in the methodology to start from where other researches have stopped. In the literature review, some of the researches in this industry are analyzed. National and International papers have been gathered. Some of them focus on construction waste in general and its quantity and others focus on the techniques and machines used to recycle them. The sources are divided into secondary sources from the Internet, books, articles, papers, etc. and primary sources such as meetings, interviews and site visits with experts in the field. Moreover, the sources are sub-divided into national ones in Egypt and international ones outside of Egypt.

A. Secondary source - Internet research on Construction waste - :

In the construction industry there exist many factors that lead to waste. Initially, this study needs to be based on some measurements and quantities of existing waste, which can be produced by suppliers, contractors and sometimes owners.

1. Review of the Literature in Egypt

Quantities of waste

In a paper that was part of a PhD research, the authors state that “timber frameworks (2-50%), and sand (2-20%)” “Timber frameworks with an average waste of 13% and sand with an average 9% showed the highest percentages of waste among all materials. While other materials such as reinforcing steel with an average of 5%, cement 5%, and concrete 4%”

(Garas, Anis and Gammal, 2013). This paper surveyed the top 35 contractors in Egypt based on the size of their capital and experience according to the classification of the Egyptian Union for Building and Construction Contractors.

In another thesis project done at AUC by Eng. Ahmed Kamel under the supervision of Dr. Mohamed Abou Zeid, the author mentioned the quantities of concrete wasted each year by several construction companies in Egypt. The following are estimates of construction waste concrete produced in Egypt every year: Egypt's total annual production of cement = 36,200,000 metric tons.

"- Total quantity of cement exported (approximately) = 5,000,000 metric tons.

- Total quantity of cement consumed in local market = 33,200,000 metric tons.

- Approximate quantity of cement used for structure concretes (assumed as 50% of total cement consumed in the local market) = 16,600,000 metric tons."

With some calculations based on a survey, the waste can be measured. From the survey in the thesis, concrete was approximately 2-3%. The following is applied if each meter cube of concrete contains approximately (1/3 metric ton) of cement = 330 kg cement. Thus, from above: 16,600,000 metric tons of cement (for structure concrete) produces about (16,600,000 ÷ 0.33) = 50,303,000 cubic meters of structure concrete. (Kamel). This source is not directly relevant to the main focus of this research, however, it contributes to the significance of the research (section I.A.6) found in chapter one. The amounts of cement and concrete calculated and their waste genearated, serves as the input of the concrete aggregates recycling plant. This is a main indication that the recycling process is needed in Egypt and that there is potential for its success due to the tremendous amount of waste produced.

Previous research to recycle and test recycled aggregates

In a paper published in Concrete International named "Reincarnation of Concrete" the differences of using recycled concrete aggregates in new mixes were examined and compared with other mixes where virgin material is used. The authors of this paper are Dr. Mohamed Nagib Abou-Zeid, Mourad N. Shenouda, Steven L. Mccabe and Farrah A. El-Tawil. The paper showed the results of the experiment. The experiment was conducted on four sets of mixes consisting of conventional, type I Portland cement, dolomite coarse aggregates, and river sand. The first mixture is composed of conventional aggregates, made with dolomite and river sand. In the second mixture, the coarse aggregates were crushed as "old" recycled concrete. The third used "new" crushed recycled concrete, returned from the job site. The final mixture had both the coarse and the fine aggregates crushed as "old" recycled concrete. The slump, slump retention, compressive and flexural strength, water and rapid chloride permeability, abrasion resistance, and resistance to elevated temperature were tested and recorded in Table II-1.

Table II-1 Recycled Aggregate experimental results (Abou-Zeid, Shenouda and Mccabe, 2005)

Mixture ID	Aggregate type	7-day compressive strength, MPa	28-day compressive strength, MPa	7 to 28 days strength ration	56-day compressive strength, MPa	28-day flexural strength, MPa
1	Old recycled coarse	21.5	32.6	0.66	35.9	4.8
2	Old recycled coarse	19.3	29.3	0.66	32.6	4.5
3	Old recycled coarse	17.8	27.4	0.65	28.2	4.0
4	New recycled coarse	20.3	31.6	0.64	33.8	4.5
5	New recycled	18.9	29.8	0.63	30.4	4.3

	coarse					
6	New recycled coarse	17.3	26.3	0.66	28.2	4.0
7	Conventional	25.1	35.7	0.70	36.8	5.3
8	Conventional	21.9	31.5	0.70	32.9	4.4
9	Conventional	18.1	28.5	0.64	29.7	4.2
10	Total recycled	19.4	29.3	0.66	33.2	4.6
11	Total recycled	18.7	26.3	0.71	29.3	4.0
12	Total recycled	17.3	26.0	0.67	27.5	3.9

Afterwards many comments and observations were made based on the following criteria:

- The slump
- Slump retention
- Compressive and flexural strength
- Water and rapid chloride permeability
- Abrasion resistance,
- Resistance to elevated temperature

The slump was primarily proportional to obtain a moderate slump in the range of 65 to 85mm. All mixtures with recycled materials had a lower slump than the conventional. In addition, the strength was relatively small compared to the conventional concrete; however, the concrete made with total replacement had a much greater strength reduction. The recycled aggregate concrete crushed at a later stage had slightly less strength than concrete that crushed at an earlier stage. For the flexural strength, the recycled aggregate concrete is similar or slightly less than the conventional concrete. As for the water permeability, the recycled aggregated concrete has higher water permeability than conventional concrete. The coefficient of permeability is also slightly higher in recycled aggregate concrete made with "new" recycled concrete than for that made with old recycled concrete. Both conventional and recycled aggregate mixtures yielded similar performance under abrasion load.

The previous paper titled "Reincarnation of Concrete" directly contributes to this research. It serves as the backbone that will back up this technology and proves its applicability. Knowing from previous studies the characteristics of the recycled aggregates, the research can start from where other researchers left off. In this thesis' chapter four, all the process will be explained and analyzed. The characteristics of the recycled concrete aggregates will be one of the main factors when designing the plant model in chapter 5.

Reasons not to recycle

The thesis performed by Eng. Kamel surveyed the reasons that prevented contactors to recycle. The author performed a survey and its results were as follows: "64% of the participating firms stated that the lack of experiences, lack of know-how and the environmental and economic concerns are the main problems and/or reasons that hinder the recycling industry of concrete, 62% of the participants mentioned that the lack of management and economic models are major problems. However, 100% of the participants stated that the absence of codes of practices is the main problem." These statistics support the fact that the lack of knowhow is present along the contractor. Therefore, operating an independent plant will facilitate the recycling process. Therefore, the model in chapter 5 is focusing on the operational feasibility of the plant.

In addition Eng. Kamel has researched in the effect of the contract type of the project. The results were as follows: "84% of the participating firms have mentioned that the unit price contract would be more acceptable; whereas, 16% have mentioned that the contract type would have no effect on the choice of recycled aggregates when compared to the conventional aggregates."

Egyptian code

According to Dr Mohamed Naguib Abou-Zeid, chair of construction and architecture department at AUC, the Egyptian code now allows contractors to use the recycled aggregates within the concrete mix with certain limits. This allows and motivates contactors to use the recycling technique but it doesn't enforce recycling and safe disposal of the wastes.

2. Review of the Literature internationally (outside of Egypt)

It is very important to conduct a research work on the previous published papers and initiatives in the recycling of construction waste. In addition, many of the organization, codes and practical initiatives should be examined carefully to start where they left off. For example, many of the codes or other researches have set rules and techniques on how to implement this process. They are very useful in the data gathering and as motivation for investors to operate the plant accordingly.

According to the cement sustainability initiative report, there was a brief statement written about each country in the field of recycling concrete from C&D waste. Figure II-1 and Figure II-2 state some facts about the quantities, locations and motives around the world. Many factors are considered in this analysis such as, country, knowhow, motive, rules and regulations, prices, function and use of recycled materials and techniques.

Figure II-1 The current recycling practice in the world (The Cement Sustainability Iniative, 2009) 1 out of 2

Figure II-2 The current recycling practice in the world (The Cement Sustainability Iniative, 2009) 2 out of 2

International Certification and accreditation initiatives

LEED certification:

In the states, in 1998, an initiative called Leadership in Energy and Environmental Design (LEED) v1.0 was established to preserve the environment. It followed the formation of U.S. Green Building Council (USGBC) in 1993. Less than a year after formation, the membership followed up on the initial findings with the establishment of a committee to focus solely on this topic

After extensive modifications, the LEED Green Building Rating System Version 2.0 was released in March 2000. This rating system is now called the LEED Green Building Rating System for New Commercial Construction and Major Renovations, or LEED-NC.

According to the article on business recovery, the features of the LEED are "The LEED Green Building Rating System is a voluntary, consensus-based, market-driven building rating system based on existing proven technology. It evaluates environmental performance from a whole building perspective over a building's life cycle, providing a definitive standard for what constitutes a "green building." The development of the LEED Green Building Rating System was initiated by the USGBC Membership, representing all segments of the building industry and has been open to public scrutiny." (History of Leed, 2013)

International Recycle Guidelines by countries:

In the UK, there is potential to increase resource efficiency in construction and reduce waste. The government has set a strategy in 2007 to reduce C&D wastes. In the UK, the construction industry is a major source of waste. It consumes over 400 million tons of resources. The construction, demolition and excavation (CD&E) sector contributes to the generation of waste more than any other sector, it produces around 1.7 million tons and contributes to the GDP by 9-10%.

According to the construction waste management guide in the UK, there exist many requirements and advices related but not limited to: appointment of principal contractor, preparation of a site waste management plan, requirements for a site waste management plan, updating a site waste management plan for a project of £500,000 or less and updating a site waste management plan for a project worth more than £500,000. (Department for Environment, food and rural affairs, 2013)

In Australia, there exist codes and guidelines for regulating construction waste management. The guide also mentions the correct ways to handle demolition and construction waste. The objective of this guide is "to help develop effective markets for materials diverted or derived from the C&D waste stream." (Edge Enviroment Rty Ltd, 2012). In the beginning it explains where all the waste is coming from, in a building road map chart. Then it explains all the potential of recycling materials to motivate the industry to implement it. The materials that can be recycled are concrete, bricks, asphalt, metals, timber, plastics, plasterboard, rock and excavation stones, soil and sand. (Edge Enviroment Rty Ltd, 2012). In the end, the guide mentions a successful case study and the attained results of recycling material wastes.

B. Primary Research and Investigations

1. Meetings, visits and interview conducted in Egypt

Interview with Dr. Ayman Ghanem, CEO of the Enhancement (Waste Management) and site visit to their factory in 6th of October city. (Primary Source)

While conducting a professional interview with Dr. Ghanem, new data was extracted to be used in this research. The information is basic since this practice is very rare and new in Egypt, compared to international processes. The interview was conducted according to the interview questions prepared by the author of this thesis and they are attached in appendix I.

The meeting was productive and proved the possibility of initiating a large scale recycling plant. The following information is a summary of the interview followed by pictures of the equipment used.

The interview began by showing Dr. Ghanem all the recent findings that were made in this research with all the supported calculations of the model. He commented and mentioned his professional opinion on the figures.

Dr. Ghanem stated that 200 TPH was too much for a single project in Egypt qnd that he is currently working with 8m3/hour (approx. 19TPH) portable. Moreover, he mentioned that outside Egypt the government forces contractors to recycle all construction waste as guidelines in construction practice.

In Egypt, his recycling plant makes many end-user products, like “bardora” for side road pavements and cement bricks. After recycling the concrete, cement is added with a certain ratio and painted at the end. These products are more profitable than selling the recycled materials as raw aggregates.

Dr. Ghanem also proposed that in the future the government could motivate people to recycle. In addition, the plant can also buy the construction debris from them with a certain level of quality, if it is bad quality the client should pay an amount of money equivalent to the filtering process. Some of the companies are ready to recycle and others are not. However, if they are interested in following the LEED requirements, then they should recycle as much as they can.

Nevertheless, he advised us to go to City Hall to review the permissions taken for all construction properties and accordingly we can have a quantity of waste per meter sq. For example, 20% of that can be taken as market share. Another approach, is concentrating only on the large-scale companies/projects. He also recommended that the government should enforce rules to recycle and consequently these kinds of plants will be well operated.

Prices of materials:

The price of the aggregates, according to the market price, is on November 2nd 2013.

- 10mm diameter = 75 LE
- 20mm diameter = 68-70 LE

For a simpler model calculation, he advised putting zero cost for buying the construction debris then calculating the profit and assigning only 20% of it as profit and the other 80% is the value of buying waste.

Labor Force

As for the labor force, he classified labor into two classes, skilled and normal. Skilled labor includes drivers and heavy hauling equipment operators.

Table II-2 Number of labor per process contains the proposed number and level of labor for each process in the recycling plant. This is not only a proposal, it is the best practice technique reached so far with his crew to operate the small capacity of his plant.

Table II-2 Number of labor per process (Ghanem, 2013)

Process	Number of labor used	Skill Level
Transportation	2	Skilled and normal
Filtering	2	Normal
Crusher	1	Normal
Monitoring	1	Forman
Management on site	1	Engineer

Cost:

All the salaries are gross, as insurance and taxes will be deducted, refer to Table II-3. These values will be used in formulating the human resources' expenses of section 5 in the model proposed in section 4. All salaries are per month.

Table II-3 Salary according to labor skills (Ghanem, 2013)

Labor Level	Salary/month (EGP)*
Driver Class A	2500-3000 LE
Forman	3000 LE
Normal Labor	1500-2000 LE
Engineer	4500 LE- 5000 LE

*Any variance in the salaries depends on the experience of the personnel

Dr. Ghanem also mentioned that he doesn't need a magnetic separator because he has one employee on site to make sure all the waste is clean. The rent of this research model is 1m per year = 83,333 LE per month which is a sufficient and suitable assumption. He has more than 6 acres for his plant. All the technical specs (ex: fuel consumption rates) can be gathered from Volvo manuals for heavy equipment. Truck's price should be a minimum of 850,000 LE. Loader's price is 1,200,000 LE.

For the proposed model in this research, he calculated the rate per day. 8 hours * 200 TPH = 1600 Ton/day. So if the truck carries 20 tons we need 1600/20 = 80 trucks per day. Therefore, during the 8 hour shift, there will be a truck dumping every 6 minutes. In addition, a storage area I needed to store this entire inventory. Also the fact that not 100% of waste will be recycled should be taken into consideration. There will always be waste from the waste.

Dr. Ghanem stated that his company calculates deprecation for this equipment to be 10 years and the salvage value is zero (1LE). It is better to assume zero salvage value considering inflation and market price fluctuations cannot be approximated after 10 years.

The number of working days per year is 250 days. These are the international production days and this is what he uses. There are 8 working hours per day and the average of labor efficiency is 75%. He advised that the price can be increased to 60LE and that this will be less than the market price for normal aggregates. The utilities are in very small amounts and should be increased to 20,000 LE per month at least. The administration fees should be 20% of the total expenses.

Dr. Ghanem did not import a jaw crusher. Instead, he made it locally. This crusher is 6-8 m^3/hour. It is very small and costs 400,000 LE to manufacture it. All these figures are used in the feasibility model framework in chapter 4, of the traditional type. However, some figures are used in other plants, such as mobile and stationary.

The factory and Dar Al-Handasah site visit:

The visit to the factory was very unique. The place is in the 6th of October city in the industrial park. The enhancement company (Ertekaa) is specialized in recycling many kinds of waste. The waste recycled includes plastic, organic, municipal solid and construction. The company was established in January 2008 as an Egyptian joint stock company. It was founded as a collaboration of leading professionals in solid waste management in Egypt who each has more than 30 years of experience in this field. The Enhancement of Integrated Services and Waste Recycling develops technologies to solve a wide range of solid waste and other environmental and recycling problems across its contracted locations. The integrated solid waste management system implemented by the Enhancement Company includes a recycling component that recycles waste materials into valuable resources to eliminate landfill disposal and protect the environment.

Recycling activities:

- Complete recycling of plastic waste, (polyethylene) using production lines and specialized equipment and machinery which include a plastic crusher, plastic shredder, granulating line to manufacture plastic rolls, and cutting machine to cut plastic waste bags.
- Tetra pack recycling using a plastic cutting machine, crushing machine and reshaping plastic machinery to reach the final recyclable product such as gift bags, cartons and boxes.

Figure II-3 Construction of Dar Al-Handasa New premises, smart village, Giza, Egypt

- Recycling phase - Cartons, P.E.T., PVC, tinplate, aluminum cans, aluminum windows, glass, and anti-shock.
- Recycling concrete aggregates to make pavement blocks in different sizes.

The site visit was mainly focused on the concrete recycling processes. They are awarded about 5 LEED contracts project. The projects are in Dar el Handasah’s new premises in smart village Figure II-3, Mars factory, Mall of Egypt and Credit Agricole Bank. This is the main source of construction waste. According to Table II-4, the processes they are using to recycle the concrete waste are explained. The process mentioned in Table II-4 illustrates the techniques used for in the traditional plant. The process technique is a main contributor in the cost, as it will be integrated later in chapter 4 when evaluating costs in the financial model. Therefore this data aids investors and contractors when implementing and operating the plant.

Table II-4 Recycling process in Dar Al-Handasa smart village. Giza, Egypt

Process	Description	Pictures
Primary Sorting	The company hires engineers and workers to make sure that the concrete is separated during the construction activity. This takes place at the construction site	 **Figure II-4 Card board waste collected**  **Figure II-5 Wood waste collected**  **Figure II-6 Loader separating concrete waste to transport it**

Secondary sorting	After the materials come to the recycling plant, there are workers who remove the unwanted objects, like steel, cupboards, wood, etc.	 **Figure II-7 concrete waste ready to be recycled**  **Figure II-8 Steel removed from construction concrete waste**
Primary crushing	All the large objects are spotted and collected to be crushed by a hammer ad-hocked to an excavator.	 **Figure II-9 Concrete waste stored for recycling**

Secondary Crushing	The material goes into a small crusher of a rate approximately 20 ton/hour. The crusher is jaw type.	 **Figure II-10 Concrete waste crushed to aggregates**  **Figure II-11 Traditional crusher used**
Screening	The concrete aggregates crushed are screened into two sizes, I and II.	 **Figure II-12 Output of the traditional crusher**

Poring curb stones	The aggregates are used in pouring curbstones of many sizes. The ratio of aggregates in the stones contributes to 75%, which are the recycling materials used. The remaining 25% includes virgin sand and cement. There is another station for pouring concrete blocks using the recycled concrete aggregates	 **Figure II-13 Production of curbstone from recycled materials 1 of 2**  **Figure II-14 Production of curbstone from recycled materials 2 of 2**  **Figure II-15 Sample of curbstone production**

C. Meetings, visits and interview conducted in Europe

1. Stationary Recycling plant in Madrid (primary source)

The recycling plant visited in Madrid was located 50 kilometers away from the city. The choice of location will be explained later in this section. This part of the literature review is very important as it explains the process and many aspects involved in the recycling of concrete demolition. This source is unique as it is a primary source, meaning that the author himself gathered all the data. The interview was conducted according to the interview questions prepared by the author of this thesis and they are attached in appendix I. The pictures taken and the interviews conducted were all at the plant investigating the recycling process, the quality measures and the cost affiliated with the project. However, in this plant the figures and numbers do not directly reflect the figures in the Middle East or Egypt. This will be explained precisely in "Chapter 3: Methodology".

Figure II-16 Stationary recycling plant in south Madrid

The process of the stationary recycling plant is summarized in the following chart. All the plant is purchased from Kleeman.

Figure II-17 Side view of the stationary plant

It is a German brand and has the largest market share in Europe. In the beginning, the truck goes in through gates of the recycling plant. The first step is to scale the truck to determine the weight of the material and thus determining the initial price to be paid to the plant. Notice in this model, the owner of the waste is the one paying the fees to recycle. This is an alternative for dumping the waste in landfill, which costs a lot more. The prices paid depending on the quality of the material, are as follows:

- Mostly Concrete or asphalt (80%-90%): 4 Euros/m^3
- If mixed with inert waste like sand or drywall (50%): 8 Euros/m^3
- Highly mixed with woods, plastics and other wastes (20%-30% pure concrete or asphalt): 15 Euros/m^3
- The price for new aggregates is approximately: 10 Euros/m^3
- They sell the recycled for 3: Euros/m^3

The workers inspect the debris visually. Sometimes they put clean material on the top and the inner material is all unwanted wasted. There is another worker to re-inspect the material after being dumped in the plant. Table II-5 summarizes the recycling process and techniques used by this stationary plant. The process mentioned in Table II-5 illustrates the techniques used in the stationary plant. The process technique is a main contributor in the cost as it will be integrated later in chapter 4 when evaluating costs in the financial model. Therefore this data aids investors and contractors when implementing and operating the plant.

Table II-5 Recycling process of the concrete waste in stationary plant, south Madrid, Spain.

Name	**Description**	**Pictures**
Dumping	All the materials are dumped to enter the recycling plant after being checked for any unwanted materials	 **Figure II-18 Entry area of debris to be**

		recycled
Screening	All the materials are transferred through the conveyor belt to be screened and only objects with a diameter larger than 40mm pass. The rest are rejected.	 **Figure II-19 Primary screening of materials**  **Figure II-20 Output of rejects after primary screening**  **Figure II-21 Pile of rejects 1of 2**

		 **Figure II-22 Pile of rejects 2 of 2**
Manual filtering	In this process the number of workers varies from 10 to 14. They remove all the unwanted materials, such as wood, plastics, etc. steel and aluminum which are not filtered in this stage. Each worker is responsible for removing one type of material.	 **Figure II-23 Manual screening room**
Crushing	The plant uses only one crusher. It is an impact crusher. The impact crusher does not apply pressure on the rock to crush, however it hits the rock to smash it into the chamber to break with its own kinetic energy. There is a rotating mass in the middle of the	 **Figure II-24 Jaw crusher side view**

	impact crusher. All the materials pass another screen to maintain a certain diameter. If the material is still large and was not crushed well, it goes back again into the crusher. This is called a closed system.	 **Figure II-25 Jaw Crusher front view**
Magnetic Separator and Screens	At this stage all the crushed materials pass through a magnetic separator and screens. All the steel and aluminum is attracted by magnetics. The screens are adjustable based on the specifications. Usually sizes are less than 40mm, if more they are returned to be crushed. The screen separates the material into small (1-10mm), medium (10-20mm) and large (40mm). Sometimes the large	 **Figure II-26 Magnet separator** 

	material is 80, 100, and 120mm.	**Figure II-27 Material separation equipment**
Air blower	The air blower acts as an extra equipment. They don't contribute directly to the crushing; however they clean all the dust on the recycled aggregates. This improves the absorption of the aggregates. Also the light material is not desired in the mix, like plastics or bricks. Upon the hardening of concrete all these materials float causing problems on the surface of the concrete.	 **Figure II-28 Air blowers side by side**
Final piles of products	Finally the piles of the different size of materials are created. They are designed to be placed with a certain space between them so they do not mix. The quality of the material is very good and competes with the natural aggregates, as stated by the manager of the plant. They are	 **Figure II-29 Piles of aggregates**

	sold for **3 Euros/m^3**	 **Figure II-30 Concrete recycled aggregates packed**  **Figure II-31 Piles of different aggregates size**

Figure II-32 Sample of size two aggregates

Figure II-33 Sample of size one aggregates 1of 2

Figure II-35 Sample of size one aggregates 2 of 2

Figure II-34 Sample of size three aggregates

Figure II-32, Figure II-33, Figure II-35 and Figure II-34 are samples of the aggregates produced. The professor, accompanying us, stated that they are of a good quality and are very clean. They can be used directly in the sub-base of the road and are used with certain percentages in noncritical concrete mixes. They separate fine materials and classify them into 3 categories. They are classified according to theirs sizes, 3-5mm, 5-10mm, and higher than 10mm.

In addition to the recycling of concrete, the manager mentioned that the plant is making more profits from the wastes generated from the filtering process, as mentioned in Table II-6. The materials that can be sold to other parties include wood, plastics, tube, paper bags, cans etc. Figure II-38, Figure II-39, Figure II-40, Figure II-37 and Figure II-36 show the sorted materials piled. The materials are the packed in several ways to be sold to other parties. (Del Barrio, 2014)

Figure II-39 Pile rubber waste

Figure II-38 Different piles of wastes

Figure II-36 Pile of plastic waste

Figure II-37 Pile of wood wastes

Figure II-40 Pile of different wood sizes

Table II-6 explains the other types and methods to recycle non concrete materials.

Table II-6 Recycling preparation of other non-concrete construction waste

Name of material and process	**Description**	**Picture**
Wood compaction	The plant bought special equipment to compress all the leftovers from the wood material. The manager made a feasibility study and he believes that having a special place to recycle wood is a good idea. Then all the wood is smashed and crushed into very small particles to be used later in medium and high-density fiberboards (MDF and HDF). They are making a lot of money out of it, as the manger stated.	 **Figure II-42 Loader dumping wood waste to be recycled**  **Figure II-41 Wood crushed to be recycled**

Rubber	The rubber is all collected and gathered to be sold separately. The selling price for this type of material is **30 Euros/ton**	 **Figure II-43 Pile of rubber to be sold for recycling**
Plastic Recycling	The plastic material is one of the main components of construction waste. There are many types of plastic used. Most of the material is used in the electro mechanical packages of the building. However, due to the diversity of plastics used, they have to be separated by sizes and color. Then they are all sold in the form of pure materials to be recycled in other places. The selling price is about **200 Euros/ton**	 **Figure II-44 Pile of plastic unsorted by size and color**  **Figure II-45Pile of plastic waste ready to be sold for recycling purposes**

		 **Figure II-46 Sorted Plastic waste to be sold for recycling purposes**
Paper/paper bag	The paper is handled by many techniques. The first type is paper shredding. The small paper sizes are processed into a machine to shred them to small sizes. Afterwards, they are compressed and wrapped tightly using a special machine.	 **Figure II-47 Paper waste shredded and packed to be sold for recycling**
	The second technique is mostly used with the large pieces of paper. Usually they are paper bags and/or boxes. They are used for packing cement, sand, gypsum, adhesives or any other fine materials. The	 **Figure II-48 Paper waste shredded and compressed to be transported for recycling**

	process is to gather all the similar sizes of paper bags or boxes and compress them in a special machine as shown in the pictures	
Plastic Bags	Plastic bags are all gathered from the construction industry. A lot of plastic bags are used for gypsum, sand and cement. When there is sufficient amount of bags, they combine them together using special equipment. A compressor is used to compress the paper material and shape it as a box with tight wrapping for easier handling.	 **Figure II-49 Plastic bags waste before compression**  **Figure II-50 Plastic bags waste shredded and compressed into box shapes to be transported for recycling**

2. Mobile Recycling plant in Paris (primary source)

During a professional meeting with Mr. Christophe, the Aggneo production director in LaFarge, Paris, many techniques about recycling concrete were discussed. The interview was conducted according to the interview questions prepared by the author of this thesis and they are attached in appendix I. Aggeno is a new product/service by recycling old concrete from demolition or construction. Aggneo is a range of new generation, high quality recycled aggregates that meet a wide array of needs for sustainable construction in the civil, industrial, commercial and residential segments. By using recycled aggregates, we divert materials away from landfills and this enables saving of natural aggregates reserves. (Hardy,2013)

Aggneo's key benefits are:

•Quality: LaFarge guarantees the highest standards of consistency, reliability and performance of its recycled aggregates, thanks to rigorous inbound sourcing process management and high frequency testing along Aggneo's manufacturing process.

•Proximity: LaFarge's network of sites and proximity to the market, offers convenient locations for the disposal of deconstruction materials and sourcing of aggregates. This provides economic advantages by optimizing the supply chain and generates environmental benefits by reducing transportation distances.

Aggneo high quality products allow a large range of applications:

• Road base and sub-base;

• Bedding sand;

• Building foundations;

• Drainage applications;

• Aggneo can also be used in concrete and for utility trenches, parking areas and driveways.

Equipment used:

The setting of the equipment is very flexible since they use mobile crushers and screens. The brand name is Kleeman, the same as the plant in Madrid mentioned above in this research. As mentioned before, Kleeman in the main producer of crushers in Europe and has the highest market share in this region. The design of the setting of the equipment depends on the job requirements. Basically, there are two types of work. The first is recycling demolition and construction waste instead of removing the waste and dumping it in landfills. LaFarge operates this as a service for contactors or project owners. The second type is recycling the leftovers from their concrete production plants. The nature of concrete production is to mix concrete and fill the concrete trucks to be dumped in the desired project or job. However, the problem he is that there is always leftovers in each truck after dumping it. The amount of leftover is approximately 2-3% in France, according to Mr. Christophe.

The Process:

The first type mentioned above involves recycling concrete onsite. As shown in the following picture, LaFarge's crew mobilizes their equipment to a site where the material to be recycled is present. The layout of the site is shown in Figure II-39. The quality of the materials doesn't convey the output quality however it conveys the quantity. The quality and quantity are directly proportional to each other. The better the quality is the more the quantity because the waste is eliminated and the material is pure. (Hardy, 2013). The interview with Prof. Hardy and the site visits include the detailed process of mobile plants, recycling construction concrete aggreagtes. The process along with the pictures are illustrated in Table II-7. The process mentioned in Table II-7 illustrates the techniques used in the mobile plant. The process technique is a main contributor in the cost as it will be integrated later in chapter 4 when evaluating costs in the financial model. Therefore this data aids investors and contractors when implementing and operating the plant.

Figure II-51 Location of mobile crushing equipment on site

Table II-7 Concrete C&D waste being recycled by mobile equipment

Process	**Description**	**Pictures**
Pre-crushing	To lower the crushing loads on the main crushers and faster production, the manager uses a special type of excavator with a crusher in its bucket. This crushes the large size materials (1000-1400mm) to smaller sizes (500-700mm)	 **Figure II-53 Excavator with an extension to crush and move concrete waste to be recycled**  **Figure II-52 Crusher extension of the excavator**
Hauling	The excavator starts to haul all the materials and empty them in the mobile groups of crushers and screen. The mobile set is composed of crushers, screen, and magnetic separator. It is even designed to re-crush the material not passing the 40mm screen.	 **Figure II-54 Excavator dumping concrete waste in the mobile equipment**

		 **Figure II-55 Concrete waste being recycled**
Screening	All the materials are transferred through the conveyor belt to be screened and only materials with a diameter larger than 40mm passes. The rest is rejected.	 **Figure II-56 Mobile Screen**
Crushing	The mobile plant is using only one crusher. It is an impact crusher. The impact crusher does not apply pressure on the rock to crush, however it hits the rock to smash it into the chamber to break with its own kinetic energy. There is a rotating mass in the middle of the impact	

	crusher.	
Screening and Magnetic separation of steel	All the materials pass another screen to maintain a certain diameter. If the material is still large and wasn't crushed well, it goes back again into the crusher. This is called a closed system. At this stage all the crushed materials pass through a magnetic separator and screens. All the steel and aluminum are attracted by magnets. The screens are adjustable based on the specifications.	 **Figure II-57 Mobile screen sorting products by size**  **Figure II-58 Mobile screen during screening**

		 **Figure II-59 Magnet Separator**
Re-crushing (if needed)	The screen is designed in a way to reject all the unwanted sizes (larger than 40mm) and re-route it to the crusher again for another cycle and this is called the closed system.	 **Figure II-60 Final product of crushed concrete aggregates**
Sorting of final materials leftover/aggregates products	At the end of the process, there are basically two types of materials recycled. They are steel and aggregate. The aggregates have a wide variety of sizes and can be manipulated according to	 **Figure II-61 Crushed concrete aggregates medium size produced**

	the requirements of the clients. The sizes can be adjusted from 2mm up to 80mm, depending of the purpose of their usage.	

The other type of recycling concrete is executed by using the leftover from the concrete mix plant in Table II-8.

Table II-8 Concrete aggregates recycling process of fresh concrete waste

Process	**Description**	**Pictures**
Empty the trucks	According to the director of concrete recycling department at LaFarge, there is always a portion of the fresh concrete mix left over. They are returned to the mixing plant, considered waste and are ranging from 2-3% from the original volume of the mixing truck.	

Mega block formation	On site, there is a truck ready to accommodate all the leftover from any truck or the rejected trucks from the site. They are all collected into one container. The container is moved after being completely filled.	 **Figure II-62 fresh Concrete wastes being dumped (Hardy, 2013)**
Hardening of return concrete	Usually while the transportation the concrete is in the hardening process. It can be left for a longer time if the concrete is not hard yet.	 **Figure II-63 Hardening of fresh concrete (Hardy, 2013)**
Transportation	The truck is transported to another place where the recycling equipment takes place. The trucks used are very large in capacity to transport the maximum amount of concrete possible. In some cases the concrete	 **Figure II-64 Transportation of fresh concrete to be recycled (Hardy, 2013)**

	is recycled next to the mixing plant if the site capacity and design are sufficient.	
Dumping of concrete	The concrete is being dumped at the location of recycling. The base of the truck is filled with a layer of oil or water to help the concrete blocks slide easily. This helps the concrete block to be dumped with minimum losses of material.	 **Figure II-65 Dumping of concrete after hardening (Hardy, 2013)**  **Figure II-66 hardened concrete after dumping (Hardy, 2013)**

Crushing with excavator	The concrete is crushed with an excavator to smaller block sizes. In the following picture the blocks are crushed to smaller sizes ranging from 700mm to 1200mm. this size is acceptable to be entered into the crushers.	 **Figure II-67 Breaking concrete into smaller blocks (Hardy, 2013)**
Recycling concrete (final product)	The normal process of concrete debris recycling is executed at this stage. However, in comparison with the concrete debris recycling process, the magnetic separator and bowing processes are eliminated since they will not affect nor enhance the quality of the output. The final products of aggregates can be used as recycled concrete aggregates in	 **Figure II-68 Mobile plant for recycling concrete (Hardy, 2013)**

	many applications as mentioned previously in the introduction.	 **Figure II-69 Concrete aggregates recycled (Hardy, 2013)**

3. Structure and Material Research Center (CEDEX) Visit in Madrid (primary source)

Figure II-71 Concrete blocks made partially by recycled aggregates

Figure II-70 Samples of blocks being tested

The visit with the research center was very beneficial. The interview is conducted according to the interview questions prepared by the author of this thesis and they are attached in appendix I. The research and experiment in CEDEX center are up to date and very practical. Their advantage is that they are funded by companies that want to improve the quality of their materials and still remain sustainable. There are large varieties of product tests that are done on the concrete mixes as shown in Figure II-70 and Figure II-71. The main project they are working on is using recycled concrete blocks for the pavement of a side road. A flooring company funds this project. Its length is 3 kilometers, approximately 30,000 square meters in area. Moreover, the project is still in the testing phase and there were many trials of concrete mixes. The difference is the percentages of the recycled aggregates. The sample ranges from 50% to 75% recycled concrete used. According to Figure II-71 and Figure II-70, the red paint shows the amount of natural aggregates used. Many tests are conducted to test the quality of the material. The tests are compressive, abrasion, permeability, freeze and thawing and shrinkage. They are conducted in the lab at the CEDEX center. The sample got good results however they are thinking of decreasing the amount of recycled materials used because the process was in the lab. However, since the process is monitored in the lab, the output material has a good quality. To be conservative, they are proposing to use the minimum amount of recycled aggregates (50%), since the input material is not controlled well enough. (Gutierrez, 2014)

III. Chapter 3: Research Methodology:

The construction waste is a critical and major contribution to the world's total waste. It is our duty to create ways to reuse this waste. Part of this waste is the concrete waste which can be in many forms. In this part of the research, the methodology used to conduct the study will be explained. In order to have the best and optimum results, the methodology should be well defined. The methodology is divided into two parts, primary and secondary gathering of data and literature review. The primary data gathering is obtained through interviews, meetings, and site visits. Some of them are conducted in Egypt and others in Europe. The diagram in

Figure III-1 summarizes the steps taken to conduct the research.

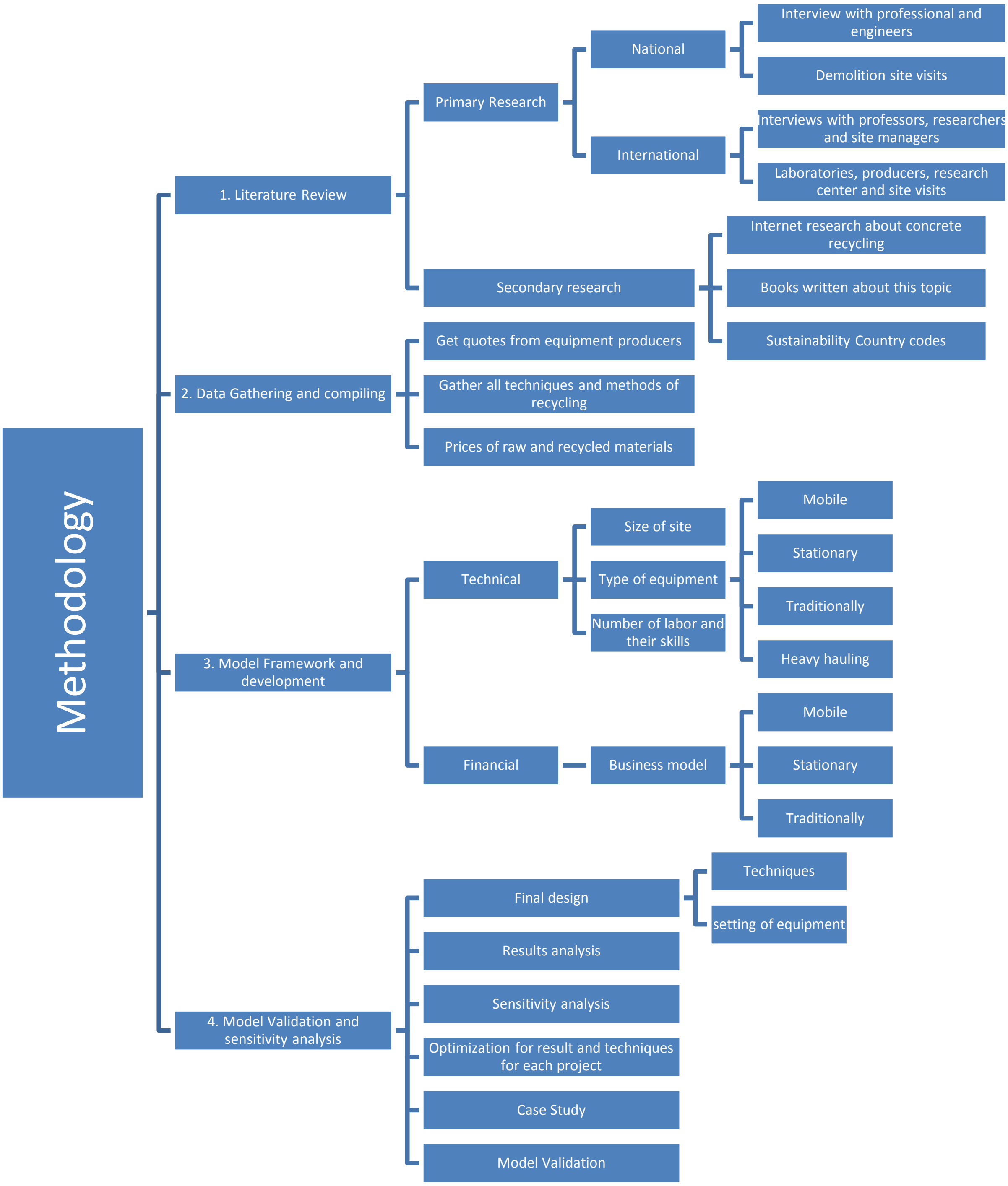


Figure III-1 Methodology process diagram of this thesis

A. Literature review:

The literature review will be the base of this research. A complete and thorough study will be conducted in the field of recycling. It includes all the data from many viewpoints. The literature review includes primary and secondary research from previous work.

The primary research includes interviews, meetings, site visits and investigations in all areas of concrete recycling, wastes management, procurement of equipment and recycling plant management. In order to gather the best information, wide spectrums of experts were interviewed and many places were investigated. The experts include, but are not limited to, researchers, professors, site managers, equipment producers, company owners and managers, and last but not least workers and engineers on site. Due to the constraints of the lack of knowhow in Egypt and the Middle East, further investigation is done abroad. The countries with the best knowhow, experts and techniques in this field are France, Germany and Spain. In addition, China has become a well-known producer of crushing and recycling equipment with certain limitations on quality and prices.

B. Data gathering and compiling

In this unique study, the data gathered is very crucial. In addition, the sources of data are also of great importance. In order to get the best and most accurate data, a methodology has to be followed. First of all, the data includes many things that are important to meet the objective of this research. It includes the prices and rates of machinery, labor, heavy hauling trucks and equipment. Most importantly, the prices of raw and recycled aggregates should also be gathered. Through interviews, meetings, and site visits, the prices of the recycled materials or products will be analyzed by process. Moreover, the sources for this part should be very diverse. In other words, one source cannot be trusted to conduct the financial model. The model includes many variables, like prices and rates. However, the rest of the variables will be explained later in the research. In this part of the research the sources should be diverse. For example the prices of the recycling equipment are gathered from different producers. The companies are categorized according to the country of origin. The companies targeted are based in Germany and China to be classified as high and low quality, respectively.

Afterwards, the rates and techniques are gathered. The rates include:

- Labor working hours
- Number of labor in each process
- Average work efficiency
- Depreciation of equipment
- Production rates of machinery and heavy hauling equipment
- Inflation rates

All these rates are subjected to change. Therefore, a wide spectrum of experts were interviewed to collect diversified and comprehensive data. The targeted experts will be classified according to the following:

- Professors with experience in sustainability and construction waste recycling
- Recycling aggregates' directors in international companies
- Site managers of recycling plants
- Owners and entrepreneurs in the field of recycling
- Researchers in research centers working for governments, companies, consultants, etc.
- Representatives and engineers in equipment production companies

This combination of well-selected experts provided the information to make the proposed model, which will be explained in the next section, making the idea more reliable and convincing for investors.

C. Model Framework and Development

After gathering enough data, a detailed proposal was written. The main reason for having the proposal is to provide those is the industrial and professional field with the relevant information and feasibility study to operate such a plant. Mainly, the proposal should be divided into two categories, technical and financial. The technical proposal will be explaining the types of equipment used and their features, the labor used for every job type, the rates, etc. The financial proposal will be focused onto the prices and costs affiliated with the materials and equipment, respectively.

The technical proposal will also include major information which will help in the decision making process for selecting each job type. The size of the plant is one of the main variables that govern production and profitability. The plant will be designed based on previous experience of site visits made by the author. This design will include places and sizes of equipment, scales, batch storages, waste storage, packing assembly line, etc. Moreover, the technical proposal shall include the labor skills, numbers and production rate.

The financial proposal will include the business model combining all the different variables together. It will be on an excel sheet for all types of plants and it will combine all the costs affiliated with the plant. The sheet will include variables like:

- Labor salaries for all skills
- Equipment costs for different capacities
- Hauling vehicles for different capacities
- Depreciation rates
- Inflation rates
- Prices for selling new aggregates
- Price proposed for recycled aggregates

D. Model Validation and verification:

The validation and verification of any model is very crucial to the credibility of the research invested in this model. The methodology for validation is conducted through applying the model on a case study and comparing the results with the actual ones. As for the verification, it is conducted through a sensitivity analysis. This exercise provides the reader with two benefits. The first one is to verify the model by changing the values of some parameters, i.e. if the cost of equipment increases, the profit should decrease. The second benefit is to study the percentage change on results (revenues, profits, expenses, etc.) when changing (increasing or decreasing) the value of basic parameters. The basic parameters are the ones contributing most to the expenses.

IV. Chapter 4: Data Gathering and Results

A. Data gathering

1. The Process

This part of the research will be covering and explaining the process of recycling the concrete waste to be used as aggregates in mixing new concrete. To begin, the process is analyzed based on other researches that were made by researchers in the same field. Thenceforward, the process is divided into smaller processes. They are priced based on machine cost, labor, rent, etc. Then this cost of the final product, which is concrete aggregates, is compared with the price of the new material. Moreover, the different types of equipment are explained in details, thus encouraging the investors to choose the most convenient method for their project.

2. Closed System:

The process of material recycling is explained in Figure IV-1 (closed system). The main difference between closed and open systems (Figure IV-1and Figure IV-2, respectively) is the re-crushing at the last phase. The 40mm screen in Figure IV-1 passes only 0-40mm size aggregates and the rest is returned to the crusher to be re-crushed.

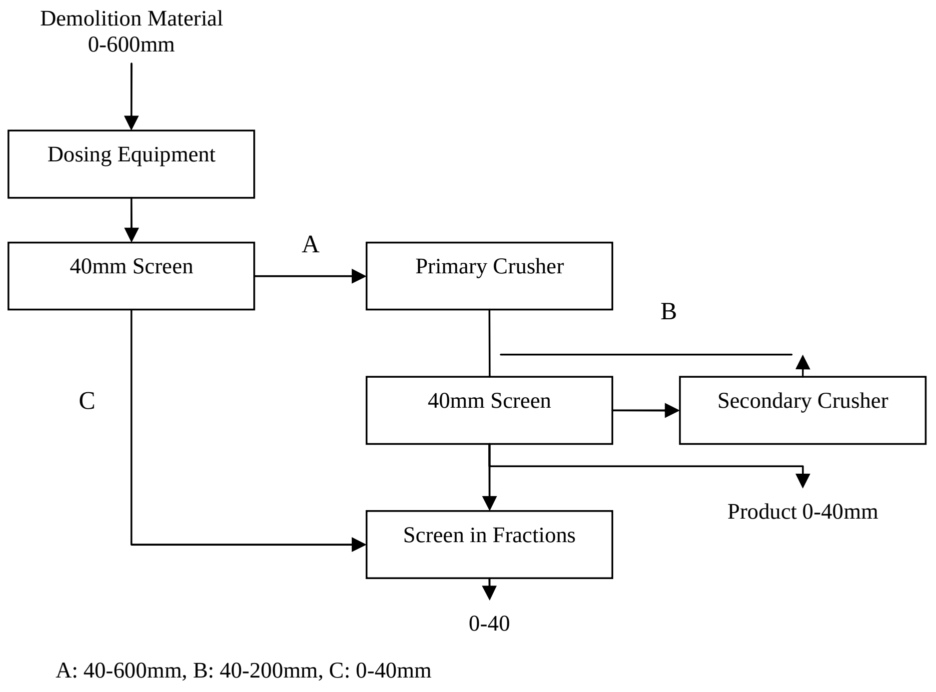


Figure IV-1 Flow-chart of typical plant for production of recycled aggregate from cornet debris which is free from foreign matter (closed system), (Boesman, 1985)

3. Open System:

The process of material recycling is explained in Figure IV-2 (open system):

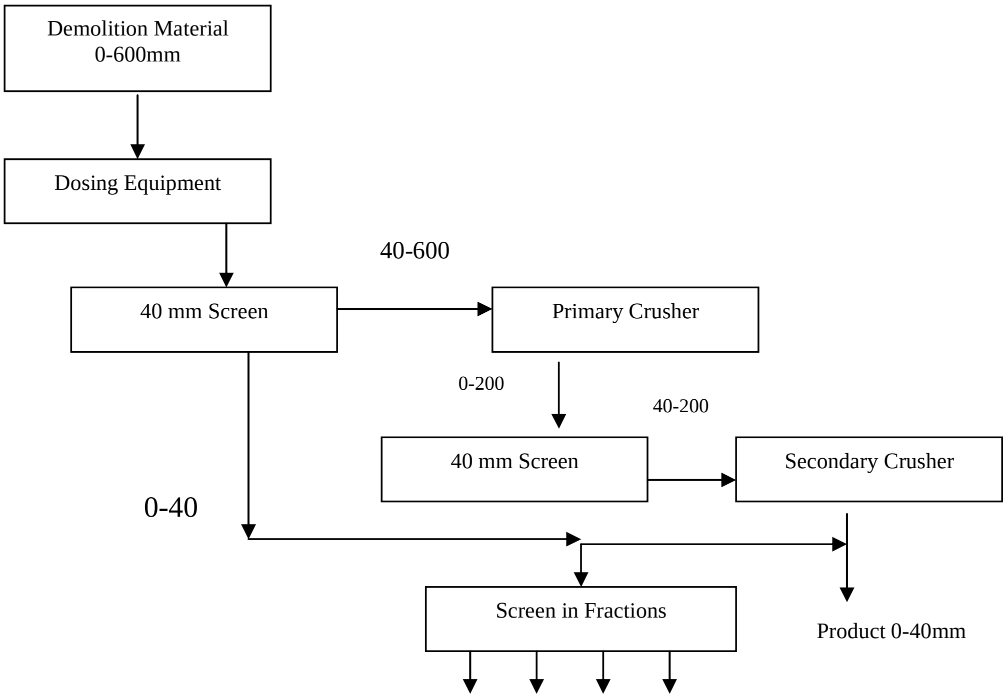


Figure IV-2 Flow-chart of typical plant for production of recycled aggregate from cornet debris which is free from foreign matter (open system), (Boesman, 1985)

A number of different processes are possible for the crushing and sieving of demolition waste, which mainly consists of concrete. This can be used for pavement rehabilitation projects. Some of these possibilities are illustrated in the block diagrams, which are shown in Figure IV-1and Figure IV-2 (Boesman, 1985).

The closed system is the most recommended one. The open system has only one advantage, which is operating with greater capacity. However the same basic equipment is used for both systems. Moreover, an advantage for the closed system is having a well-defined maximum aggregate size and this can lead to larger variations in the size of the end product, especially when the input size variations is large (Hansen, 1992).

4. Plant Generations:

Plants are classified into two generations, first and second. The first generation is composed of process scheme that can intake small amounts of contaminants and, before crushing, removes larger pieces of foreign matters manually or mechanically (Hansen, 1992). It is not recommended to assume that the concrete will be free of other materials. It may contain other foreign materials such as metals, wood, plastics, bentonite sheets, cladding, and roof covering of various kinds. Hence, many techniques are used to filter rejected materials, manually or by machine.

The second-generation plants are designed as the initial basic design as shown in Figure IV-3. The process begins with large pieces of debris arriving to the plant, typically from 0.4m to 0.7m as maximum size. This range can be formed from demolition by wrecking ball and hydraulic shears to cut reinforcement (Boesman, 1985). Some materials should be removed by hand such as steel, wood, plastics, and paper. Then, the filtered material is crushed in a primary crusher, which can be a jaw or impact crusher (Hansen, 1992).

Before entering the primary crushers, the material is screened on a deck consisting of 10mm scalping screen to remove anything less than 10mm. This helps eliminate fine contaminants such as dirt and gypsum. Sizes larger than 40mm are passed through a secondary crusher to reduce their size to maximum 40mm. This can be done by jaw, cone, hammer or impact crushers depending on the material (Hansen, 1992). Afterwards all materials should be cleaned by air sifting or washing to get rid of the lightweight contaminants such as wood, plastic and gypsum. Self-cleaning magnets that are located in critical locations above the conveyor belts collect any steel or iron. Then all the steel is stored separately for further reuse (Hansen, 1992).

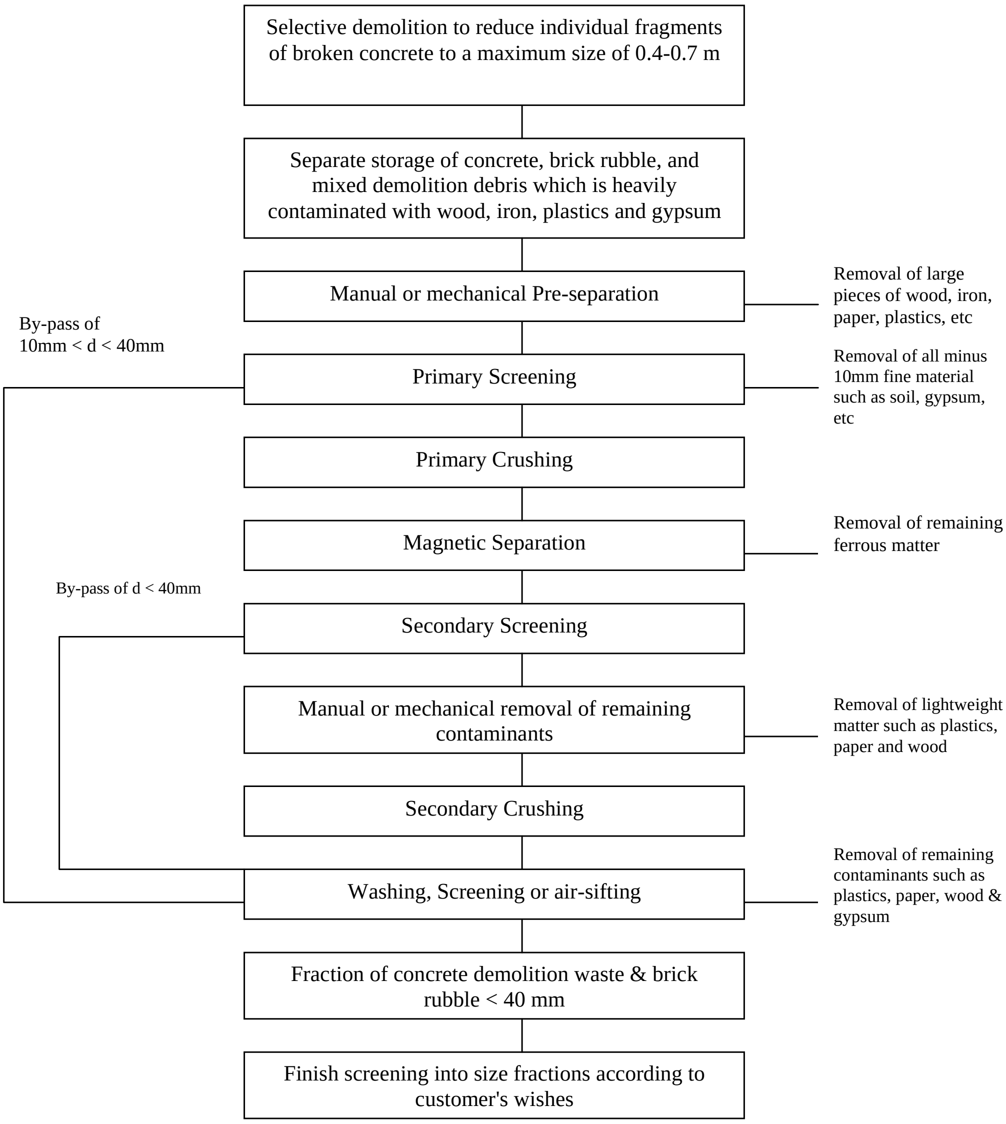


Figure IV-3 Processing procedure for building and demolition waste (Hartmann & Jakobsen, 1985)

Table IV-1 is a summary simplifying the recycling of concrete aggregates. It shows the processes in order of crushing, the descriptions of the process and the machine used in each phase.

Table IV-1 Detailed theoretical process of concrete aggregates recycling

Process	**Description of process**	**Machine**
Broken down to	Large pieces of debris arriving from	Means of a wrecking

smaller pieces (0.4-0.7m)	demolition sites are typically reduced to 0.4-0.7 m maximum size	ball and hydraulic shears to cut reinforcement
Manual or mechanical pre-separation	Large pieces of steel, wood, plastics, and paper are removed by hand when going through the conveyor belt	By hand
Primary screening	Removing particles of 10mm<d<40mm. Remove all minus 10mm particles such as sand, gypsum, etc.	Straight or swing conveyor with screen.
Primary crushing	Incoming material is then crushed in a primary crusher.	Crusher is usually of the jaw or impact type
Magnetic separation	All iron and steel is removed by self-cleaning magnets, which are placed at one or more critical locations above conveyor belts.	Self-cleaning magnets/permanent magnetic separator
Secondary screening	Products from the primary crusher are screened on a deck typically consisting of a 10mm scalping screen. Minus 10mm material is wasted in order to eliminate fine contaminants such as dirt and gypsum.	Straight or swing conveyor with screen.
Secondary	Plus 40mm material is passed through	Jaw, cone, hammer

crushing	a secondary crusher in order to reduce all products to 40mm maximum size.	or impact crusher
Washing, screening or air-sifting	All materials are then washed or air-sifted in order to remove remaining lightweight matter such as wood, paper, and plastics, and the clean product is screened into various size fractions according to customer specifications.	Straight or swing conveyor with screen.

B. Difference between current method and concrete recycling method

The methodology to produce aggregates by recycling concrete is similar to the current used method of aggregates production. Therefore, the possibility for this model to succeed is very high since the initial cost will be almost the same (Tam, 2007). The next section will explain both processes to produce aggregates, current and concrete recycled.

1. Current method:

The current method to produce aggregates is completely analysis in a case study paper produced by Vivan Tam, who focused on the cost and benefit for each method. Figure IV-10 is extracted from this paper.

The process starts as follows:

- Stripping: Rocks are cleared and leveled
- Blasting: This process involves the use of blasting equipment to extract the rock in cube shapes from the heart of the mountain.
- Stockpiling: This is when the labor is gathering all the blasted materials.

- Sorting: at this stage, the excavator is used to sort the materials by size. Separating the large blocks from the small blocks does this.
- Crushing: this stage is divided into two processes, primary and secondary. The primary crushing breaks the large blocks into smaller ones, and then, the secondary crushing crushes them much smaller to get the desired size.
- Washing, Screening or air sifting: this is the final stage where the aggregates get ready to be sold. They are screened according to size and washed with recycled water to remove all the fines from them.

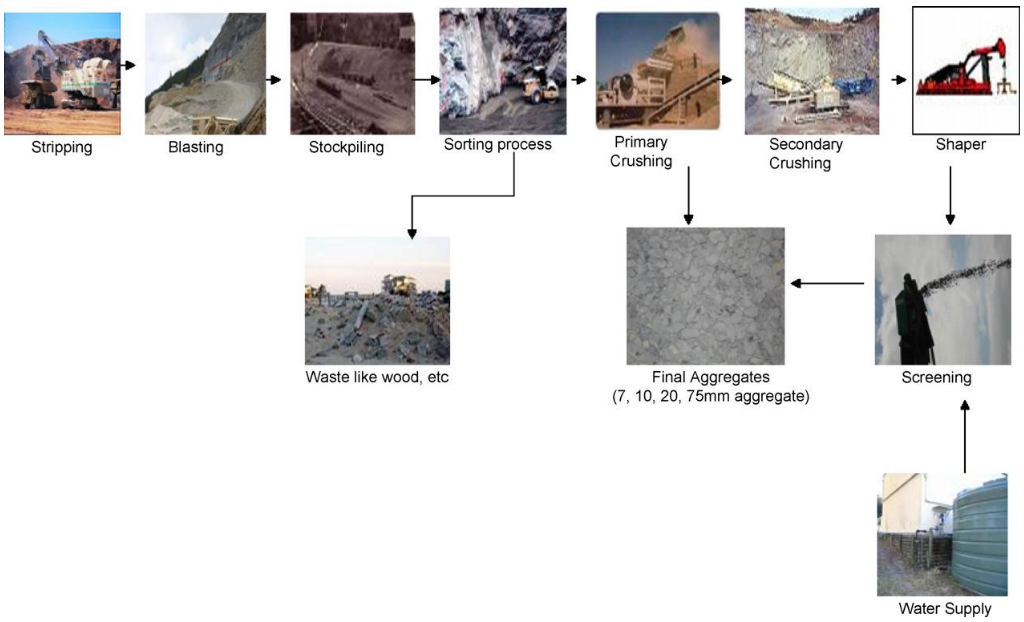


Figure IV-4 Flow chart of the current method (Tam, 2007)

2. The recycling method:

The recycling process chart is extracted as of Figure IV-5. The process is:

- Construction waste Transportation and Stockpiling: collecting the concrete waste from different sites. This process requires the operation of heavy hauling equipment.

- Sorting Process: this process involves sorting the materials and removing the unnecessary waste like large pieces of steel, wood, gypsum, etc. However this is not the final sorting process, as minor unnecessary materials will be removed later.
- Crushing: this stage is divided into two processes, primary and secondary. The primary crushing breaks the large blocks into smaller ones, and then, the secondary crushing crushes them further to get the desired size.
- Magnetic Separator: All the iron, metal and steel components are removed mechanically by a permanent magnetic separator.
- Washing, Screening or air sifting: this is the final stage where the aggregates get ready to be sold. They are screened according to size and washed by recycled water to remove all the fines from them. This process in executed between the primary and secondary crushing.
- Manual removing: at this stage all the aggregate is almost finished, however one worker is responsible to manually remove any non-aggregate material.

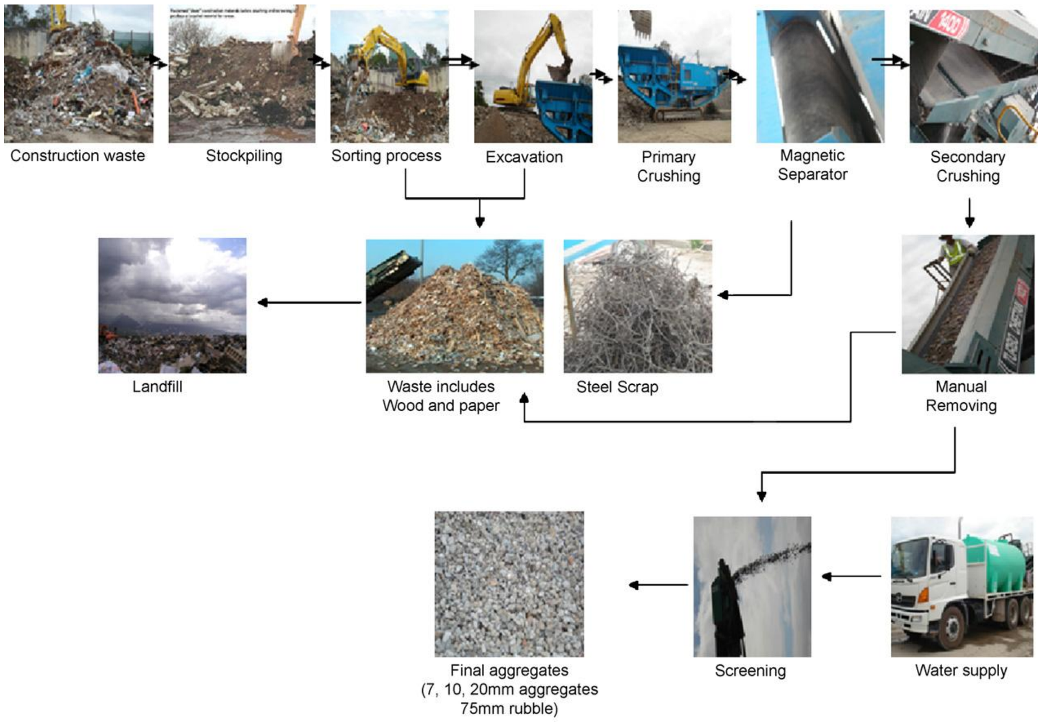


Figure IV-5 Flow chart of the concrete recycling method (Tam, 2007)

C. Equipment needed:

A typical site set-up in the UK to produce crusher run material consists of the following items of plant (Trevorrow, Joynes, & Wainwright, 1986):

1. Wheel Loader.
2. Trucks
3. Vibratory feeder
4. Jaw crusher or Impact crusher, as primary crushers
5. Cone Crusher, as secondary crusher
6. Straight or swing conveyor with screen.
7. Permanent magnetic separator
8. Sand Washer

D. Types of Crushers:

The crushers in the quarrying industry are diverse. There exists many types and technologies regarding the desired end result. Crushing projects differ from each other. Each one has its own needs, based on which, the type of crusher is selected. The material type, size, maximum nominal size, deviation in size distribution, capacity, etc. contribute to the choice of the crusher. In this paper the study of crushers is limited to jaw crushers, impact crushers and cone crushers. In addition, an in-depth investigation is presented to compare the performance of crushers when crushing old concrete. Moreover, the technical specifications for mobile and stationary plant types are attached in appendix III as manufacturers' brochures.

1. Jaw Crusher:

They are the most commons type used in quarries. The process can be explained as follows: crushing the material under pressure in a cyclic manner to decrease the material size until it gets out of the chamber. The pressure is produced by two jaws that make the chamber smaller as they are designed in a tilted way as shown in the Figure IV-6. Usually the angle between them is 19-22 degrees. This allows the crushing force to be transmitted to very hard rock. The process is measured into positions of the cycle, close stetting system (CSS) when the jaws are closest to each other, and the other is open setting system (OSS) with the jaws farthest apart. In the concrete recycling plant, jaw crushers are typically used as the primary crushers (Marmash, 2010).

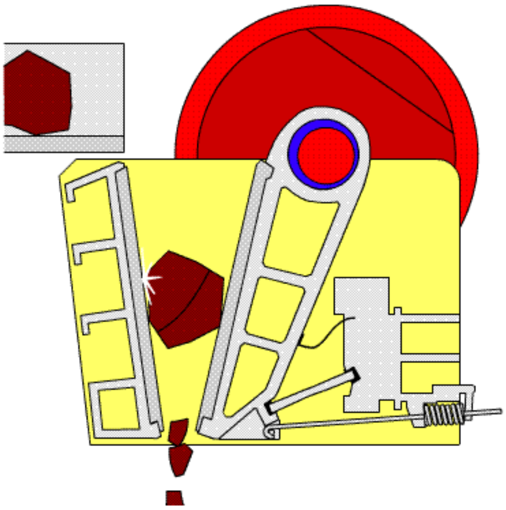


Figure IV-6 Jaw Crusher side view diagram

2. Impact Crushers:

As indicated in Figure IV-7, the impact crusher doesn't apply pressure on the rock to crush it, however it hits the rock to smash it into the chamber to break with its own kinetic energy. There is a rotating mass in the middle of the impact crusher. It revolves at a high speed giving any rock the energy to impact the chamber and break into smaller pieces. This technique gives the material a good shape and helps produce a product free from stress. At last, the material is discharged from the crusher by gravity; sometimes it passes through a grid to assure the minimum of oversize is produced. There are two types of impact crushers: Horizontal Shaft Impactor (HSI) and Vertical Shaft Impactor (VSI). The crusher normally produces larger amounts of fine aggregates than coarse aggregates. The product was less elongated towards round shapes forming acute edges (Marmash, 2010).

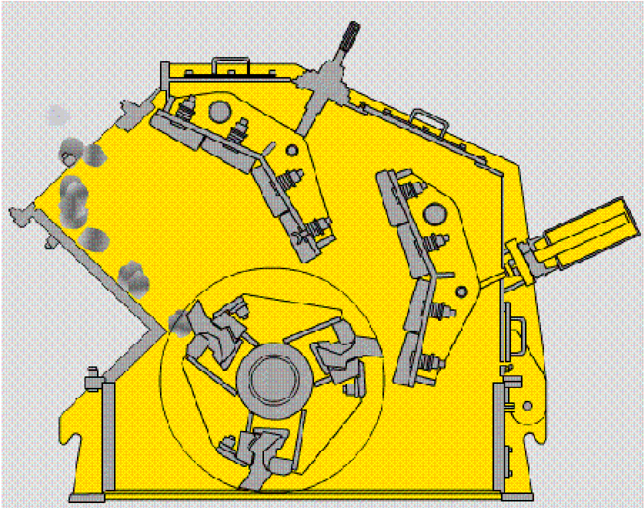


Figure IV-7 Impact Crusher side view diagram

3. Cone Crusher:

They are developed from the gyrating crushers' family. They are considered the most important crushers in the quarrying field. The material gets compressed between two cone shaped plates. As indicated in Figure IV-8, The high speed of the cone crushes the concrete into smaller sizes leaving it to fall freely under its own weight out of the chamber with the required size. When the crusher is fed large pieces, that surely have at least one dimension equal to or less than the setting, it is quoted as closed-side setting (CSS). This crusher is faster than the jaw crusher due to the high speed of the cones. However it will be slower and inefficient if fed a wide range of particle size. Therefore it is best to be used as a secondary crusher (Marmash, 2010).

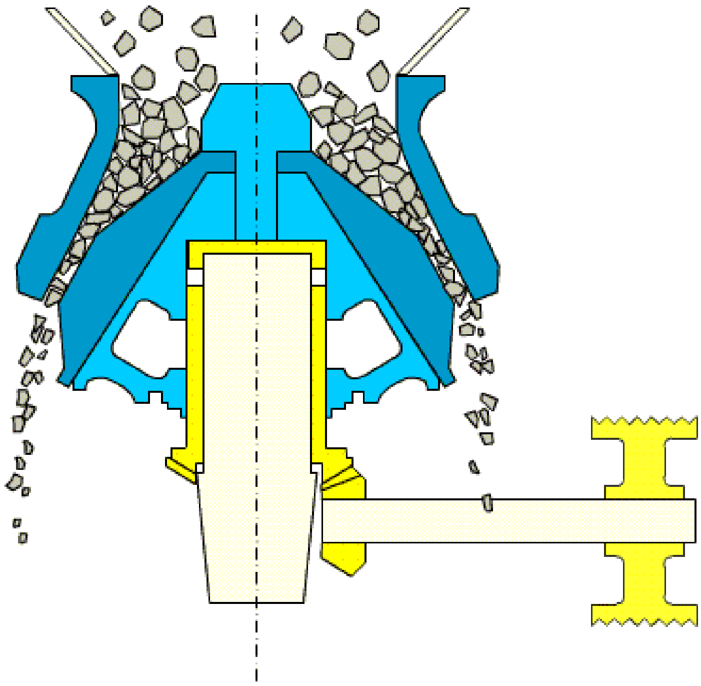


Figure IV-8 Cone Crusher side view diagram

E. Fixation Type of Crushers

1. Portable crushers:

They are mounted on rubber-tired chassis and towed to the site by trucks. On site loaders or tugs move them.

2. Mobile crushers

They are carried to the site by truck and trailer and have their own onboard drive system typically track driven. These units move easily on sites where several moves are required

3. Stationary crushers

They are permanently fixed to the ground. Typically used in a recycling yard where all material is trucked to the site.

F. Comparison of Types of Crushers

A Dutch investigation was made in order to compare the performance of crushers when crushing old concrete. The results can be summarized as follows: jaw crusher is the best choice to provide the best grain size distribution of recycled aggregates for concrete production. The cone crusher is best used as secondary crusher with 200mm maximum feeding size. The impact crusher is best used in projects related to road construction. They provide the better grain-size distribution and are less sensitive to obstacles that cannot be crushed like steel or iron (Hansen, 1992).

However, jaw crusher produce better grain-size distribution than impact crushers because jaw crushers crush smaller proportions of the original aggregate particles in the old concrete. On the other hand, impact crushers crush old mortar thus produce lower quality aggregate. In addition, another economic disadvantage for the impact crushers is its high wear and tear. Therefore it needs relatively higher maintenance cost.

The study proved that all crushers approximately produce the same percentage of cubical particles in cubical aggregates and it also proved that the quality improves when having a secondary crushing (Hansen, 1992).

G. Capacity of the plant

The capacity worldwide ranges from 50 to 800 tons per hour TPH, on average. This data is used to develop the model in chapter 5. However, based on the practiced capacity rates, only 200, 400, 800 are to be analyzed for all types of plant, mobile, stationary and traditional.

H. Results

In order to start implementing the project many factors should be considered. This investigation proposes the feasibility of starting a concrete recycling plant. The plant will operate all year long mainly using the construction debris from all the construction sites. All this data is presented in an excel model which will calculate all the necessary revenues and expenses.

On the other hand, there is a huge variety of expenses and they are all important. With more research and surveys, more expenses are analyzed and taken into consideration. The main expense is the initial investment. It consists of three main things, crushing plant investment, hauling equipment investment, transportation investment. Nevertheless, the salaries of the workers and engineers should also be taken into consideration. The workers are classified into 3 categories, highly skilled, semi-skilled and normal labor. In addition, a resident engineer supervises all the work in the plant. All these expenses are subject to increase according to the contract type. In addition, there is another type of expense, which is the depreciation of the equipment. This aids in the estimation of pricing of the equipment on site. The revenues and expenses are analyzed in details in this chapter section I and J.

I. Revenues:

The revenues are basically the volume of material sold multiplied by their market price. Of course for this case, the market price should not be a competitive one since this kind of product is new to the market. People are always scared of changing their habits and the way they are used to execute things. Resistant to change is the main problem here.

Basically, this is the main revenue stream for this project. However, there might be other revenue streams for this project since its main function is crushing. The plant can crush any material within the input range 400mm to 700mm. Moreover, the plant can also recycle other kinds of materials like granite, coarse aggregates, asphalt debris, etc. The revenues are forecasted along a 10 year period of time. Inflation is taken into consideration since it is a major variable in the construction industry.

Another revenue source is selling the metal extracted from the magnetic separator. All the steel waste can be reused in many construction activity and steel fabrication. This is a good revenue stream depending on the amount of steel collected from the concrete debris. In this research this revenue stream is not considered in the model, as it can be secondary revenue for the project. Another revenue stream is to make end-user products like concrete blocks and/or curbstones. This procedure is mentioned in depth in chapter one section D-2.

According to Eng. Roufauel, managing director at Roufouel construction group, the prices for the aggregates are different every day. However for the period of 2013, second half of the year the prices are as follows:

- For coarse aggregate the price of large quantities >50m^3 is about **50LE/m^3**
- For small quantities from 10m^3 around **70LE/m^3**
- As for fine aggregate the cost is around **10-12LE/m^3**

According to these market prices, the selling price for this project can be concluded. The plan is to have a lower price than the market price in order to maintain market share and motivate the contractors to buy it. The model will have variable prices within a certain range. Moreover, this range will be tested to check its sensitivity on the profits.

J. Expense

1. Initial Investment:

In this part of the research, all the equipment needed will be analyzed financially. In order to choose the right equipment for the job many technical factors will be analyzed in the equipment itself. As mentioned before the equipment needed basically consists of:

1. Wheel Loader.
2. Trucks

3. Vibratory feeder
4. Jaw crusher or Impact crusher, as primary crushers
1. Cone Crusher, as secondary crusher
2. Straight or swing conveyor with screen.
3. Permanent magnetic separator
4. Sand Washer

There are many types of machinery setting. They can be set as traditional, portable, mobile or stationary. In this research stationary, mobile and traditional are compared. Later on, this model will be duplicated in other areas as further expansion of the initial plan. This will aid in decreasing the cost of transportation.

After choosing the setting of the plant, many technical factors should be selected. The following charts will describe all the possibilities for machinery choice. One of the common factors is the equipment price (initial investment) and there are other factors relevant to each machine, like rate of content passing, power, volume, etc.

The pricing is found in section 2 in this chapter under section J: expenses with more details and numerical justifications. It should be noted that the estimated costs given in the model development part are confidential and could be verified using different sources found in the appendices. The only source used to collect these cost data is from in-depth interviews with companies' on-site representatives. The data obtained and the brands mentioned are confidential to this study, as the manufacturers do not accept to reveal their market prices. It is also believed that this practice is very common in the field of construction industry.

2. Crushing Plant Equipment

The cost of the equipment is based on production. According to a Chinese crusher manufacturer, the minimum and maximum production rates for a plant is between 200-800 ton per hour (TPH). It is possible to combine more machines in order to increase the TPH.

The following Figure IV-9and Figure IV-10 shows the orientation, setting and combinations to produce more TPH. The detailed financial quotations are extracted from offers given by several companies. As per their request, all the prices of equipment are confidential; therefore, the quotations are attached in Appendix IV anonymously. The technical specifications for mobile and stationary plant types are attached in Appendix III as manufacturers' brochures.

The following chart includes (in order):

A. Loader
B. Vibratory feeder
C. Jaw Crusher
D. Conveyor belt
E. Magnetic Separator
F. Impact crusher
G. Conveyor belt
H. Screen

Piles

A. Pile 1: Pile of fine material not being able to be crushed
B. Pile 2: Size 0-10mm
C. Pile 2: Size 10-20mm
D. Pile 3: Size 20-40mm

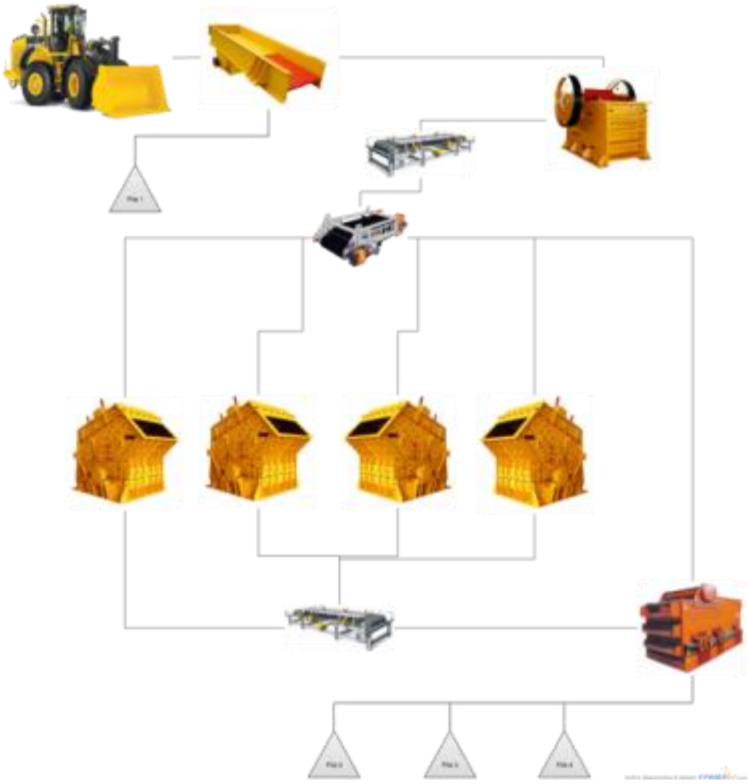


Figure IV-9 Stationary Plant layout proposal for 800 TPH

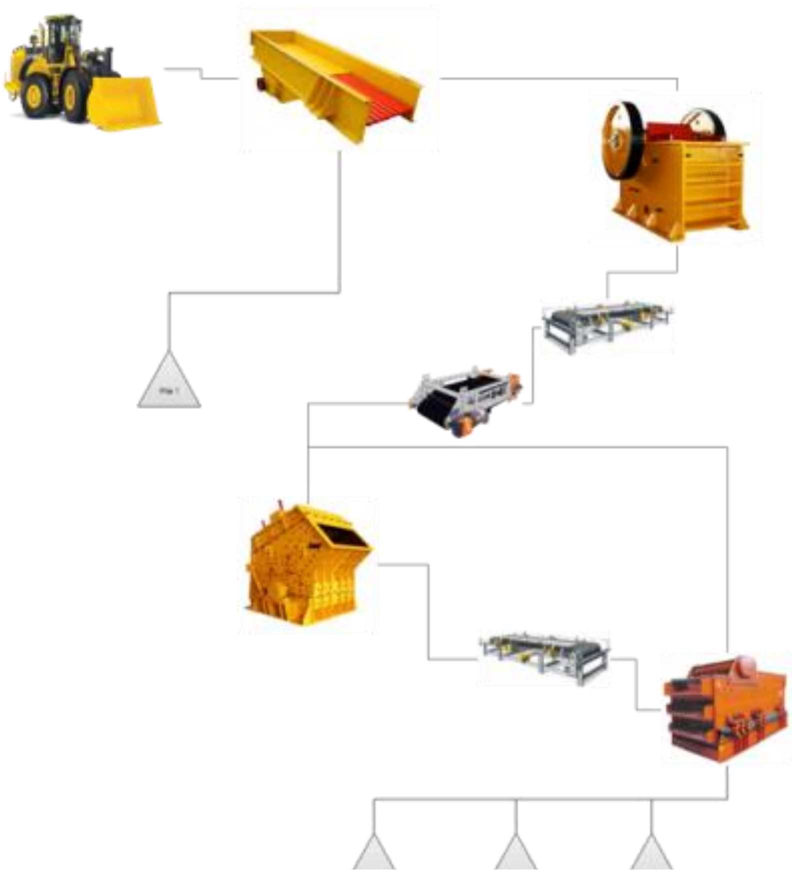


Figure IV-10 Stationary Plant layout proposal for 200 TPH

3. Truck Equipment

The truck equipment is mainly used for transportation purposes. This type of equipment usually has two operator labors, one skilled and one semi-skilled, as previously mentioned in the literature review section 0. The price given to each truck is 1,500,000LE as per the Egyptian market prices. All these prices were re-checked with the experts from working in the field.

4. Heavy hauling Equipment:

The heavy equipment is mainly used for hauling materials after and/or before transportation of concrete aggregates. This depends on the type of plant. For example if the plant is of a mobile type, the hauling equipment will be used to haul the material across the site. If the plant is of a stationary or traditional type, the equipment will be used to haul the materials form and/or to the trucks. The heavy hauling requires two operator labors, one skilled and one semi-skilled, as previously mentioned in the literature review section 0. The equipment planned to be used is the new wheel loader. The price given to each truck is 1,200,000LE as per the Egyptian market prices. All these prices where re-checked with the experts from working in the field.

5. Human Resource Salaries

The human resource is one of the most important resources to operate the plant. The categories of the human resources are divided as follows:

- Highly skilled labor
- Semi-skilled labor
- Normal skilled labor
- Forman

- Engineer

Table IV-2, Table IV-3 and Table IV-4 clarify the assignment and salaries of the labor on the process of each plant type. In the three plant types, stationary, mobile, and traditional, the number of labor will differ in each process. These data are developed from many experts in the field who were interviewed, as previously stated in chapter 2: the literature review, sections C. However, the labor chart of the traditional type was extracted from the local experts as it is only implemented in Egypt, as mentioned in chapter 2 section B.

Stationary Plant:

Table IV-2 Manning Figures for stationary plant type 200, 400, 800 TPH

200 TPH													
Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation	Total	Rate/Day	Salary/Month	Total Salary/Year
# of workers													
Highly Skilled Labor	2							1	1	4	134	3500	168000
Semi-Skilled Labor		1		1	1	1				4	100	2600	124800
Normal Skilled Labor			8							8	76	2000	192000
Engineer							1			1		4500	54000
Foreman							1			1		3000	36000
										Total		15,600.00	574,800.00

400 TPH													
Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation	Total	Rate/Day	Salary/Month	Total Salary/Year
# of workers													
Highly Skilled Labor	4	0	0	0	0	0	0	2	2	8	134	3500	336000
Semi-Skilled Labor	0	2	0	2	1	2	0	0	0	7	100	2600	218400

Normal Skilled Labor	0	0	16	0	0	0	0	0	0	16	76.	2000	384000
Engineer	0	0	0	0	0	0	2	0	0	2		4500	108000
Forman							1			1		3000	36000
										Total		**12,600.00**	**1,046,400.00**

800 TPH													
Activity	**Haul-Input**	**Feeder**	**Manual Filtering**	**Primary Crusher**	**Secondary Crusher**	**Screen**	**Monitor**	**Post-Handling**	**Transportation**	**Total**	**Rate/Day**	**Salary/Month**	**Total Salary/ Year**
# of workers													
Highly Skilled Labor	6	0	0	0	0	0	0	3	3	12	134.	3500	504000
Semi-Skilled Labor	0	3	0	2	2	4	0	0	0	11	100	2600	343200
Normal Skilled Labor	0	0	24	0	0	0	0	0	0	24	76.	2000	576000
Engineer	0	0	0	0	0	0	3	0	0	3		4500	162000
Forman							1			1		3000	36000
										Total		**12,600.00**	**1,585,200.00**

<u>Mobile Plant:</u>

Table IV-3 Manning Figures for mobile plant type 200, 400, 800 TPH

200 TPH													
Activity	**Haul-Input**	**Feeder**	**Manual Filtering**	**Primary Crusher**	**Secondary Crusher**	**Screen**	**Monitor**	**Post-Handling**	**Transportation**	**Total**	**Rate/ Day**	**Salary/ Month**	**Total Salary/Year**
# of workers													
Highly Skilled Labor	2							1	1	4	134	3500	168000
Semi-Skilled Labor		1		1	1	1				4	100	2600	124800
Normal Skilled Labor			4							4	76	2000	96000
Engineer							1			1		4500	54000

Forman							1			1		3000	36000
										Total		**15,600.00**	**478,800.00**

400 TPH													
Activity	**Haul-Input**	**Feeder**	**Manual Filtering**	**Primary Crusher**	**Secondary Crusher**	**Screen**	**Monitor**	**Post-Handling**	**Transportation**	**Total**	**Rate/Day**	**Salary/Month**	**Total Salary/Year**
# of workers													
Highly Skilled Labor	4							2	2	8	134	3500	336000
Semi-Skilled Labor		2		2	1	2				7	100	2600	218400
Normal Skilled Labor			8							8	76	2000	192000
Engineer							2			2		4500	108000
Forman							1			1		3000	36000
										Total		**12,600.00**	**854,400.00**

800 TPH													
Activity	**Haul-Input**	**Feeder**	**Manual Filtering**	**Primary Crusher**	**Secondary Crusher**	**Screen**	**Monitor**	**Post-Handling**	**Transportation**	**Total**	**Rate/Day**	**Salary/Month**	**Total Salary/Year**
# of workers													
Highly Skilled Labor	6							3	3	12	134	3500	504000
Semi-Skilled Labor		3		2	2	4				11	100	2600	343200
Normal Skilled Labor			12							12	76	2000	288000
Engineer							3			3		4500	162000
Forman							1			1		3000	36000
										Total		**12,600.00**	**1,297,200.00**

Traditional:

Table IV-4 Manning Figures for traditional plant type 200, 400, 800 TPH

200 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation	Total	Rate/Day	Salary/Month	Total Salary/Year
# of workers													
Highly Skilled Labor	2							2	1	5	134	3500	210000
Semi-Skilled Labor		1		1						2	100	2600	62400
Normal Skilled Labor			8					2		10	76	2000	240000
Engineer							1			1		4500	54000
Forman							1			1		3000	36000
										Total		15,600.00	602,400.00

400 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation	Total	Rate/Day	Salary/Month	Total Salary/Year
# of workers													
Highly Skilled Labor	4							4	2	10	134	3500	420000
Semi-Skilled Labor		2		2						4	100	2600	124800
Normal Skilled Labor			16					4		20	76	2000	480000
Engineer							1			1		4500	54000
Forman							1			1		3000	36000
										Total		12,600.00	1,078,800.00

800 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation	Total	Rate/Day	Salary/Month	Total Salary/Year
# of workers													
Highly Skilled Labor	6							8	4	18	134	3500	756000

Semi-Skilled Labor		3		2						5	100	2600	156000
Normal Skilled Labor			24					8		32	76	2000	768000
Engineer							2			2		4500	108000
Forman							2			1		3000	36000
										Total		**12,600.00**	**1,788,000.00**

6. Rent Expense

The rent expense contributes to the land used for operating the plants. The expense is evaluated as per the area required for each plant type. The land should be away from any urban city; however, it should be as close as possible to the construction sites. The land space would also differ from one type to the other. The traditional and stationary plants need more space for operation as they are permanently fixed. However, the mobile plant operates on site and doesn't require a permanent place. It will need a space for storing the equipment if it is not operating. Therefore, the rent expenses for the mobile type is significantly less than the other types.

7. Depreciation Expense

The depreciation expense is the value reduction of the equipment over the lifetime of the plant. The salvage value is assumed to be 50% of the original price over 10 years and the depreciation calculation method is linear.

K. Site layout

The site layout will be designed in a way to suit all the needs of the plant. However the only design available will be for the stationary and traditional types as they are the ones that require their own site. As for the mobile type, it will be transported to the site and will be designed according to the project site characteristics and regulations. Figure IV-11shows the mobile setting for two main pieces of equipment, crusher and screen. The company is Kleeman, it is German and it is one of the best crushing equipment producers in Europe and has the highest market share. As illustrated in the figure, the mobile equipment can move in the site with its tracker. It does not take a lot of space as it does not need a permanent place, such as the stationary.

Figure IV-12 shows the stationary plant equipment setting. This figure illustrates the size of a 400 TPH plant. The variance is very small between greater or less capacity plants. The equipment includes the conveyor belt, screen, crushers and magnetic separators.

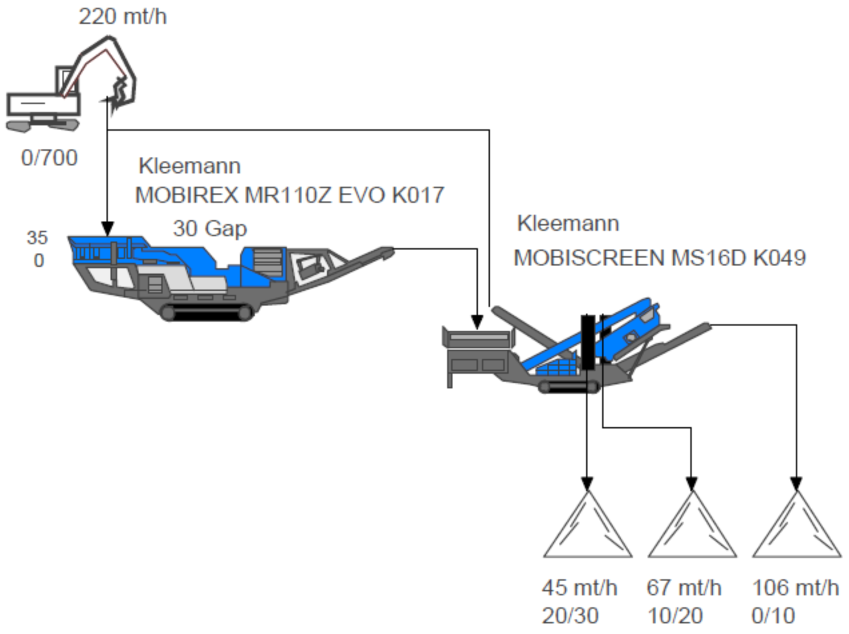


Figure IV-11 200 TPH Mobile Equipment setting, as found in Appendix III: Manufacturers sheets specifications of Kleeman company

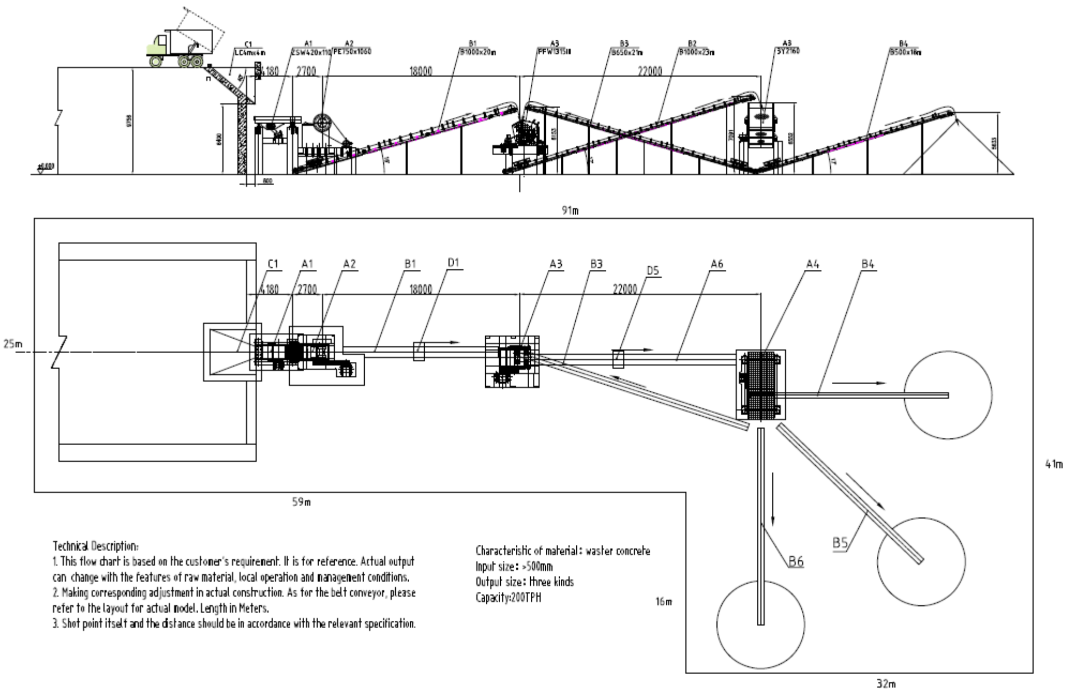


Figure IV-12 Stationary Equipment setting, as found in Appendix III: Manufacturers sheets specifications

V. Chapter 5: Model Framework and development:

A. Introduction of the model

The core of this research lies in the proposed model. All the previous parts, especially in chapter 2 and 4 (the literature review, data gathering and results, respectively), are the backbone of the model. Data was extracted from the literature review and was used in the model including the quantity of the materials in Egypt that are expected to be generated from waste in chapter 2 section A. In addition, all properties of recycled concrete discussed in chapter 2 section A are essential to decide on the price of aggregates when sold from the plant, as it will be the main source of revenue. Moreover, the techniques and types of plants are treated differently in them model. In chapter 2, section B of this thesis, many interviews, visits and meetings were conducted in Egypt and Europe to form a clear picture of all the possible ways that can be used to recycle concrete. The model is designed to serve three types of recycling plants, mobile, stationary and traditional.

B. Objective of the model

The objective of this model is to financially evaluate and compare three different types of concrete aggregate recycling plants. The model contains all the parameters, mentioned in chapter 4 sections I and J, as input and output. Moreover, there is a summary sheet combining all the parameters to be adjusted by the user for more diverse choices of costs like, renting, utilities, equipment, salaries, etc.

C. Model framework

In order to understand the model and its function all the basic parameters, included in chapter 4 revenues section I and expenses section J, are entered in the model. Moreover, all the equations used are to be analyzed accordingly. First of all the model is repeated several times with the same structure for all the three types used throughout the thesis. There are duplicates of the model in the excel sheets to calculate and evaluate the business model according to the main factor of equipment choice which is the capacity, as stated in chapter 4 section G. The capacities are 200,400,800 Tph. Therefore; there are three types multiplied by three capacity rates, leading to nine duplicated sheets.

The model is structured into two main sheets and one secondary sheet. The main sheets are called "parameters ### Tph" and "proforma ### Tph", where ### indicates the capacity rate of the equipment, either 200, 400 and 800 Tph, as shown in the Figure V-1. The secondary sheet is called workers' plan, which contains all staffing personnel in each process of the recycling, as shown in the following figure. This sheet has the number of workers, their salaries and skill category for all processes, as shown in the Figure V-3. Note that the workers' plan sheet cannot be edited, as this is the best practice data used to generate the number and salaries of the workers.

The screen shot in Figure V-1 and Figure V-2 are a sample screen shot of the main and secondary sheet in the model. More data about the human resources are found in another sheet called "workers' plan" as shown in Figure V-3.

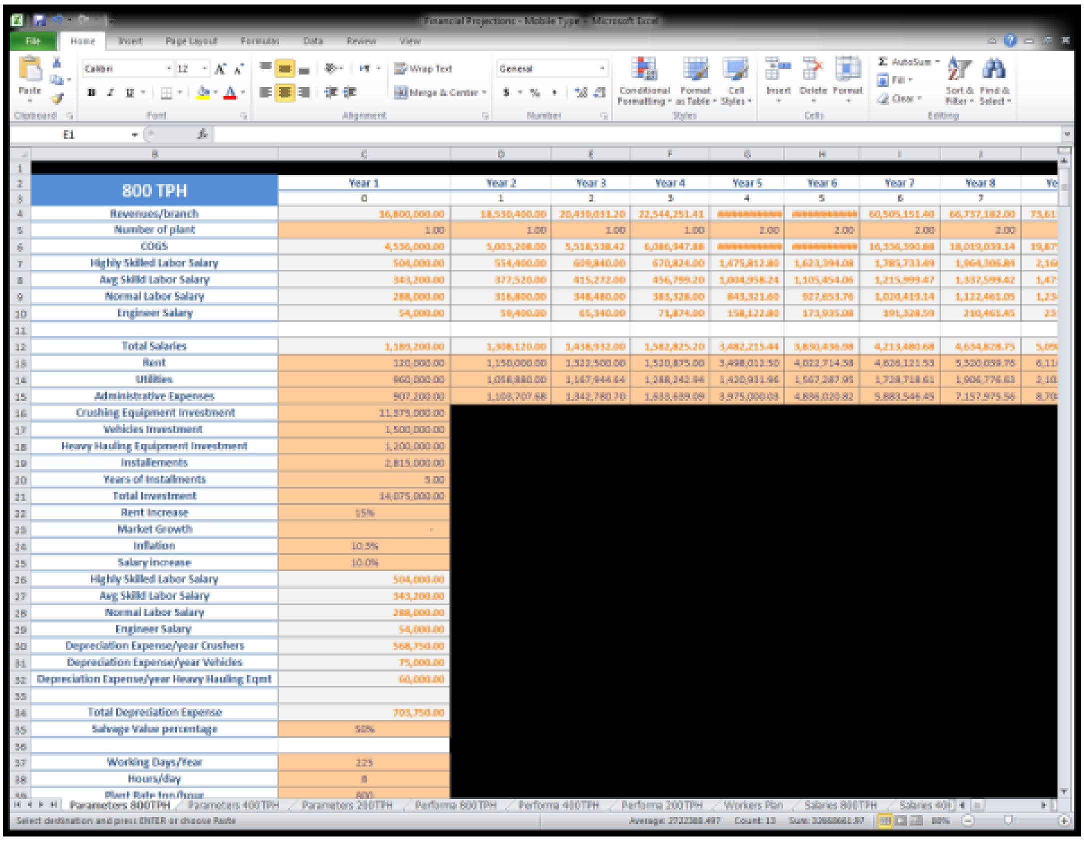


Figure V-1 Screen shot of the excel sheet "Parameters" containing the model 1 of 2

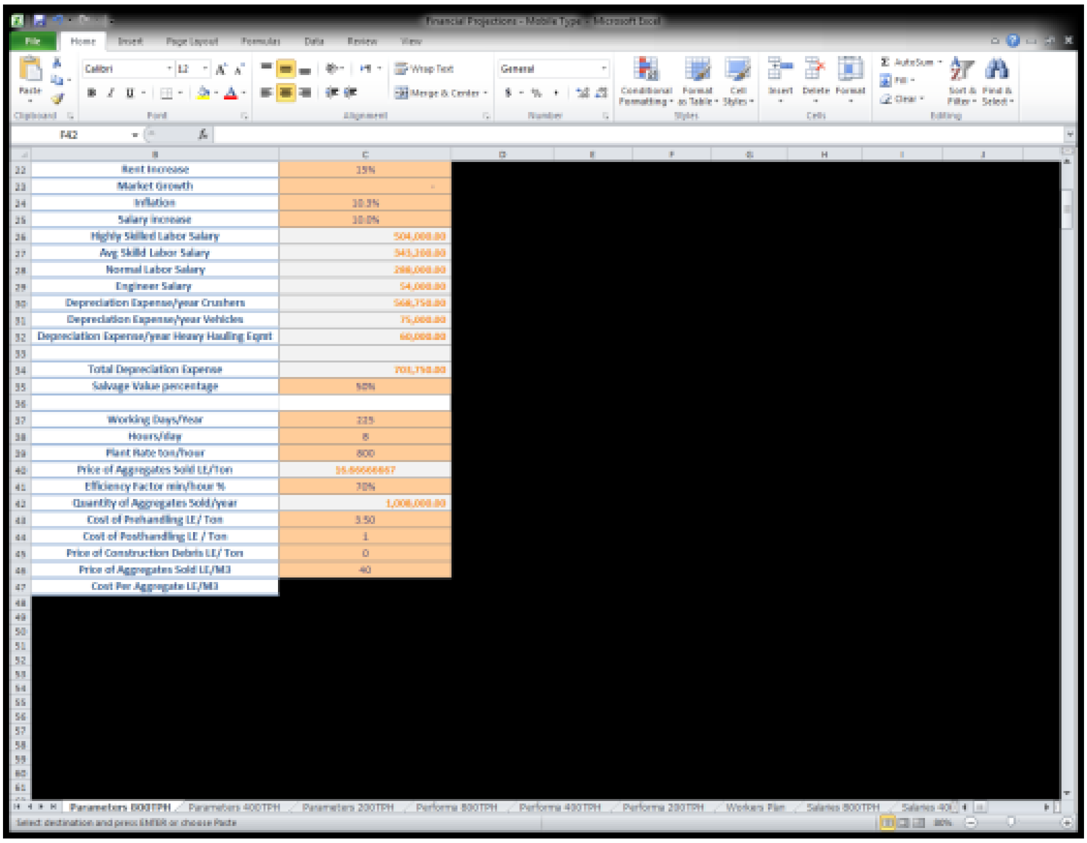
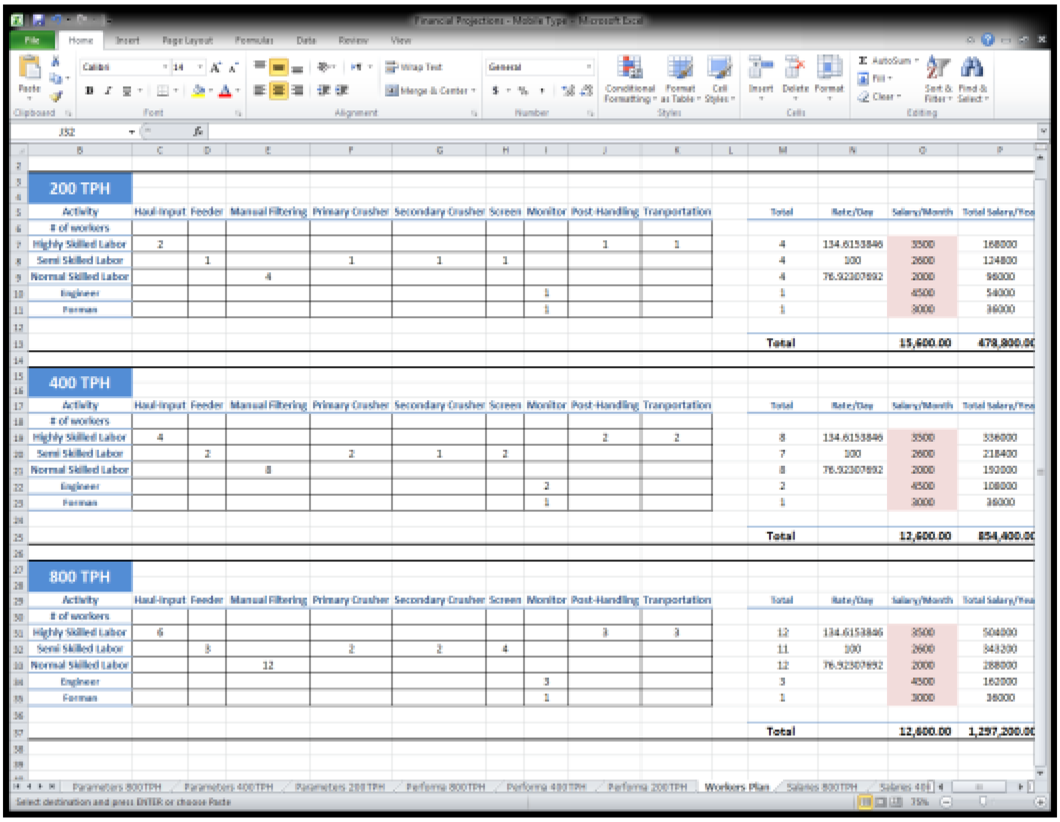


Figure V-2 Screen shot of the excel sheet "Parameters" containing the model 2 of 2



200 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Tranportation	Total	Rate/Day	Salary/Month	Total Salary/Yea
# of workers													
Highly Skilled Labor	2							1	1	4	134.6153846	3500	168000
Semi Skilled Labor		1		1	1	1				4	100	2600	124800
Normal Skilled Labor			4							4	76.92307692	2000	96000
Engineer							1			1		4500	54000
Forman							1			1		3000	36000
										Total		15,600.00	478,800.0

400 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Tranportation	Total	Rate/Day	Salary/Month	Total Salary/Yea
# of workers													
Highly Skilled Labor	4							2	2	8	134.6153846	3500	336000
Semi Skilled Labor		2		2	1	2				7	100	2600	218400
Normal Skilled Labor			8							8	76.92307692	2000	192000
Engineer							2			2		4500	108000
Forman							1			1		3000	36000
										Total		12,600.00	854,400.0

800 TPH

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Tranportation	Total	Rate/Day	Salary/Month	Total Salary/Yea
# of workers													
Highly Skilled Labor	6							3	3	12	134.6153846	3500	504000
Semi Skilled Labor		3		2	2	4				11	100	2600	343200
Normal Skilled Labor			12							12	76.92307692	2000	288000
Engineer							3			3		4500	162000
Forman							1			1		3000	36000
										Total		12,600.00	1,297,200.0

Figure V-3 Workers plan showing all the manning salaries

The screenshot, in Figure V-4, shows a sample of the "pro-forma" sheet. The sheet's main function is to collect all the different inputted parameters in the "parameters" sheet. Then, the data is categorized and listed as an income statement. The headings are:

- Income Statement
  - Revenues
  - Cost of Goods sold
  - Gross Profit 800TPH
- Operating expense
  - Total Salaries
    - Total Depreciation
  - Rent
  - Utilities

- Administrative Expenses
- Initial Investment

- Total Expenses 800TPH
- Net Profit 800 TPH
- Profit margin

The data is analyzed and forecasted throughout the 10-year period of analysis.

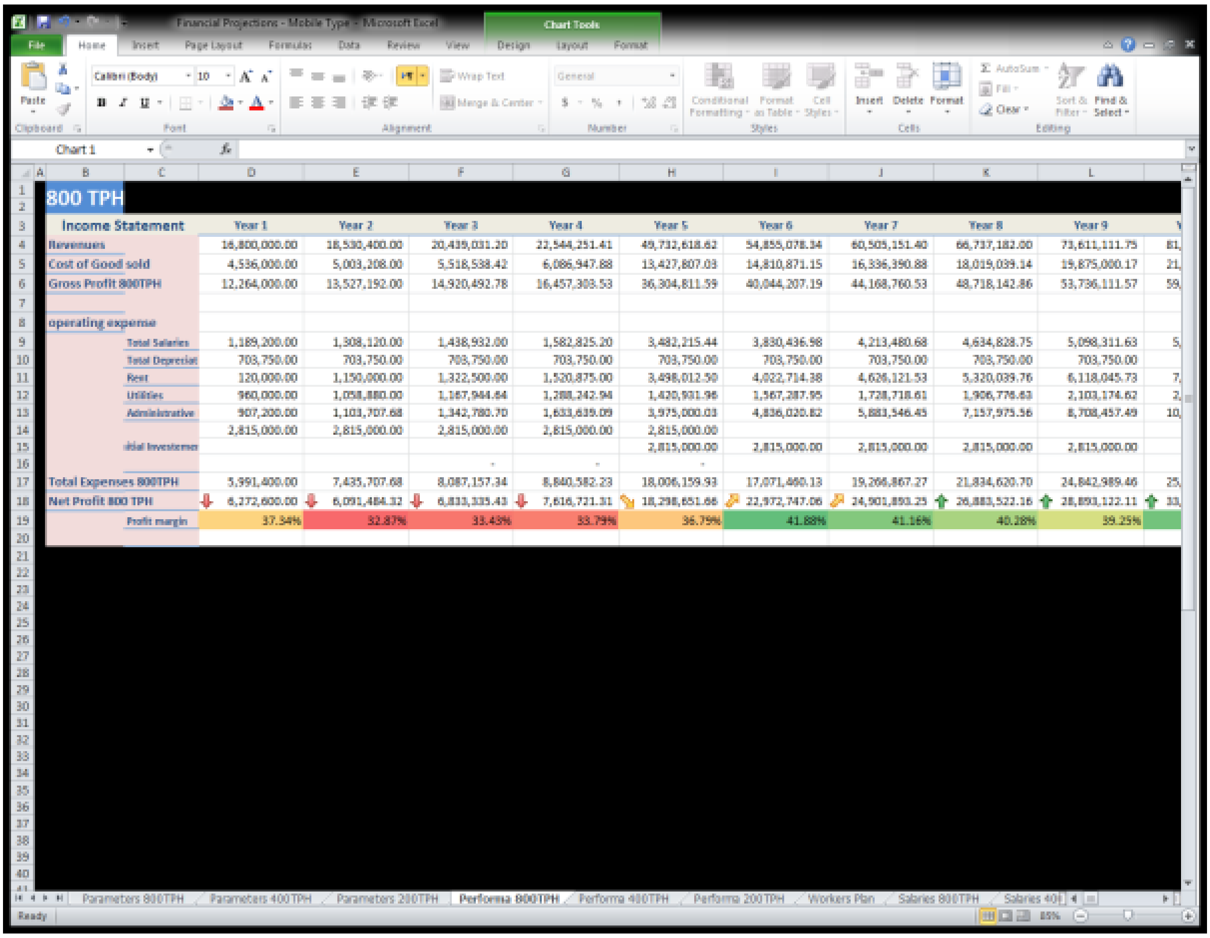


Figure V-4 Screen shot of the excel sheet "Per-foam" containing the model

Table V-1 includes all the variables in the parameters sheet. All the variables highlighted cells indicate that this is an input by the user and all the grey highlighted cells indicate that the value is calculated by the model. The currency used across the model is EGP since the application of the model is in Egypt. However, the model can work with any other currency but it needs to be consistent throughout the model.

Table V-1 Parameters used as inputs in the model

Parameter	Sample Cost (LE or else indicated)	Description
Revenues/branch	18,000,000.00	This is the revenue that each branch generates.
Number of plant	1.00 (number)	This is the number of branches found for each plant type. Later, the number of branches can increase to study the impact profits.
COGS	3,456,000.00	The COGS is the cost of goods sold (materials recycled and pre and post handling costs of construction debris).
Highly Skilled Labor Salary	504,000.00	The salary for the highly skilled labor per year
Avg. Skilled Labor Salary	343,200.00	The salary for the average skilled labor per year
Normal Labor Salary	288,000.00	The salary for the normal skilled labor per year
Engineer Salary	54,000.00	The salary for the engineer per year

Total Salaries	1,189,200.00	The total salaries of all workers and engineers per year
Rent	120,000.00	The rent of land where the plant operates. This amount is per year
Utilities	960,000.00	Utilities includes electricity, fuel, and any other direct costs that contribute to the operation of the plant
Administrative Expenses	691,200.00	Admin expenses includes the indirect costs affiliated with the operation of the plant such as paper work, secretary, administrative office expenses, etc.
Crushing Equipment Investment	11,375,000.00	The initial investment of crushing equipment and this price includes the sea freight, customs and currency exchange rates.
Vehicles Investment	1,500,000.00	The initial investment of vehicles used in transportation of the material and this price includes the sea freight, customs and currency exchange rates

Heavy Hauling Equipment Investment	1,200,000.00	The initial investment of heavy hauling equipment used in moving material between the plant and trucks and this price includes the sea freight, customs and currency exchange rates
Installments	2,815,000.00	All the investments are expected to be installed in equal installments according to the number of years indicated
Years of Installments	5.00 (years)	The number of years of all the installment to be paid by then
Total Investment	14,075,000.00	The total investment includes the prices of crushing, vehicles and hauling equipment.
Rent Increase	15%	This is the rent increase per year
Inflation	10.3%	This is the material inflation increase in the market per year
Salary increase	10.0%	This is the salary of the staffing personnel increase per year
Depreciation Expense/year Crushers	568,750.00	This is the depreciation expense of crushing equipment per year based on linear depreciation.
Depreciation Expense/year Vehicles	75,000.00	This is the depreciation of vehicles equipment per year

		based on linear depreciation.
Depreciation Expense/year Heavy Hauling Equipment	60,000.00	This is the depreciation of heavy hauling equipment per year based on linear depreciation
Total Depreciation Expense	703,750.0 0	This is the total depreciation expense for the crushing, vehicles and hauling equipment.
Salvage Value percentage	50%	This is salvage or book value at the end of the depreciation period
Working Days/Year	225 (days)	The international working days per calendar year.
Hours/day	8 (hours)	The number of hours of plant operation per day
Plant Rate ton/hour	800 (TPH)	The production capacity of the plant
Price of Aggregates Sold LE/Ton	16.67	The calculated price of aggregates sold by the plant per ton. (assuming ton=2.4 m3 of aggregates)
Efficiency Factor min/hour %	75%	The efficiency of the labor and equipment working in the plant
Quantity of Aggregates Sold/year	1,080,000.	The quantity sold per year

	00	and calculated according to all the factors mentioned above, as capacity, inflation, market increase, efficiency, working hours and days.
Cost of Pre-handling LE/ Ton	2.00 (LE/ Ton)	This is the cost of pre-handling as transportation, toll fees, separation, or any other costs affiliated with the materials before coming to the plant
Cost of Post-handling LE / Ton	1.2 (LE/ Ton)	This is the cost of post-handling like packaging, toll fees, marketing, labeling, etc.
Price of Construction Debris LE/ Ton	0	This is the price of the material if it will be bought from certain places to increase the input material in the plant. (It will differ from plant type and the other)
Price of Aggregates Sold LE/M3	40	This is the price of selling the aggregates from the plant

Moreover, the model is designed to generate graphs for a time period of ten years. The graphs represent the profit/loss, revenues, expenses, different salaries, etc. for all the predicted values of the period of the plant model. The model will be further developed to include more types of equipment. This is evaluated in model development section D.

D. Model development

In order to get the best results out of the model, many types of plants' operation data was entered to generate the predictions and graphs. They are generated based on the parameters explained in model framework section C. The specifications of the plant type will be the base on changing the costs affiliated with it in the model. The explanation of the fixation type of each category of plant is explained in chapter 4 section E. This section explains how the plant is functioning, if needed. This data is used in this section to develop the model and change costs. For example, the mobile type does not require renting costs as it will be operating on site however, it will need transportation costs.

In order to make the model user-friendly, a summary file is created, as shown in Figure V-8, Figure V-9, Figure V-10. This file is the main control panel for all other files and sheets. As shown in Figure V-5, the first sheet of the summary file contains all the necessary instructions to aid the user. Then, there is the data input button that allows the user to change any of the data used in the model. The interface allows the user to input data in certain cells. All other cells are blocked to avoid any modifications in the basic calculations. The user must enter numbers only in the allowed cells. After adding the desired input data, the user should click the back button to return to the home page of the instructions. The user should decide on what to do, either run the feasibility for one type, as shown in Figure V-5 and observe all the generated graphs or compare all types to decide on the best type for his/her project. Figure V-6, shows the menu board of each plant type. It helps the user to navigate through the model and generate many useful data by simple clicks.

The excel file is duplicated three times for the three types of plants, mobile, traditional and stationary. All files include the same main and secondary sheets, which were introduced in the model framework section C. The following screenshots are taken from the duplicated excel files.

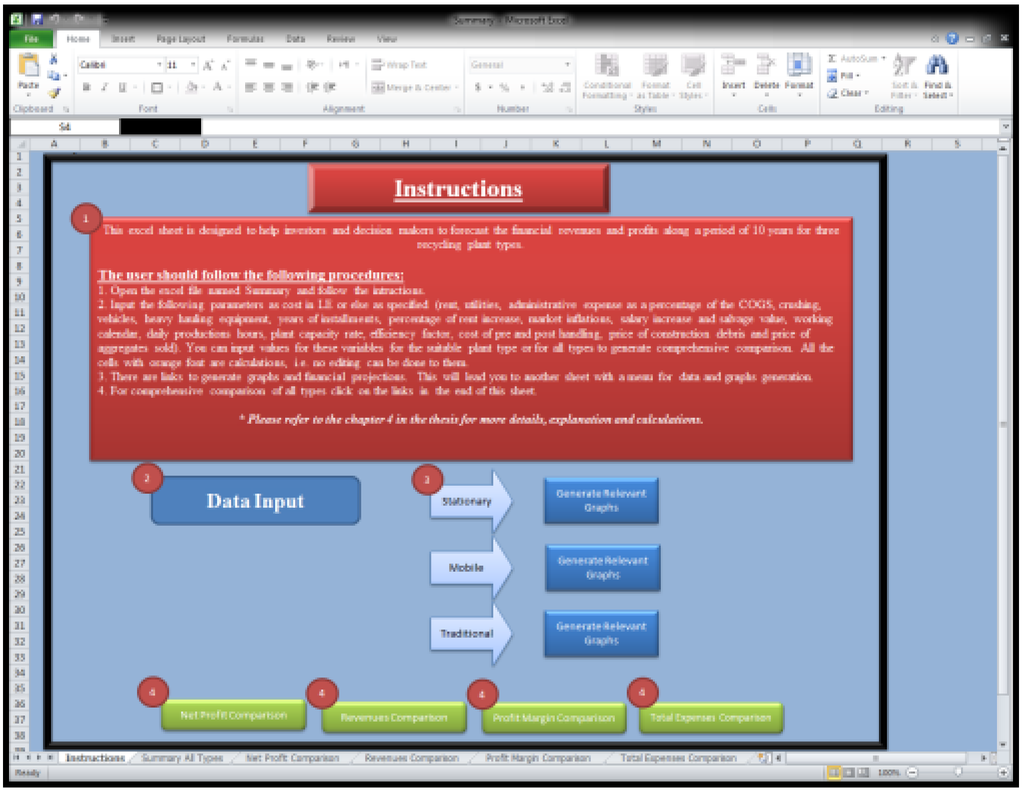


Figure V-5 Summary file with the instructions home page acting as the control panel for all the other files and sheets

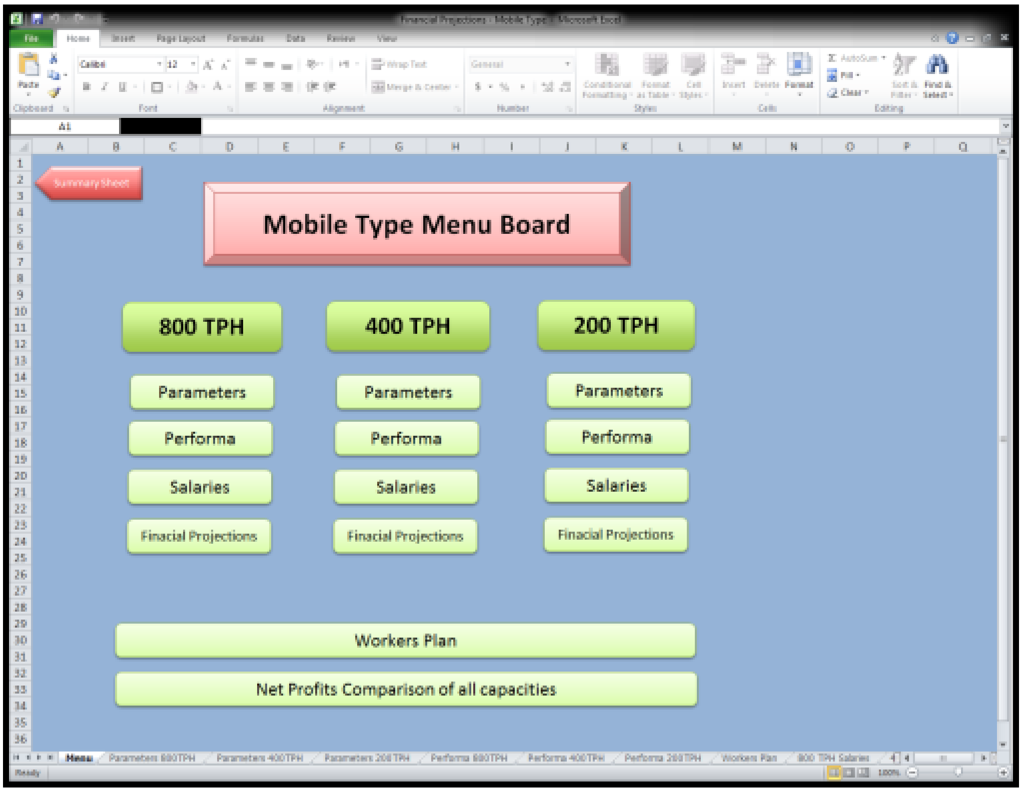


Figure V-6 Main menu Board for applied for every model for every type of plant (sample sheet)

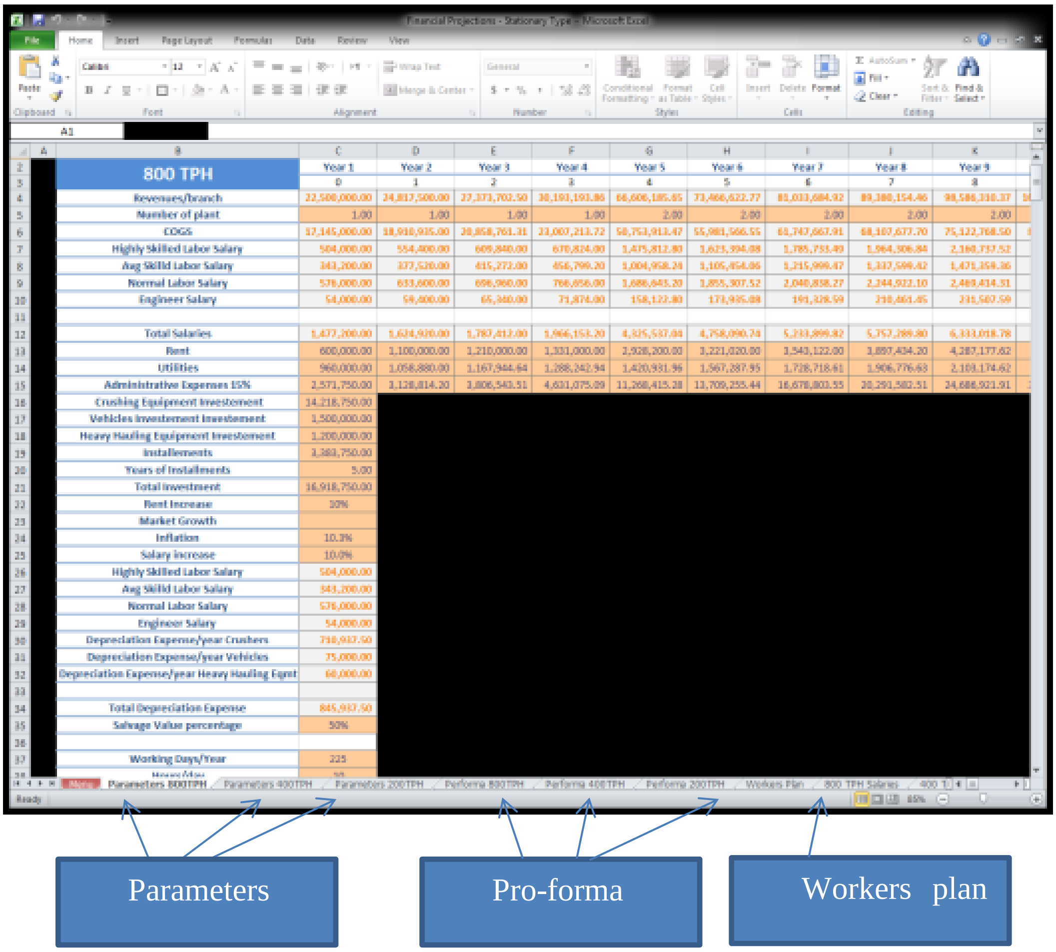


Figure V-7 Model Creation and development screen shot

Stationary	Capacity	800	400	200
	Variables			
	Rent (LE)	600,000.00	420,000.00	240,000.00
	Utilities (LE)	960,000.00	960,000.00	240,000.00
	Administrative Expenses (percentage of COGS	15%	13%	12%
	Crushing Equipment Investement (LE)	14,218,750.00	85,312,500.00	2,843,750.00
	Vehicles Investement Investement (LE)	1,500,000.00	1,500,000.00	850,000.00
	Heavy Hauling Equipment Investement (LE)	1,200,000.00	1,200,000.00	1,200,000.00
	Installements (LE)	3,383,750.00	17,602,500.00	978,750.00
	Years of Installments (Years)	5.00	5.00	5.00
	Total Investment (LE)	16,918,750.00	88,012,500.00	4,893,750.00
	Rent Increase (%)	10%	10%	10%
	Market Growth (%)			
	Inflation (%)	10.3%	10.3%	10.3%
	Salary increase (%)	10%	10%	10%
	Salvage Value percentage (%)	50%	50%	50%
	Working Calendar (Days/Year)	225	250	250
	Daily Production Hours (Hours/day)	10	10	10
	PlantCapacity Rate (ton/hour)	800	400	200
	Price of Aggregates Sold (LE/Ton)	16.66666667	16.66666667	16.66666667
	Efficiency Factor min/hour (%)	75%	75%	75%
	Quantity of Aggregates Sold/year (ton)	1,350,000.00	750,000.00	375,000.00
	Cost of Prehandling (LE/ Ton)	1.20	1.2	1.2
	Cost of Posthandling (LE / Ton)	1.5	2	2
	Price of Construction Debris (LE/Ton)	10	10	10
	Price of Aggregates Sold (LE/M3)	40	40	40

Figure V-8 Summary Sheet screenshot of Stationary Plant

Mobile	Capacity	800	400	200
	Rent (LE)	120,000.00	120,000.00	96,000.00
	Utilities (LE)	960,000.00	960,000.00	240,000.00
	Administrative Expenses (percentage of COGS	20%	18%	15%
	Crushing Equipment Investement (LE)	11,375,000.00	9,100,000.00	5,175,625.00
	Vehicles Investement Investement (LE)	1,500,000.00	1,500,000.00	850,000.00
	Heavy Hauling Equipment Investement (LE)	1,200,000.00	1,200,000.00	1,200,000.00
	Installements (LE)	2815000	2360000	1445125
	Years of Installments (Years)	5.00	5.00	5.00
	Total Investment (LE)	14075000	11800000	7225625
	Rent Increase (%)	15%	15%	15%
	Market Growth (%)			
	Inflation (%)	10.3%	10.3%	10.3%
	Salary increase (%)	10%	10%	10%
	Salvage Value percentage (%)	50%	50%	50%
	Working Calendar (Days/Year)	225	250	250
	Daily Production Hours (Hours/day)	8	6	6
	PlantCapacity Rate (ton/hour)	800	400	200
	Price of Aggregates Sold (LE/Ton)	16.66666667	16.66666667	16.66666667
	Efficiency Factor min/hour (%)	70%	70%	70%
	Quantity of Aggregates Sold/year (ton)	1,008,000.00	420,000.00	210,000.00
	Cost of Prehandling (LE/ Ton)	3.50	3.5	3.5
	Cost of Posthandling (LE / Ton)	1	1	1
	Price of Construction Debris (LE/Ton)	0	0	0
	Price of Aggregates Sold (LE/M3)	40	40	40

Figure V-9 Summary Sheet screenshot of Mobile Plant

Tradtional	Capacity	800	400	200
	Rent (LE)	720,000.00	480,000.00	240,000.00
	Utilities (LE)	120,000.00	96,000.00	24,000.00
	Administrative Expenses (percentage of COGS	12%	12%	10%
	Crushing Equipment Investement (LE)	500,000.00	350,000.00	200,000.00
	Vehicles Investement Investement (LE)			
	Heavy Hauling Equipment Investement (LE)			
	Installements (LE)	100000	70000	40000
	Years of Installments (Years)	5.00	5.00	5.00
	Total Investment (LE)	500000	350000	200000
	Rent Increase (%)	15%	15%	15%
	Market Growth (%)			
	Inflation (%)	10.3%	10.3%	10.3%
	Salary increase (%)	12%	10%	10%
	Salvage Value percentage (%)	50%	50%	50%
	Working Calendar (Days/Year)	250	250	250
	Daily Production Hours (Hours/day)	8	8	8
	PlantCapacity Rate (ton/hour)	800	400	200
	Price of Aggregates Sold (LE/Ton)	16.66666667	16.66666667	16.66666667
	Efficiency Factor min/hour (%)	75%	75%	75%
	Quantity of Aggregates Sold/year (ton)	1,200,000.00	600,000.00	300,000.00
	Cost of Prehandling (LE/ Ton)	10.00	10	10
	Cost of Posthandling (LE / Ton)	0	0	0
	Price of Construction Debris (LE/Ton)	10	10	10
	Price of Aggregates Sold (LE/M3)	40	40	40

Figure V-10 Summary Sheet screenshot of Traditional Plant

1. Explanation of all calculations

This part of the thesis explains the calculation steps. The screen shot, in Figure V-11, shows the calculations formulas of one type of the recycling plant model. However these calculations are applied in all models but only the parameters are changed to suit the expenses and revenues associated with each type.

2. Equations

This part shows all calculations for each item in the model and its equation. The following equations are located in each sheet named "Parameters" in Appendix II for the different plant types. It is noted that if any equation was taken from the summary sheet, this means that it can be edited and/or has another equation embedded in it. The equations of the summary sheet Appendix II will also be included in this section.

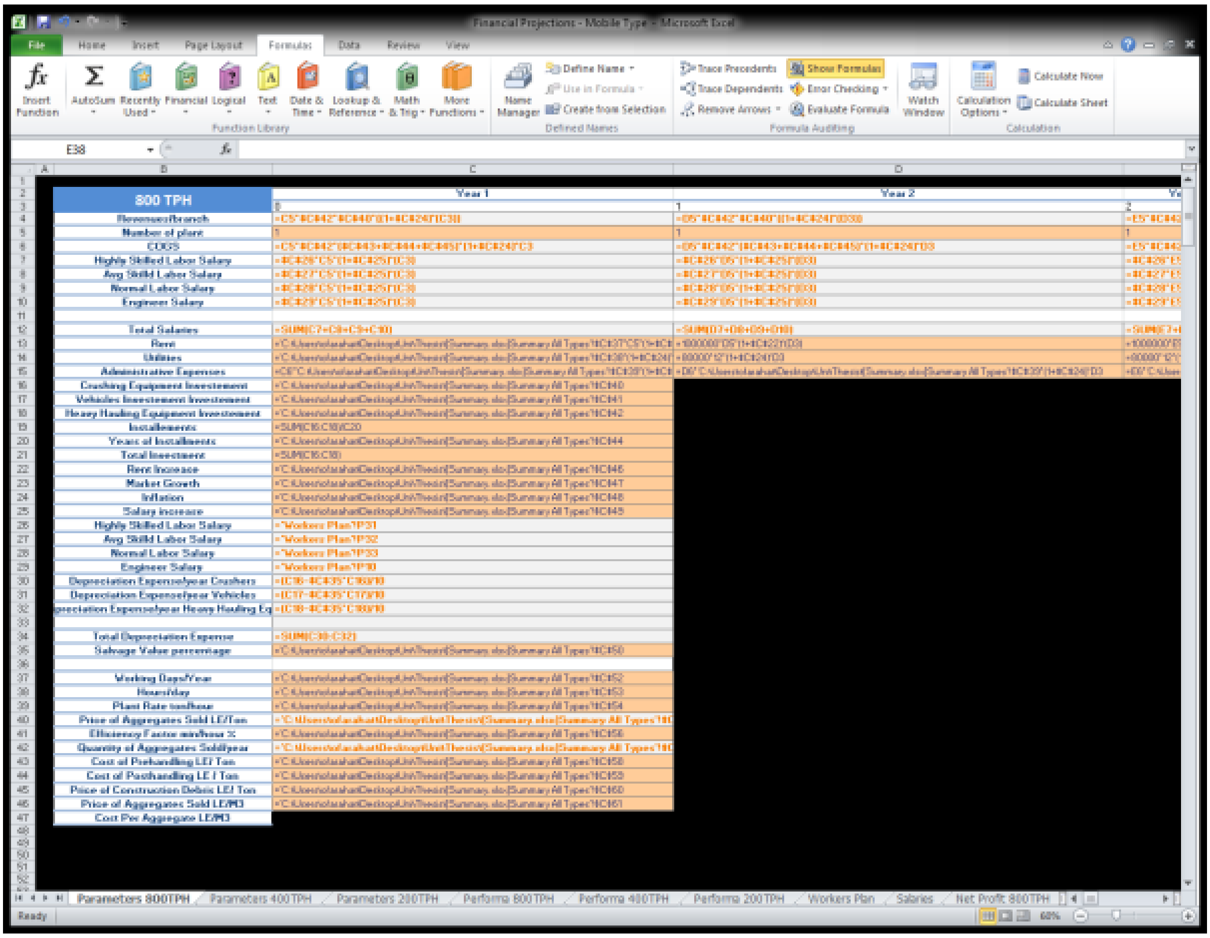


Figure V-11 The formulas in the "Parameters" sheet of the model

Equation V.1 **<u>Revenues per branch</u>**

- **<u>Revenues per branch</u>** = Number of plant * quantity of aggregates sold per year * price of aggregates sold * ((1+inflation rate) ^ number of years passed)

(1)

Equation V.2 **<u>Cost of goods sold (COGS)</u>**

- **<u>Cost of goods sold (COGS)</u>** = Number of plants * quantity of aggregates sold per year * (cost of pre-handling + cost of post-handling + price of construction debris bought) * (1+inflation rate) ^ number years passed

(2)

Equation V.3 <u>Highly Skilled Labor Salary/year</u>

- **Highly Skilled Labor Salary/year** = Highly skilled labor salary/year *number of plants * (1 + salary increase rate) ^ number of years passed

(3)

Equation V.4 Average Skilled Labor Salary/year

- **Average Skilled Labor Salary/year** = Average skilled labor salary/year *number of plants * (1 + salary increase rate) ^ number of years passed

(4)

Equation V.5 Normal Skilled Labor Salary/year

- **Normal Skilled Labor Salary/year** = Normal skilled labor salary/year *number of plants * (1 + salary increase rate) ^ number of years passed

(5)

Equation V.6 Engineers Salary/year

- **Engineers Salary/year** = Engineers salary/year *number of plants * (1 + salary increase rate) ^ number of years passed

(6)

Equation V.7Total Salaries

- **Total Salaries** = Highly skilled labor salary + Average skilled labor salary + Normal skilled labor salary + Engineers salary

(7)

Equation V.8Rent Expense

- **Rent Expense** = (rent/year *from summary sheet)**number of plants * (1+ rent increase rate) ^ number of years passed

(8)

Equation V.9 Utilities

- **Utilities** = (utilities expense/year *from summary sheet)* * (1+inflation rate) ^ number of years passed

(9)

Equation V.10 **Administrative Expense**

- **Administrative Expense** = COGS *(percent of administrative expense *from summary sheet)* * (1+ inflation rate) ^ number of years passed

(10)

Equation V.11 **Crushing Equipment Investment**

- **Crushing Equipment Investment** = *from summary sheet*

(11)

Equation V.12 **Vehicles Investment**

- **Vehicles Investment** = *from summary sheet*

(12)

Equation V.13 **Heavy Hauling Equipment Investment**

- **Heavy Hauling Equipment Investment** = *from summary sheet*

(13)

Equation V.14 **Installments**

- **Installments** = (Crushing Equipment Investment + Vehicles Investment + Heavy Hauling Equipment Investment) / years of installments

(14)

Equation V.15 **Years of Installments**

- **Years of Installments** = *from summary sheet*

(15)

Equation V.16 **Total Investment**

- **Total Investment** = (Crushing Equipment Investment + Vehicles Investment + Heavy Hauling Equipment Investment)

(16)

Equation V.17 **Rent Increase**

- **Rent Increase** = *from summary sheet*

(17)

Equation V.18Market Growth

- **Market Growth** = *from summary sheet*

(18)

Equation V.19Inflation

- **Inflation** = *from summary sheet*

(19)

Equation V.20Salary increase

- **Salary increase** = *from summary sheet*

(20)

Equation V.21Highly Skilled Labor Salary

- **Highly Skilled Labor Salary** = (number of highly skilled labor/activity * monthly salary *12) *from workers plan sheet.*

(21)

Equation V.22Average Skilled Labor Salary

- **Average Skilled Labor Salary** = (number of average skilled labor/activity * monthly salary *12) *from workers plan sheet.*

(22)

Equation V.23Normal Labor Salary

- **Normal Labor Salary** = (number of normal skilled labor/activity * monthly salary *12) *from workers plan sheet.*

(23)

Equation V.24Engineer Salary

- **Engineer Salary** = (number of engineer/activity * monthly salary *12) *from workers plan sheet.*

(24)

Equation V.25Depreciation Expense/year Crushers

- **Depreciation Expense/year Crushers** = (Crushing equipment investment – salvage value * Crushing equipment investment)

(25)

Equation V.26Depreciation Expense/year Vehicles

- **Depreciation Expense/year Vehicles** = (vehicles equipment investment – salvage value * vehicles equipment investment)

(26)

Equation V.27Depreciation Expense/year Heavy Hauling Equipment

- **Depreciation Expense/year Heavy Hauling Equipment** = (heavy hauling equipment investment – salvage value * heavy hauling equipment investment)

(27)

Equation V.28Total Depreciation Expense

- **Total Depreciation Expense** = Depreciation Expense/year Crushers + Depreciation Expense/year Vehicles + Depreciation Expense/year Heavy Hauling Equipment

(28)

Equation V.29Salvage Value percentage

- **Salvage Value percentage** =*from summary sheet*

(29)

Equation V.30Working Days/Year

- **Working Days/Year** = 250 Days

(30)

Equation V.31Hours/day

- **Hours/day** = *from summary sheet*

(31)

Equation V.32Plant Rate ton/hour

- **Plant Rate ton/hour** = *from summary sheet*

(32)

Equation V.33Price of Aggregates Sold LE/Ton

- **Price of Aggregates Sold LE/Ton** = *from summary sheet*

(33)

Equation V.34Efficiency Factor min/hour %

- **Efficiency Factor min/hour %** = *from summary sheet*

(34)

Equation V.35Quantity of Aggregates Sold/year

- **Quantity of Aggregates Sold/year** = *from summary sheet*

(35)

Equation V.36Cost of Pre-handling LE/ Ton

- **Cost of Pre-handling LE/ Ton** = *from summary sheet*

(36)

Equation V.37Cost of Post-handling LE / Ton

- **Cost of Post-handling LE / Ton** = *from summary sheet*

(37)

Equation V.38Price of Construction Debris LE/ Ton

- **Price of Construction Debris LE/ Ton** = *from summary sheet*

(38)

Equation V.39Price of Aggregates Sold LE/M3

- **Price of Aggregates Sold LE/M3** = *from summary sheet*

(39)

The next sheet that is also present for each model called "Pro-forma". This is the income statement over 10 years showing the main categories of the parameters such as:

- **Revenues**
  - Cost of Goods sold
- **Gross Profit ###TPH**[1]
- **Operating expense**
  - Total Salaries
  - Total Depreciation
  - Rent
  - Utilities
  - Administrative Expenses
  - Initial Investment
- **Total Expenses 800TPH**
- **Net Profit 800 TPH**
  - Profit margin %

The screenshot,

Figure V-7, shows the calculations of the Pro-forma sheet.

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[1] ### depends on the capacity of the plant

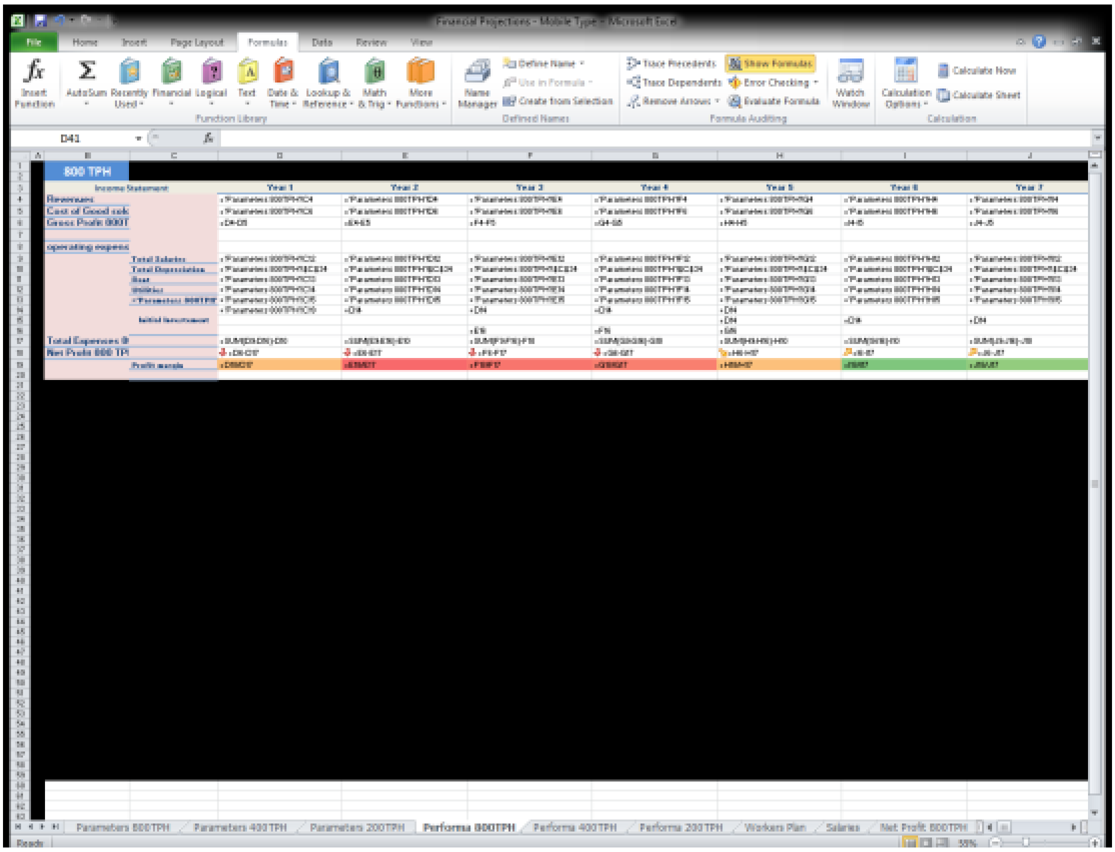


Figure V-12 The formulas in the "Pro-forma" sheet of the model

The equations used in this sheet,

Figure V-7, are as follows:

Equation V.40<u>Gross Profit ###TPH</u>

- **<u>Gross Profit ###TPH</u>** = Revenues - Cost of Goods sold

(40)

Equation V.41<u>Total expense</u>

- **<u>Total expense</u>** = Total Salaries + Total Depreciation + Rent + Utilities + Administrative Expenses + Initial Investment

(41)

Equation V.42 Net Profit

- **Net Profit** (EBIT) = Gross Profit – Total Expense[2]

(42)

Equation V.43 Profit Margin

- **Profit Margin** = Net Profits/Revenues

(43)

E. Assumptions and limitations

The model has several assumptions that should be considered by the user after conducting it. The assumption affects the results directly.

The model assumes the items available in Table V-2.

Table V-2 Model Assumptions

Title	Assumption	Can be change by user (applicable if checked √)
Number of Plant increase in year 5	From 1 to 2 plants	
Percentage of final product sold	100%	
Rent increase percentage	15%	√
Salaries increase percentage	10%	√

[2] Note that the net profit calculated is before interests and taxes.

Inflation rate	10.3%	
Number and skill of Labor assigned	According to table IV-2, IV-3 and IV-4	
Salvage Value of equipment	50% of original price	√
Interest rates on installments	Not available	
Income taxes deduction	Not available	

Limitations of the model

- The model is limited to the three types of plants mentioned earlier, mobile, stationary and traditional.
- The model cannot work with negative numbers which makes it unrealistic, for example if the equipment price or salaries are input as negative number.
- The model generates graphs indicating revenues, expenses and net profits.
- The model can compare revenues, expenses and net profits for one type with all three capacities , 200, 400 and 800 TPH on bar charts
- The model can compare revenues, expenses and net profits for one capacity (200, 400 or 800 TPH) with all three plant types mobile, traditional and stationary on graphs

F. Results of the model

1. Stationary

The results are all calculated based on the calculations found in this chapter section D. All the variables and parameters are modifiable in the excel file called "summary", as explained in section C.

The results are divided as follows:

- Revenues vs. total expense vs. profits 200 TPH

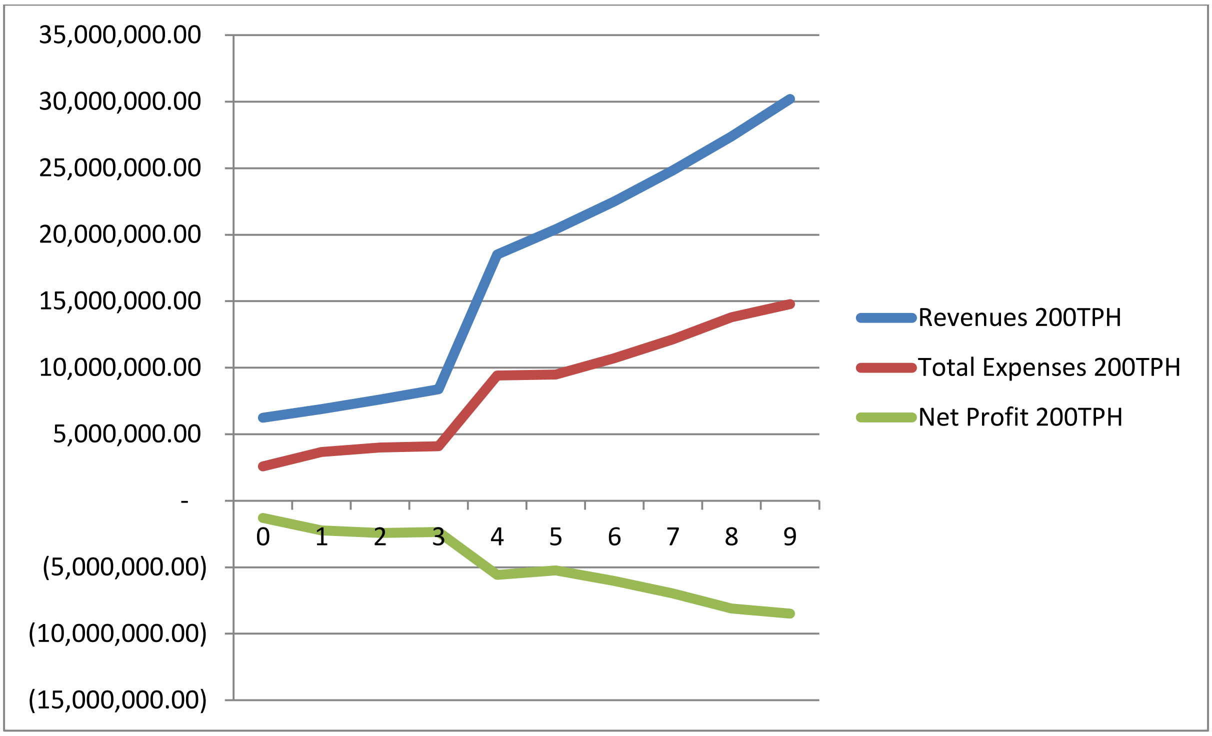


Figure V-13 Revenues vs. total expense vs. profits 200 TPH for stationary plant

- Revenues vs. total expense vs. profits 400 TPH

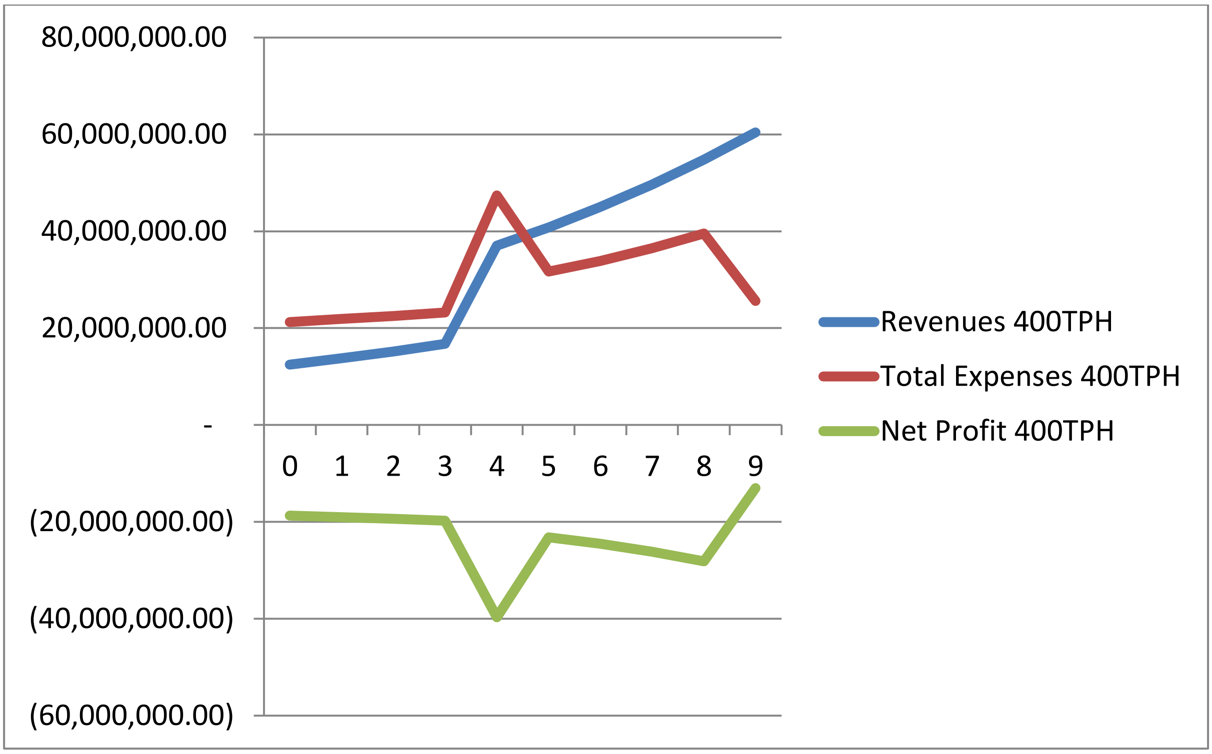


Figure V-14 Revenues vs. total expense vs. profits 400 TPH for stationary plant

- Revenues vs. total expense vs. profits 800 TPH

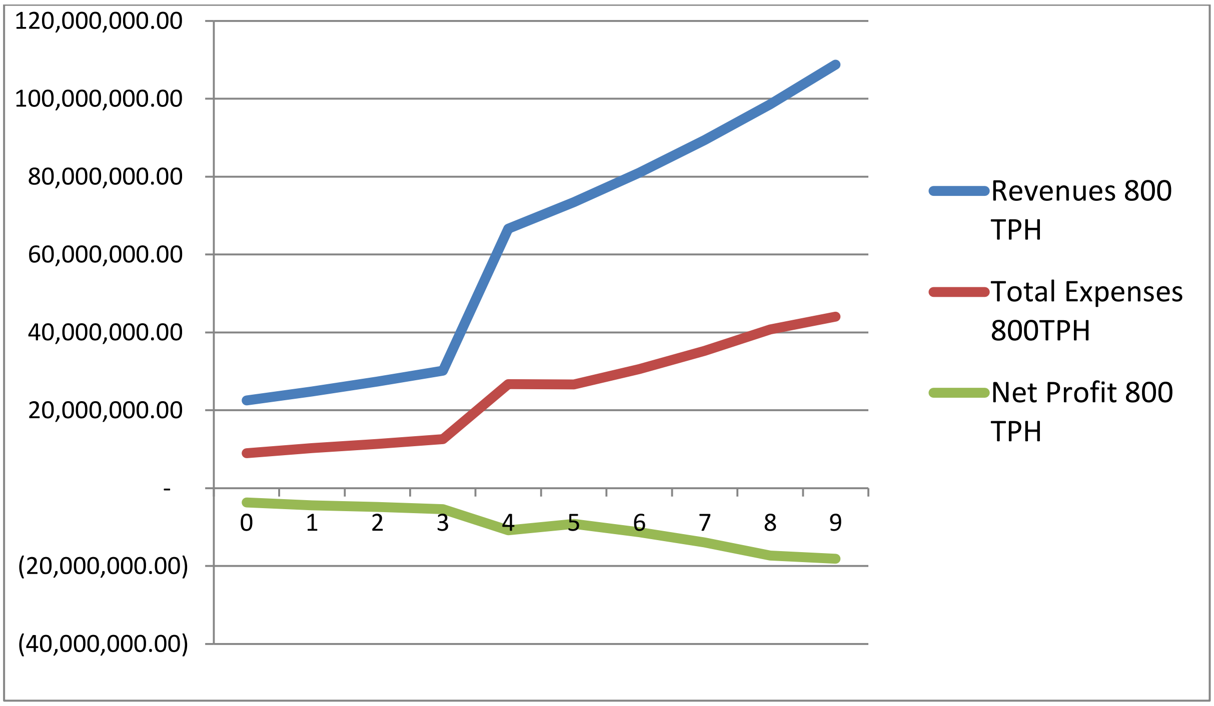


Figure V-15 Revenues vs. total expense vs. profits 800 TPH for stationary plant

- Net Profits 200,400,800 TPH

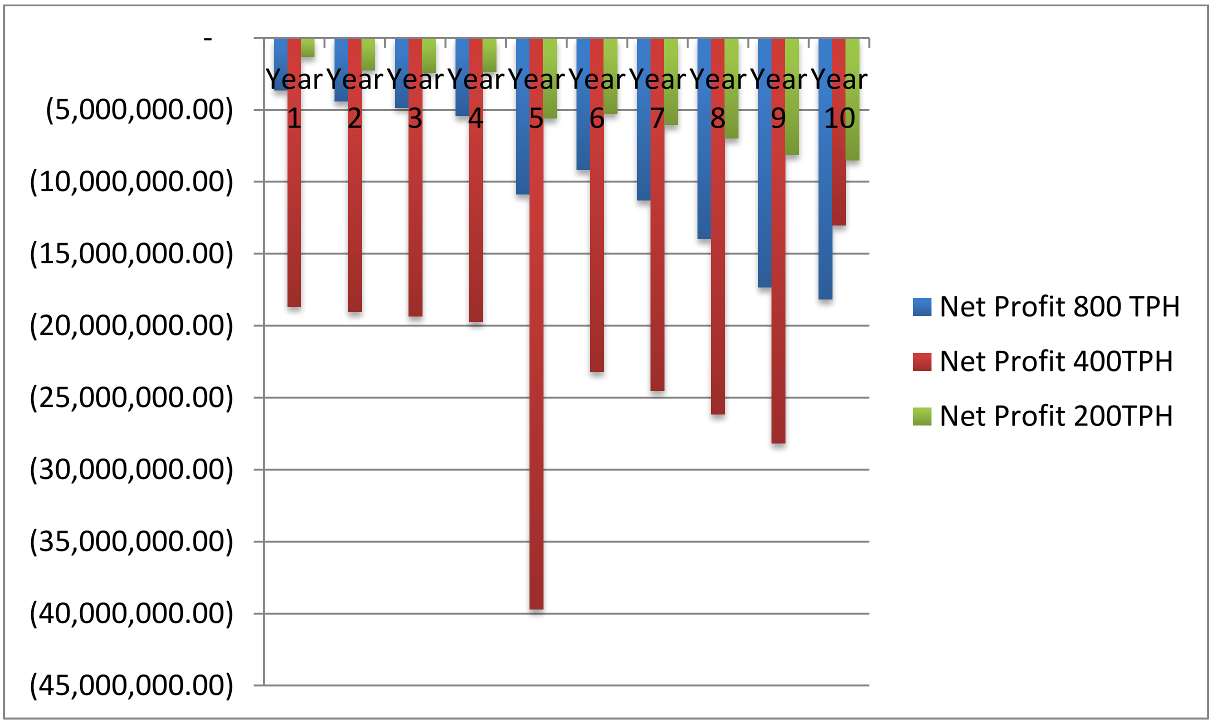


Figure V-16 Profits for all stationary plant

- Salaries 800TPH

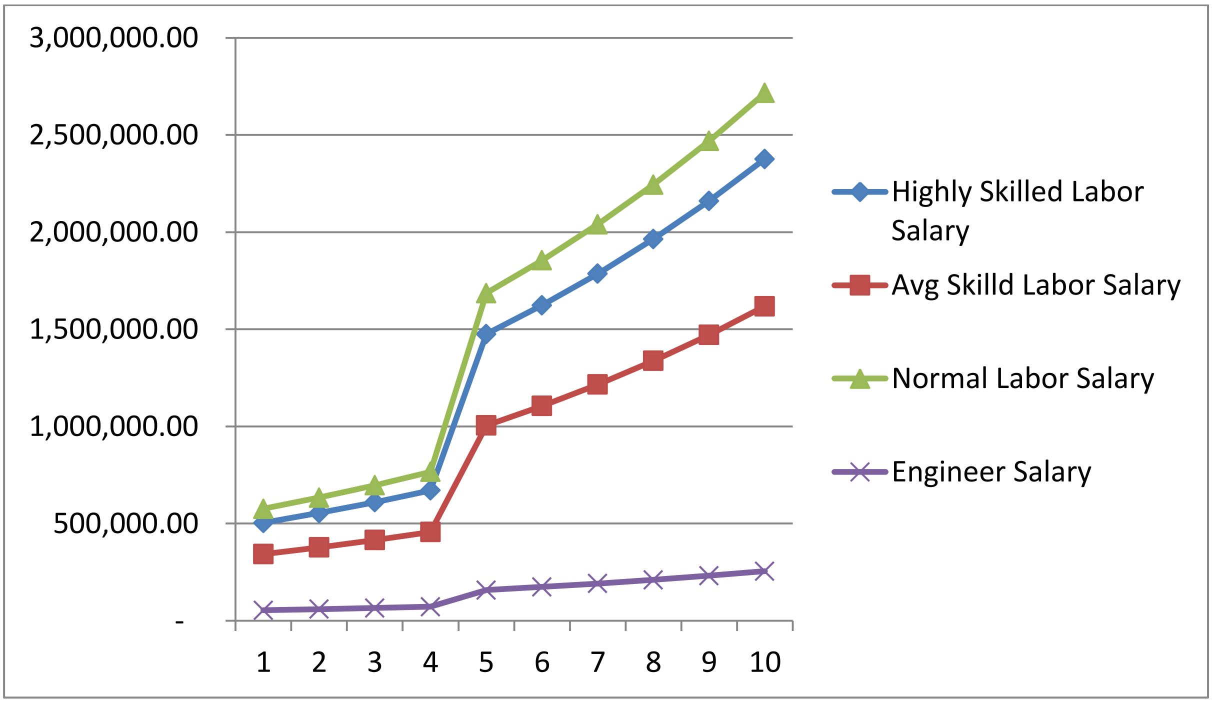


Figure V-17 Salaries 800 TPH of stationary plant

- Salaries 400TPH

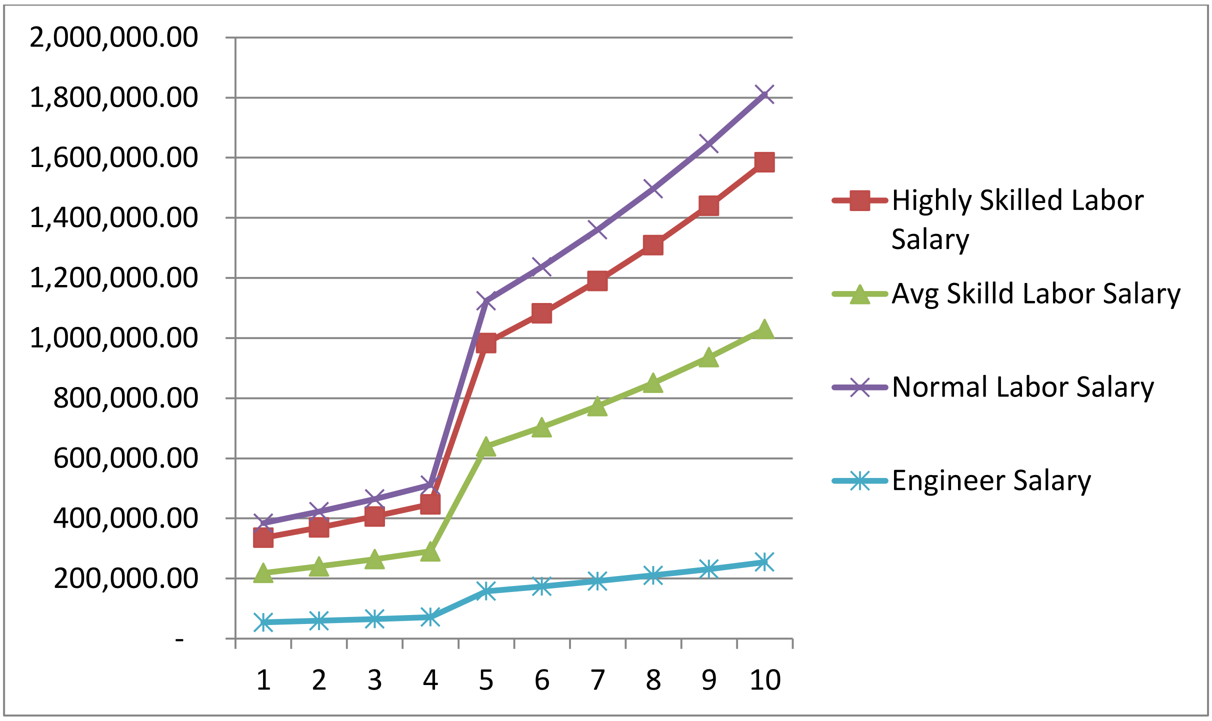


Figure V-18 Salaries 400 TPH of stationary plant

- Salaries 200TPH

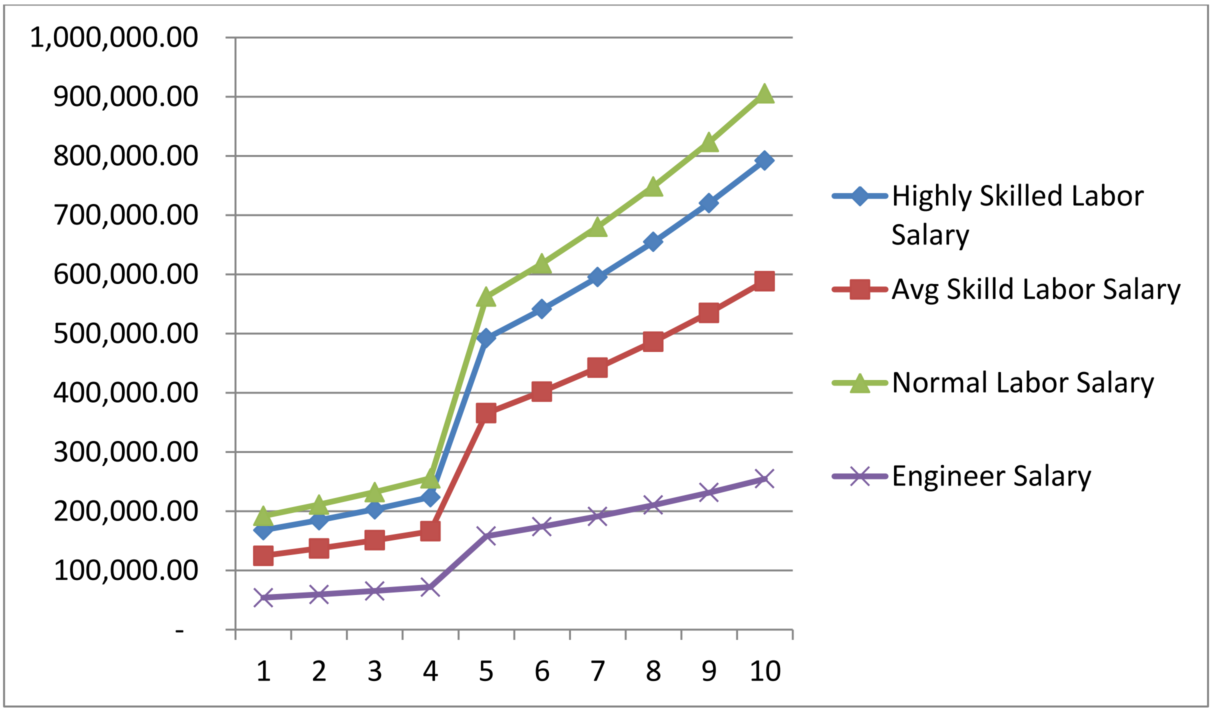


Figure V-19 Salaries 200 TPH of stationary plant

2. Mobile

The results are all calculated based on the calculations found in this chapter section D. All the variables and parameters are modifiable in the excel file called “summary”, as explained in section D.

The results are divided as follows:

- Revenues vs. total expense vs. profits 200 TPH

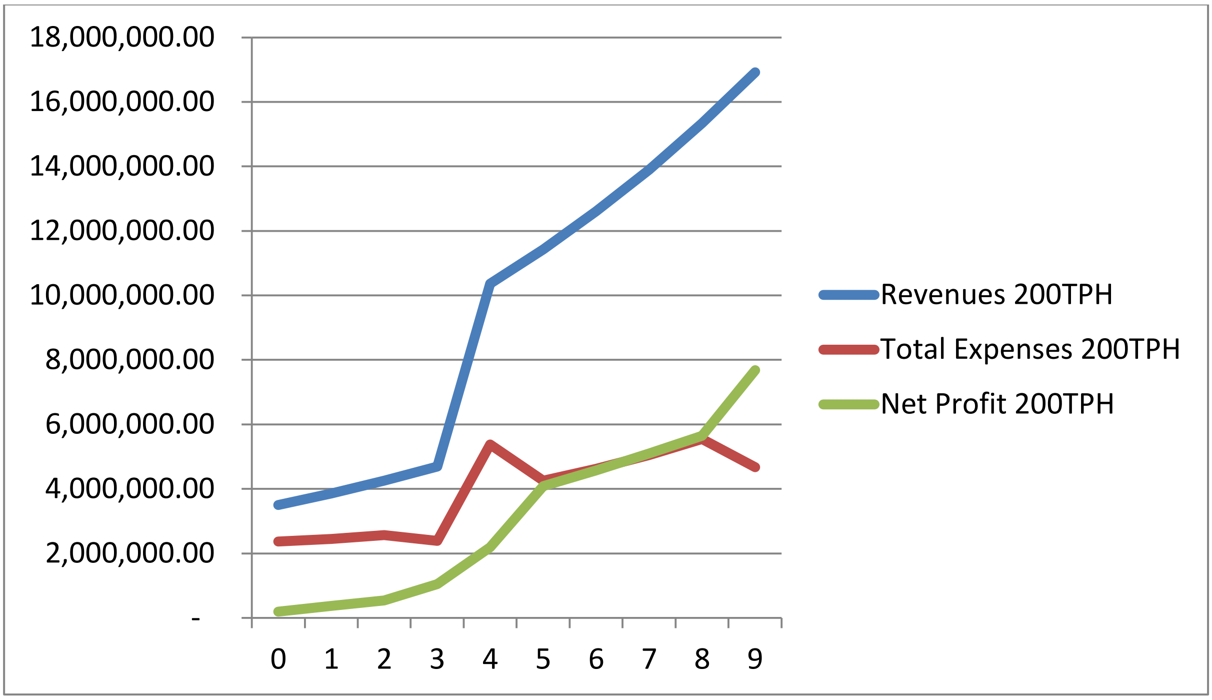


Figure V-20 Revenues vs. total expense vs. profits 200 TPH for mobile plant

- Revenues vs. total expense vs. profits 400 TPH

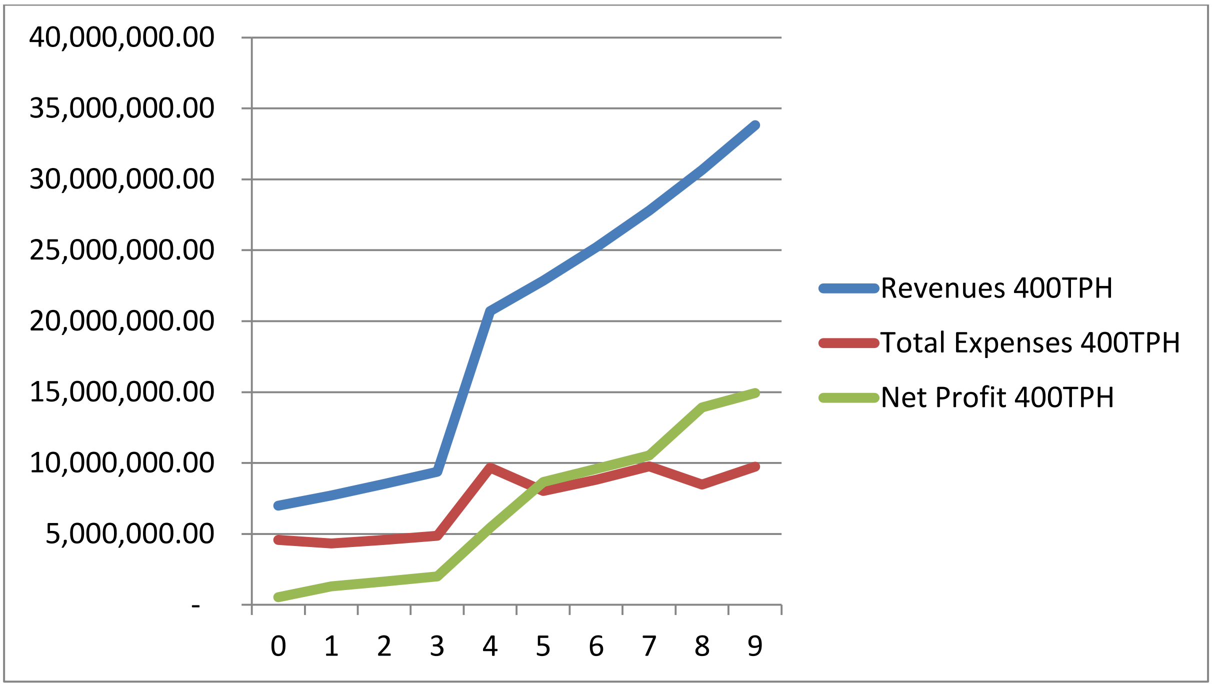


Figure V-21 Revenues vs. total expense vs. profits 400 TPH for mobile plant

- Revenues vs. total expense vs. profits 800 TPH

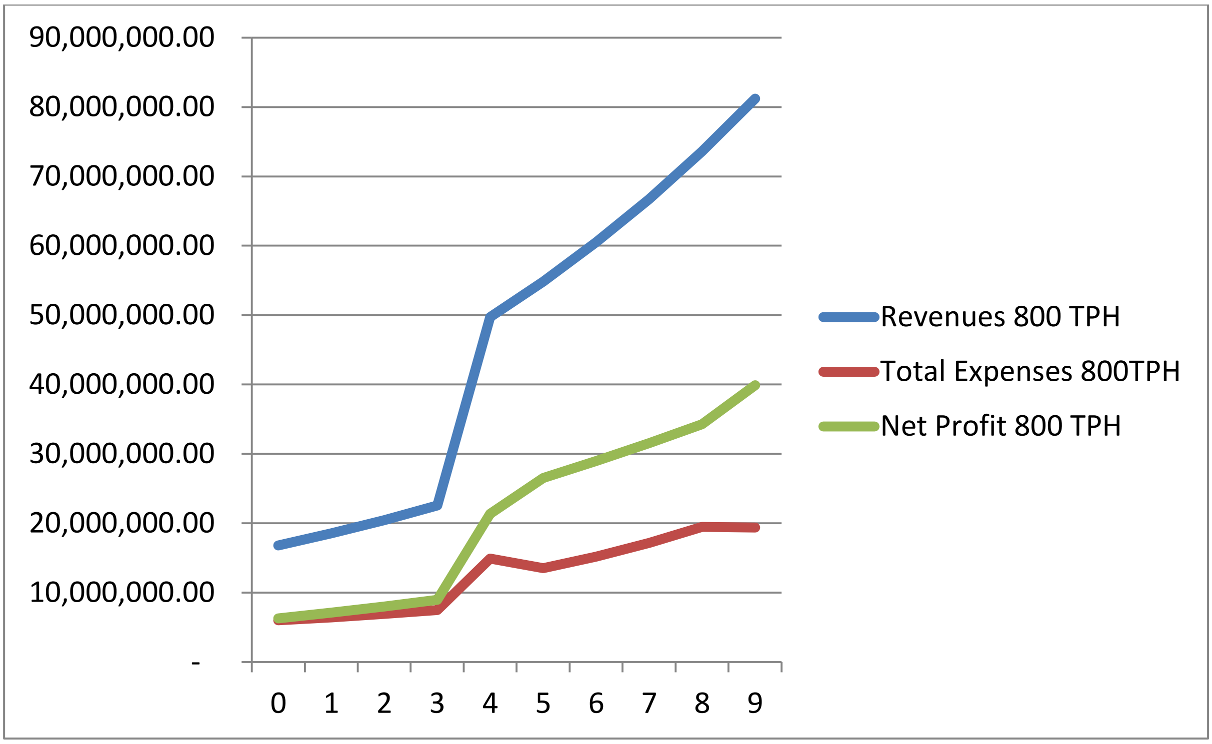


Figure V-22 Revenues vs. total expense vs. profits 800 TPH for mobile plant

- Net Profits 200, 400, 800TPH

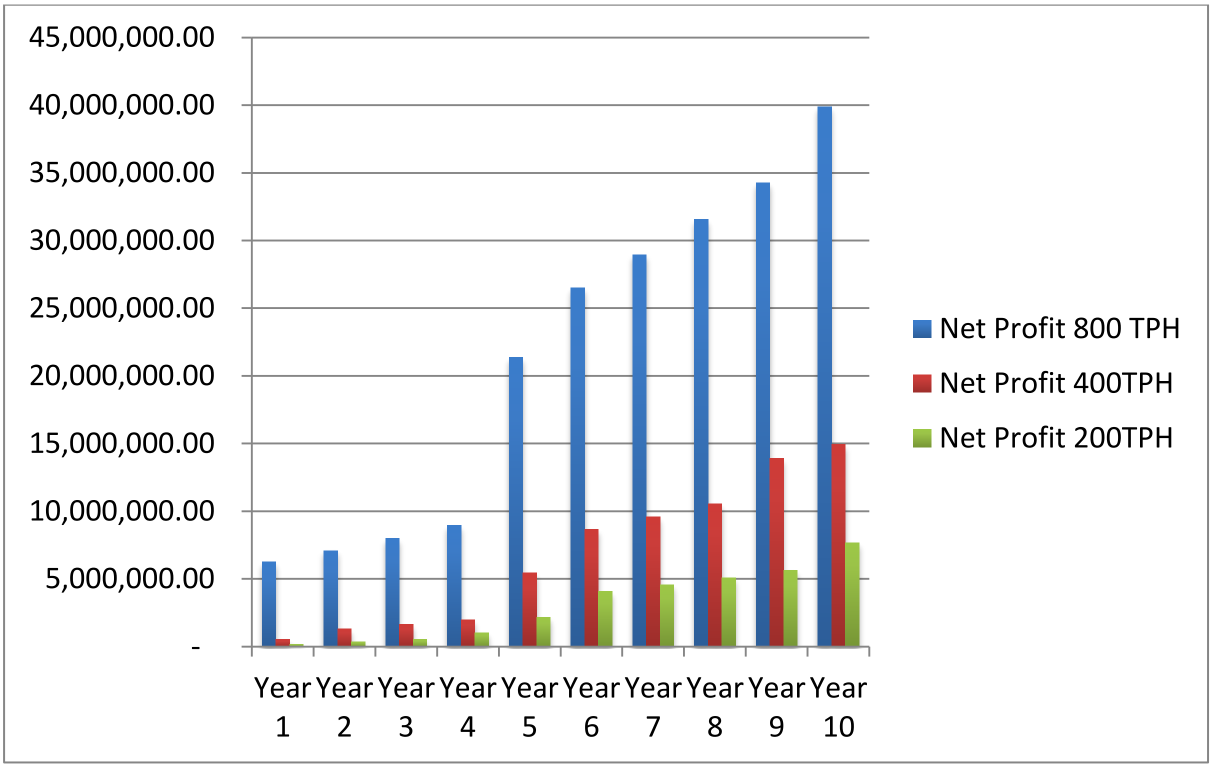


Figure V-23 Net profits for all mobile plant

- Salaries 800TPH

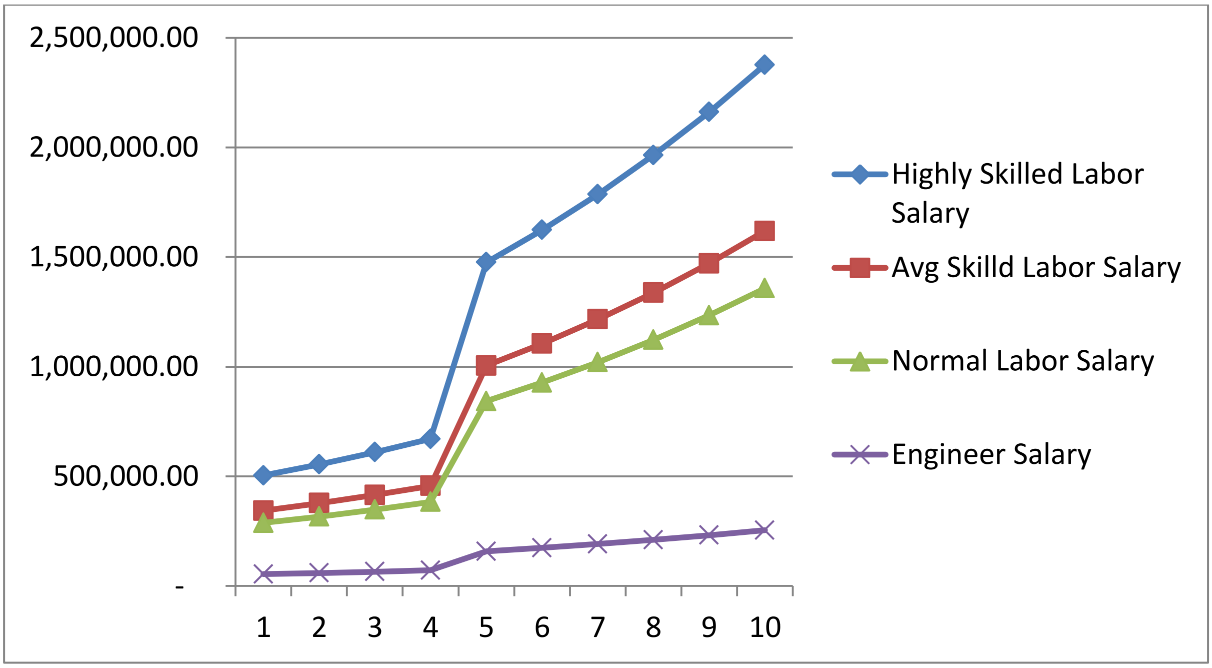


Figure V-24 Salaries for mobile plant 800TPH

- Salaries 400TPH

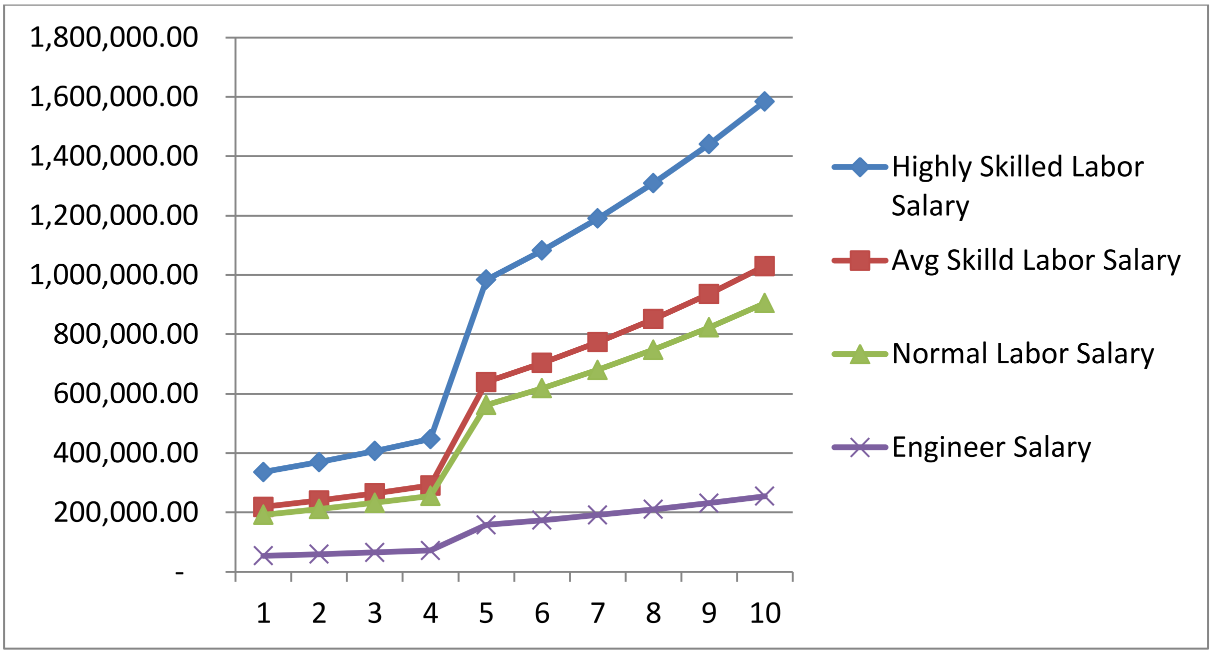


Figure V-25 Salaries for mobile plant 400TPH

- Salaries 200TPH

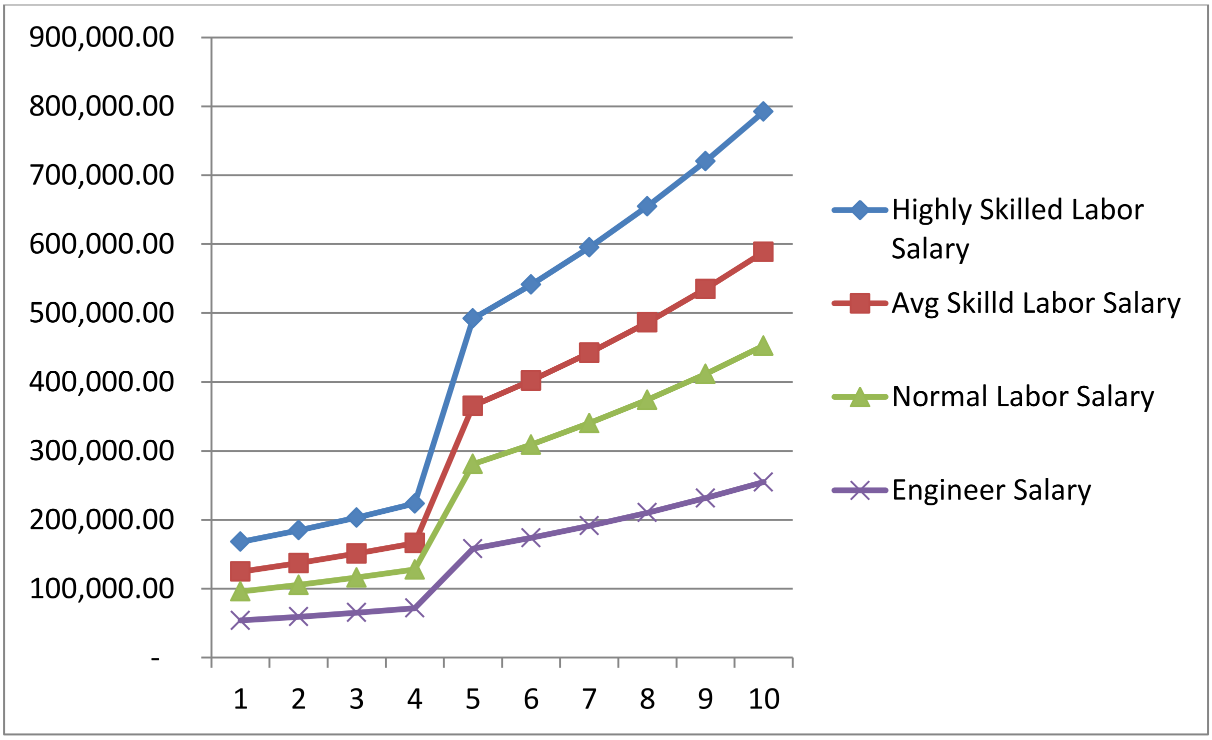


Figure V-26 Salaries for mobile plant 200TPH

3. Traditional

The results are all calculated based on the calculations found in this chapter section 0. All the variables and parameters are modifiable in the excel file called "summary", as explained in section D.

The results are divided as follows:

- Revenues vs. total expense vs. profits 200 TPH

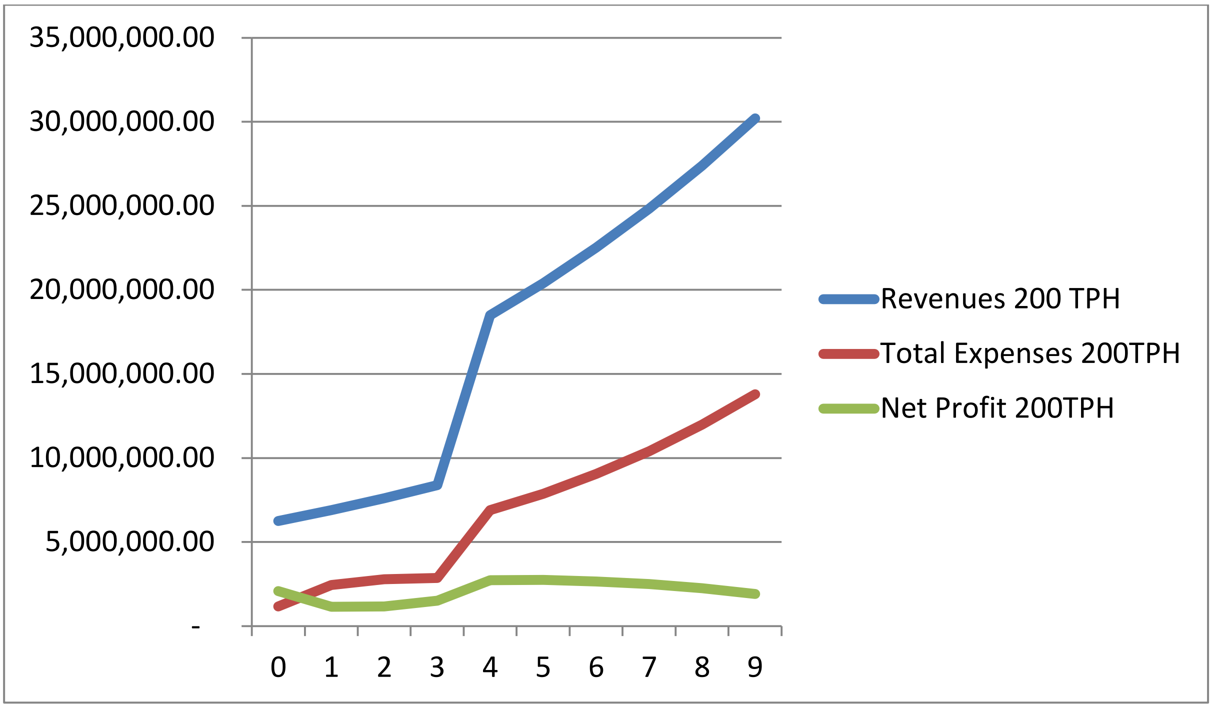


Figure V-27 Revenues vs. total expense vs. profits 200 TPH for traditional plant

- Revenues vs. total expense vs. profits 400 TPH

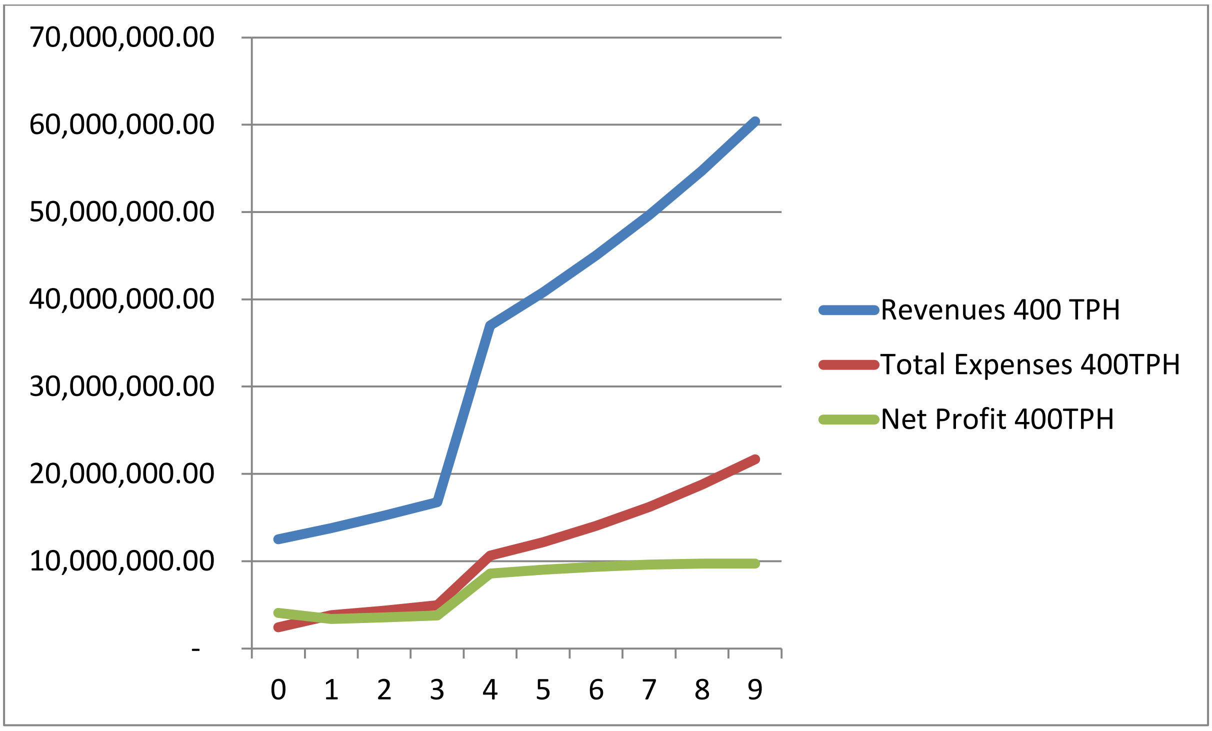


Figure V-28 Revenues vs. total expense vs. profits 400 TPH for traditional plant

- Revenues vs. total expense vs. profits 800 TPH

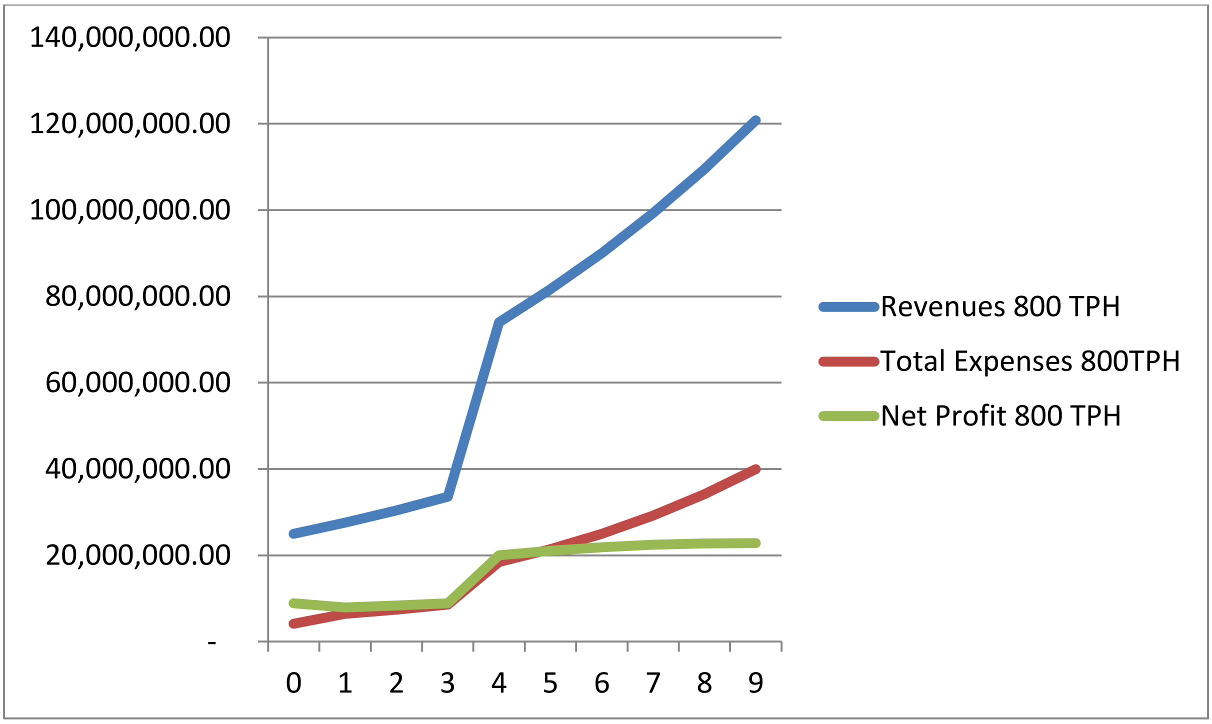


Figure V-29 Revenues vs. total expense vs. profits 800 TPH for traditional plant

- Net Profits 200, 400, 800TPH

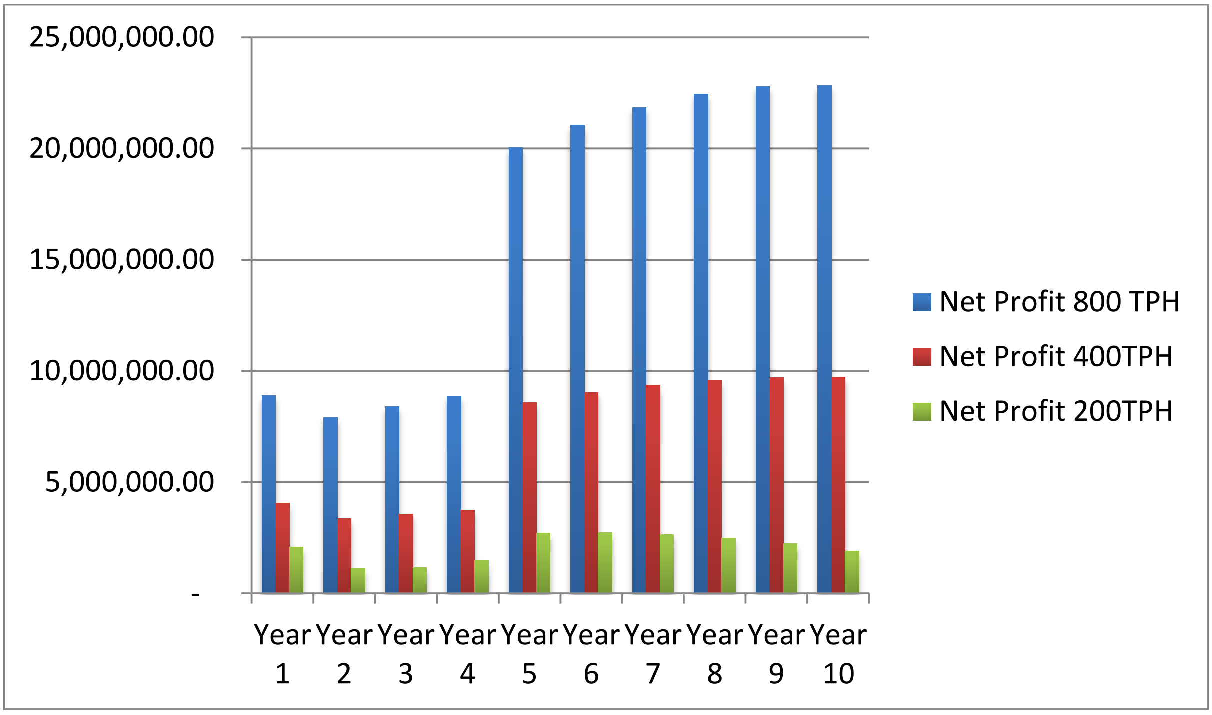


Figure V-30 Net profits for all traditional plant

- Salaries 800TPH

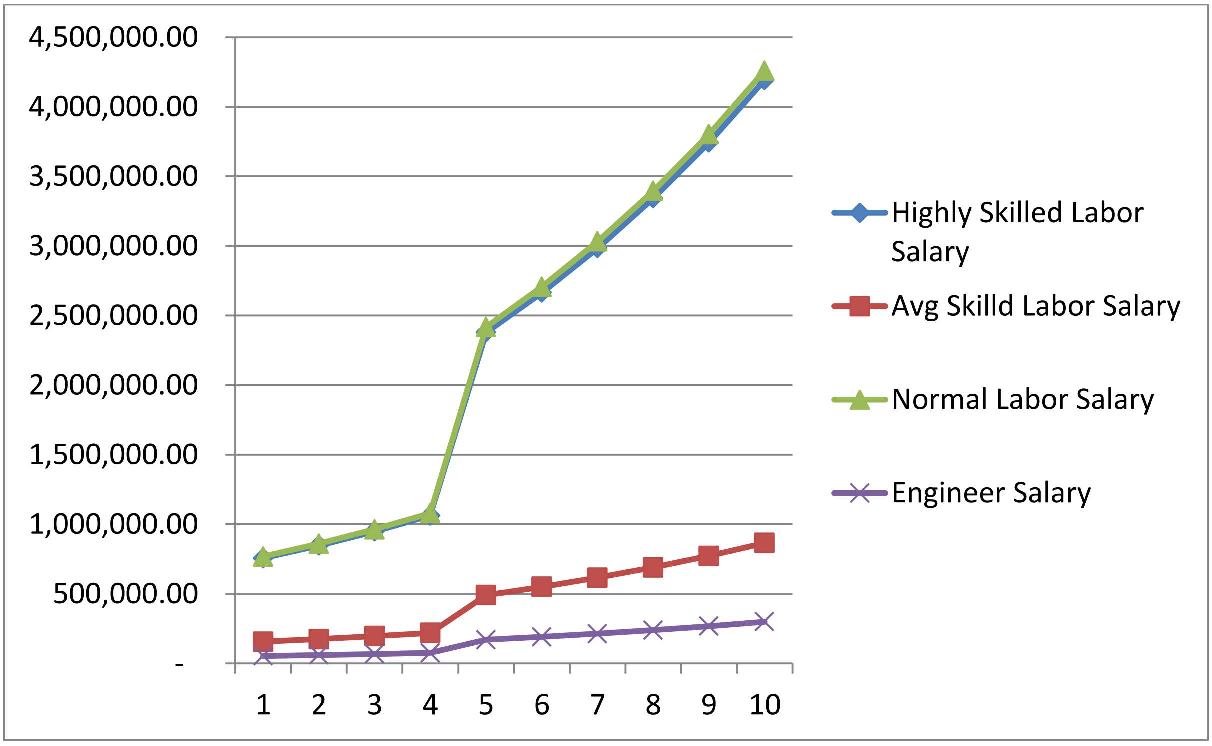


Figure V-31 Salaries for traditional plant 800 TPH

- Salaries 400TPH

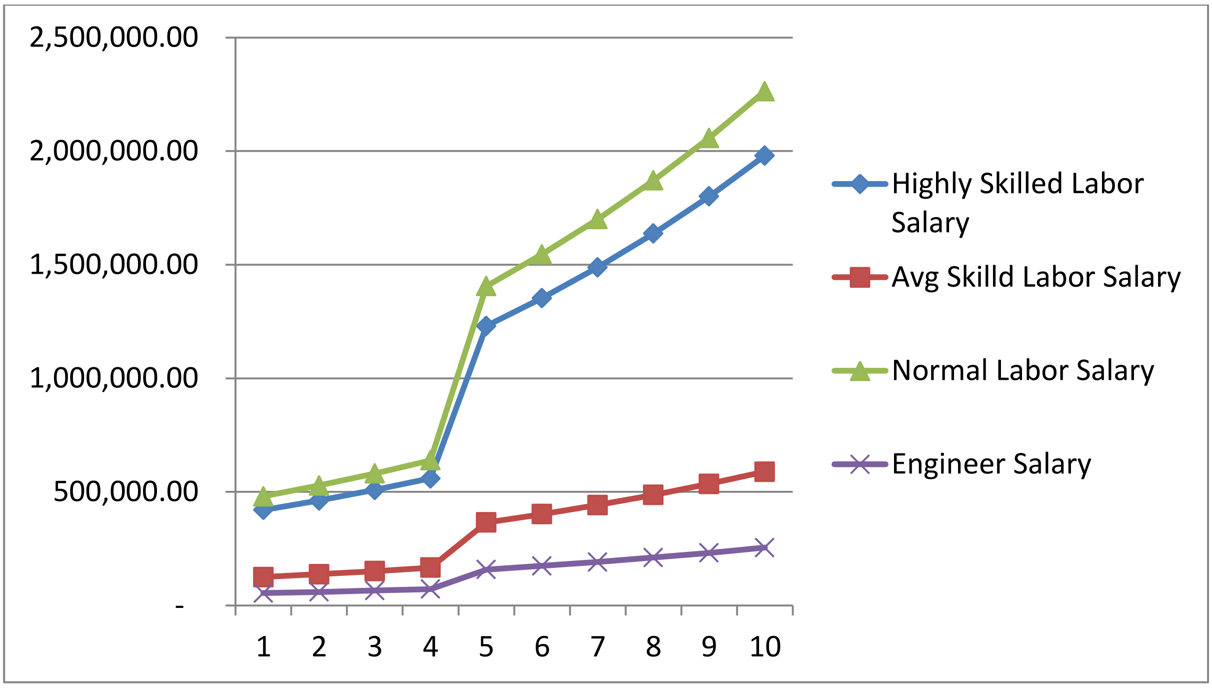


Figure V-32 Salaries for traditional plant 400 TPH

- Salaries 200TPH

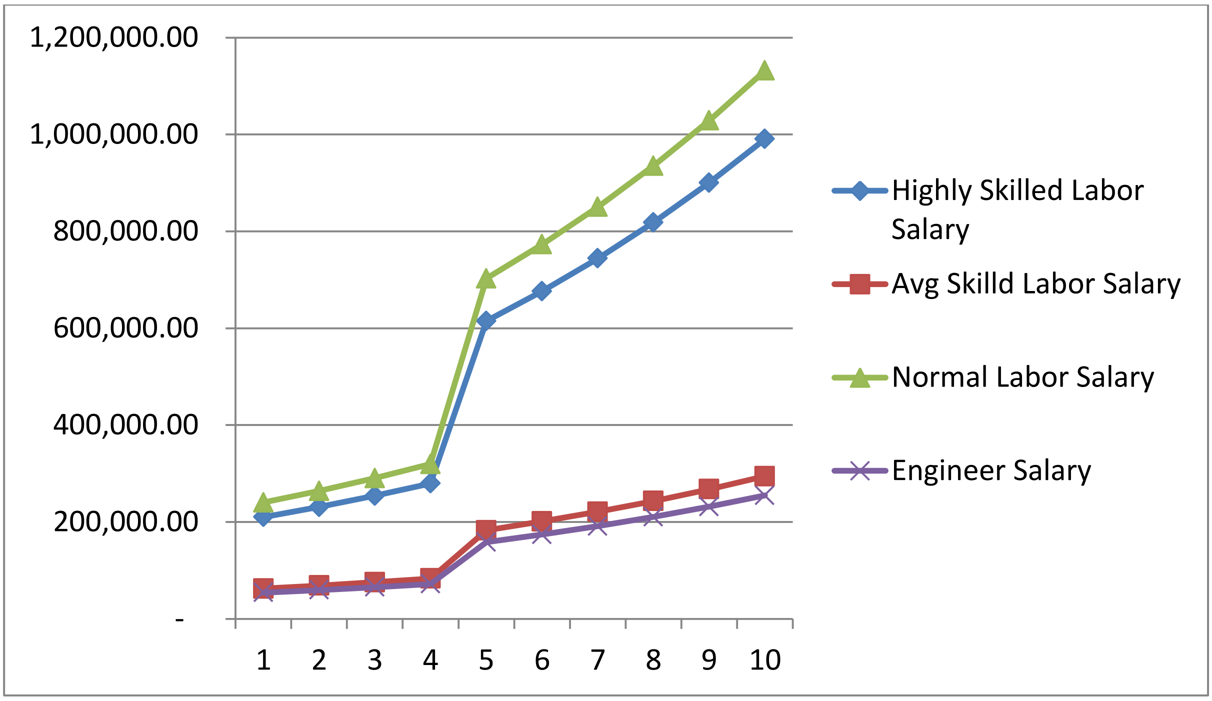


Figure V-33 Salaries for traditional plant 200 TPH

G. Comparison of Plants' Capacity

1. Net Profits

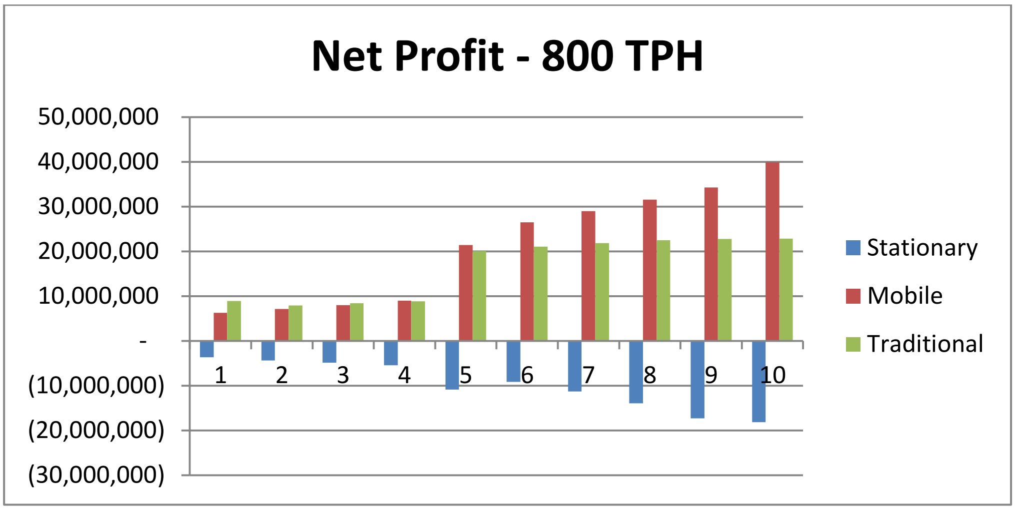


Figure V-34 Net profits all plant types 800 TPH

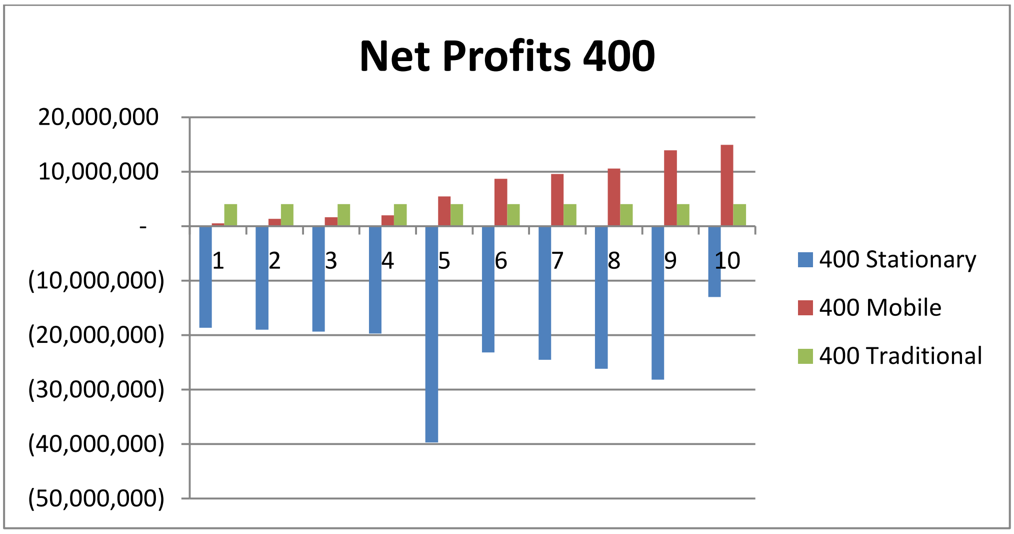


Figure V-35 Net profits all plant types 400 TPH

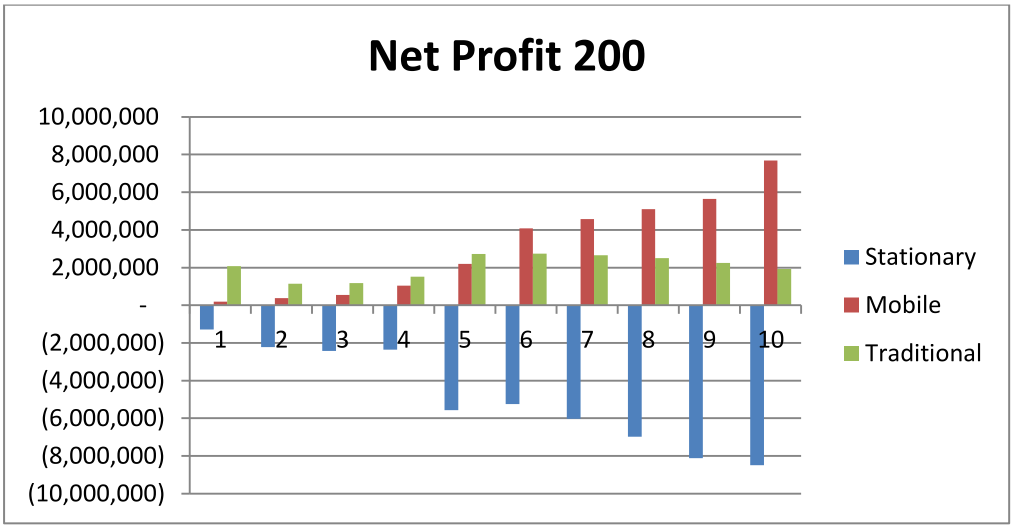


Figure V-36 Net profits all plant types 200 TPH

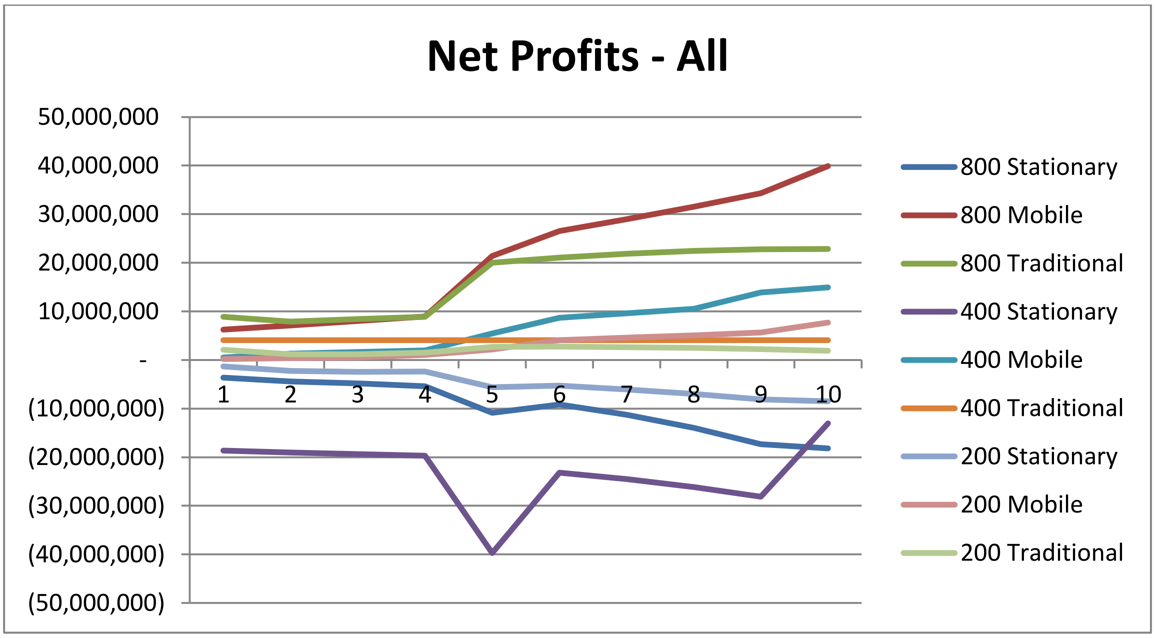


Figure V-37 Net profits all plant types all capacities

2. Revenues

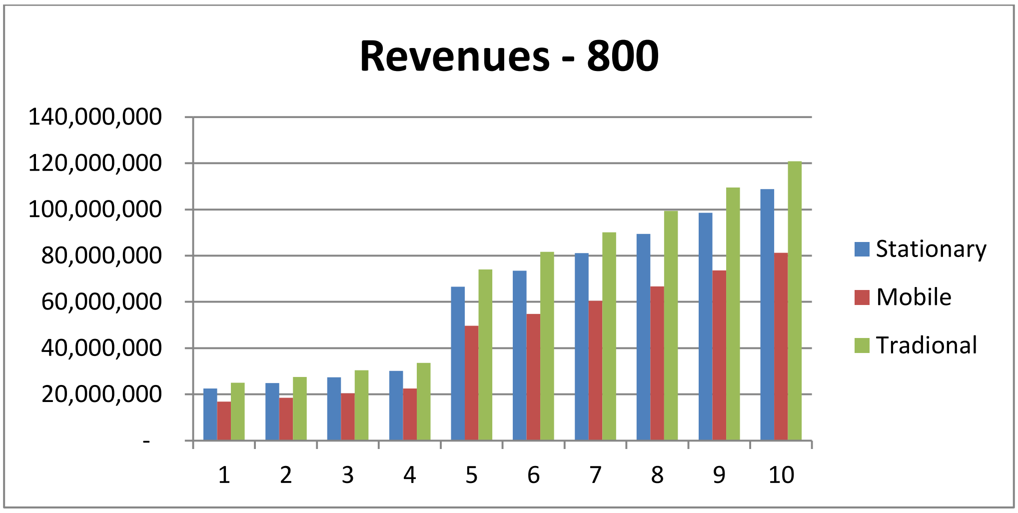


Figure V-38 Revenues all plant types 800 TPH

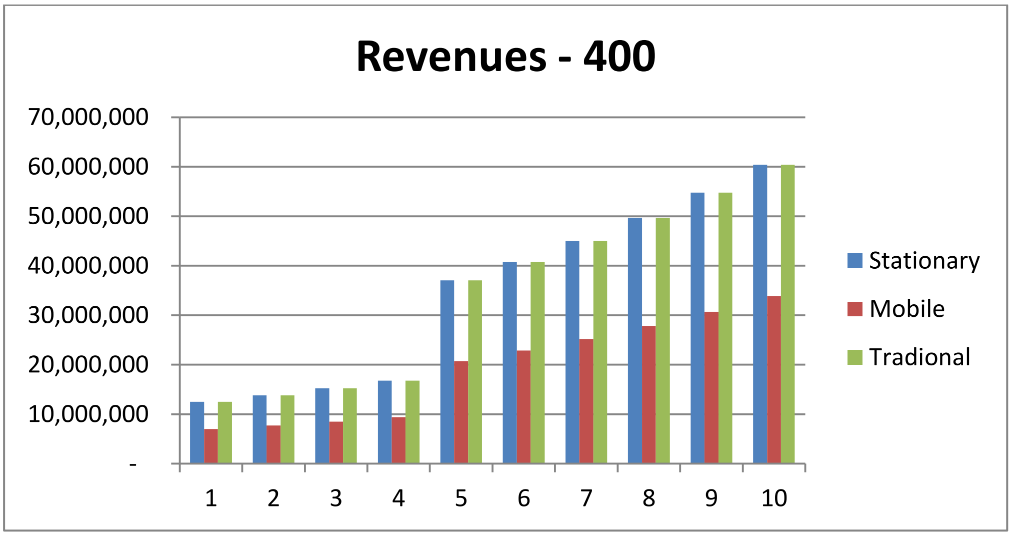


Figure V-39 Revenues all plant types 400 TPH

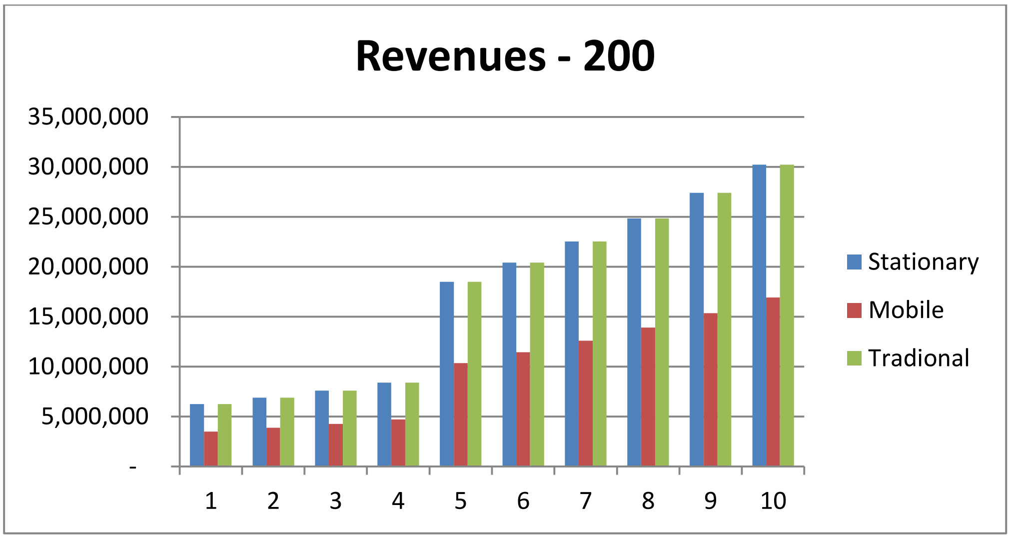


Figure V-40 Revenues all plant types 200 TPH

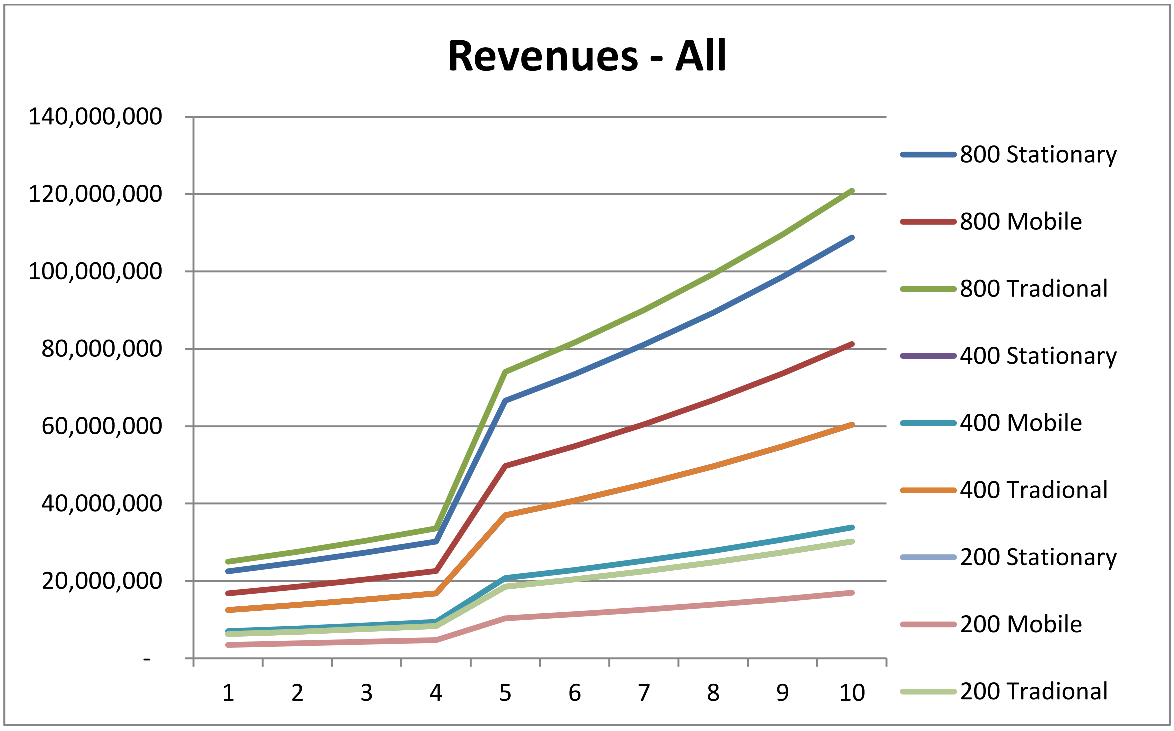


Figure V-41 Revenues all plant types all capacities

3. Profit margin

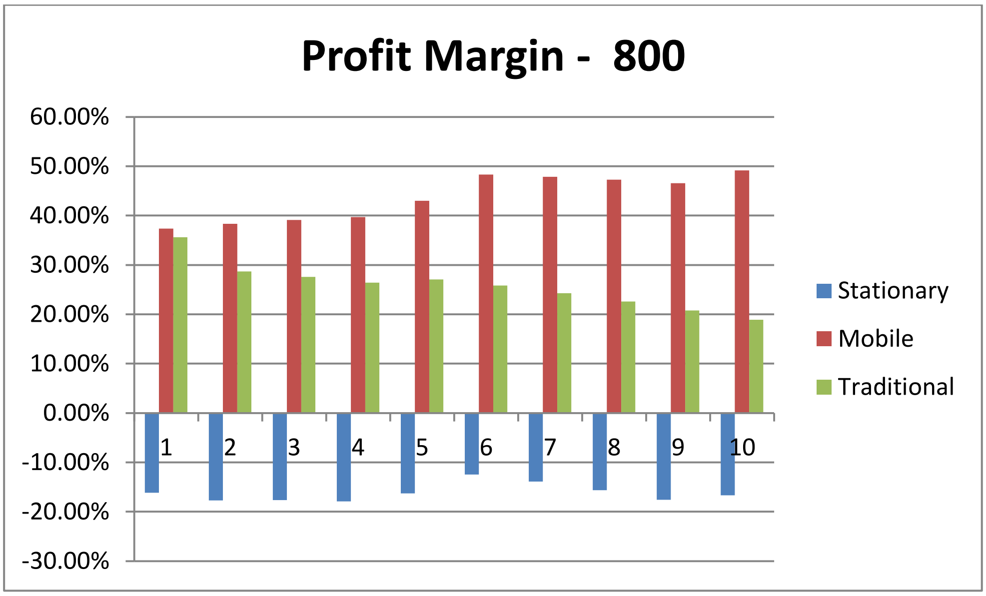


Figure V-42 Profit margin all plant types 800 TPH

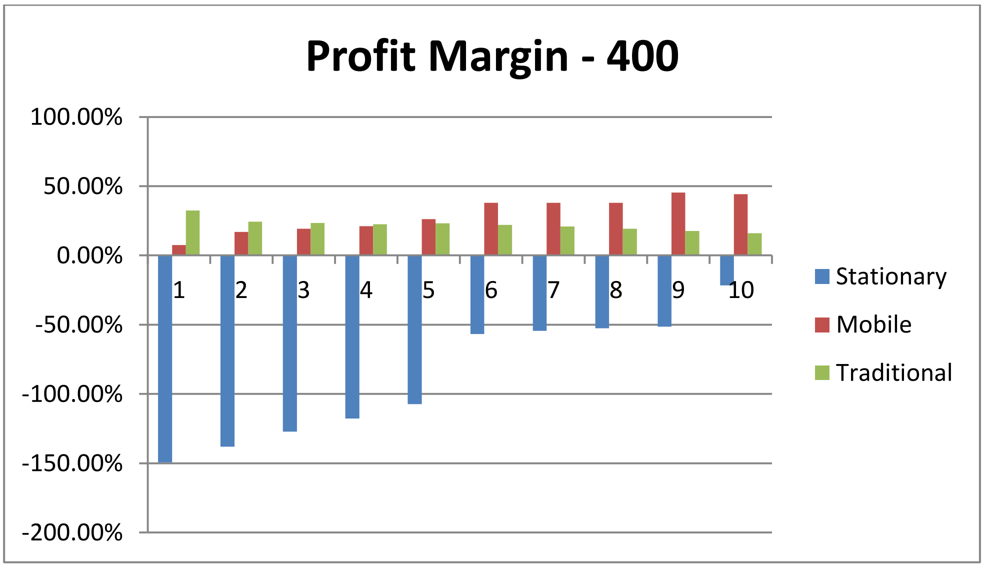


Figure V-43 Profit margin all plant types 400 TPH

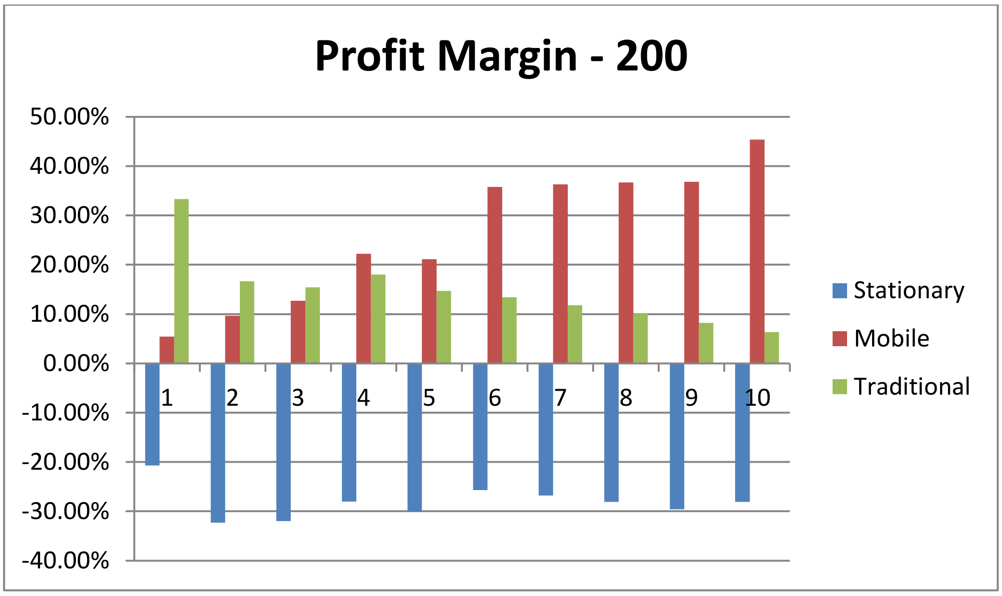


Figure V-44 Profit margin all plant types 200 TPH

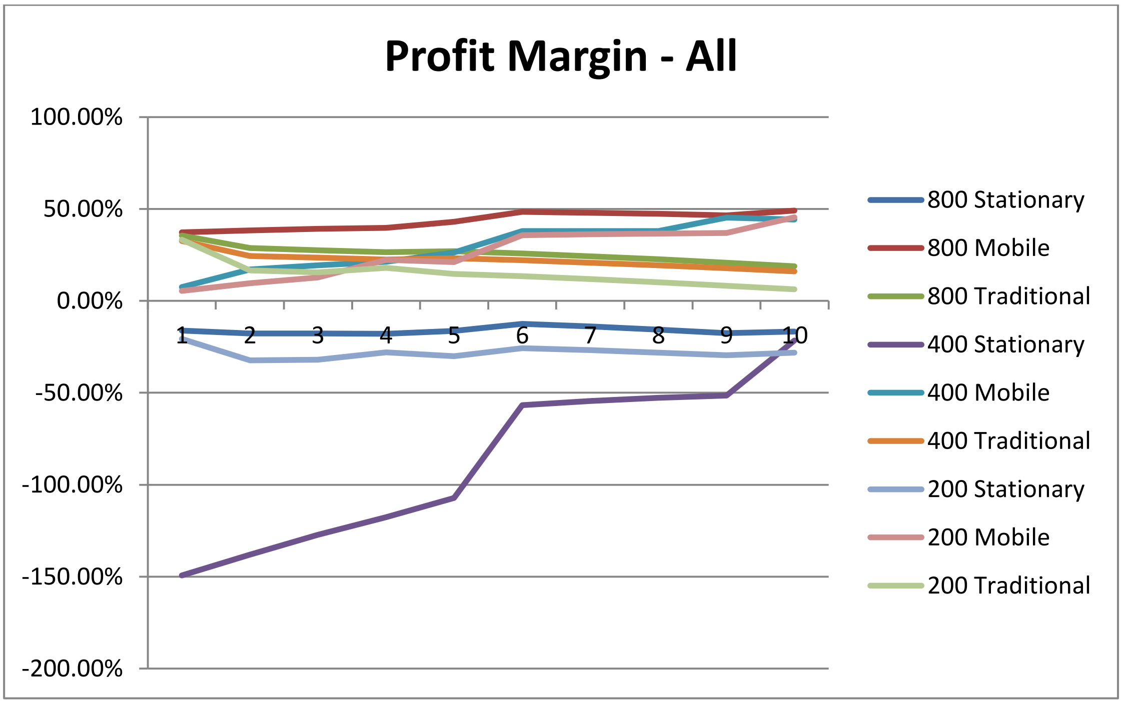


Figure V-45 Profit margin all plant types all capacities

4. Total expenses

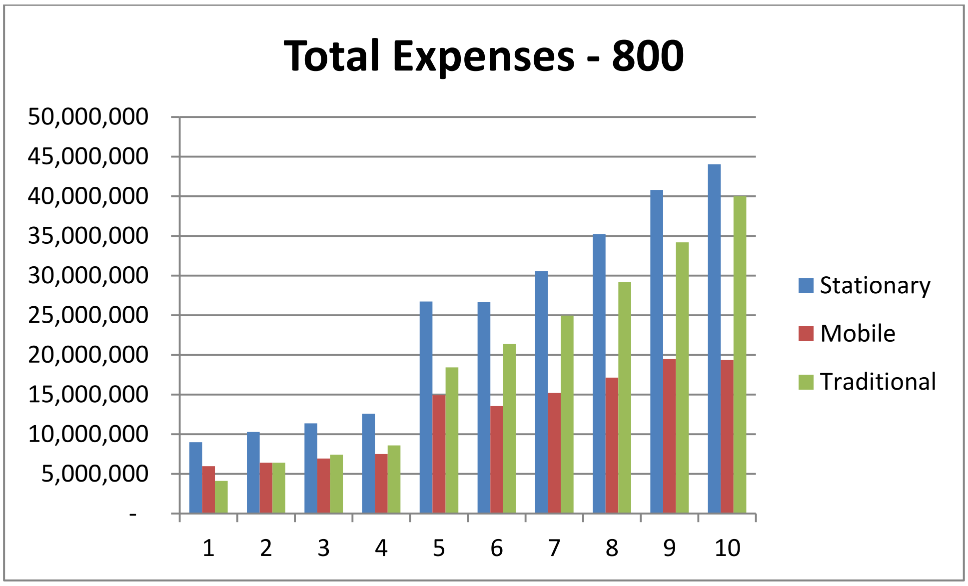


Figure V-46 Total expenses all plant types 800 TPH

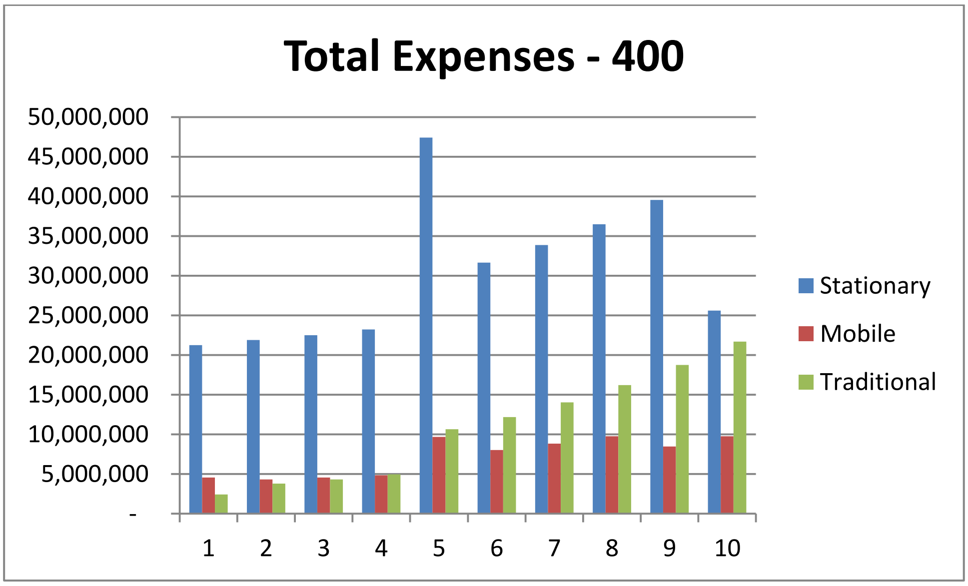


Figure V-47 Total expenses all plant types 400 TPH

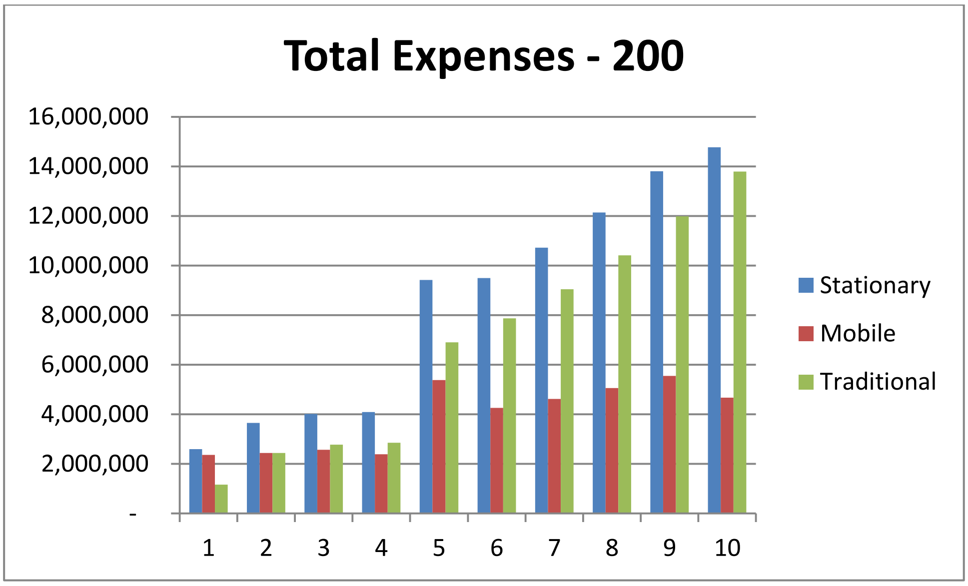


Figure V-48 Total expenses all plant types 200 TPH

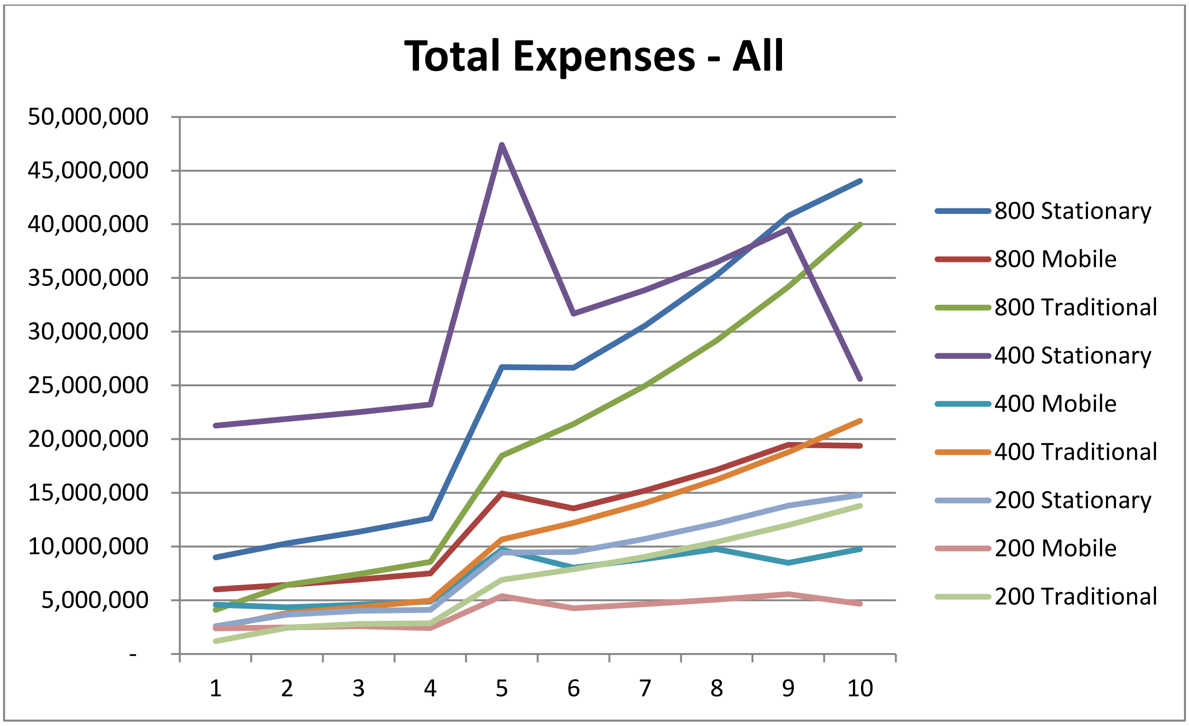


Figure V-49 Total expenses all plant types all capacities

H. Sensitivity Analysis

This part of the thesis is the testing of the model parameters and observing the results. It also tests each parameter's sensitivity and effectiveness in the output of the model, such as expenses, revenues and profits. The methodology that will be used consists of the following:

Figure V-50 Steps followed for sensitivity analysis

1. Step 1:

The first step is selecting the parameters based on the 20/80 rule. Basically, according to this rule, 20% of the parameters are targeted and should be contributing to the total expense by 80%. The model used for the sensitivity analysis is in the 800 TPH mobile plant sheets.

According to Figure V-51, the expenses that had a contribution of 80% of the total expenses are

1. Cost of Goods Sold,
2. Administrative expense and
3. Total salaries expense.

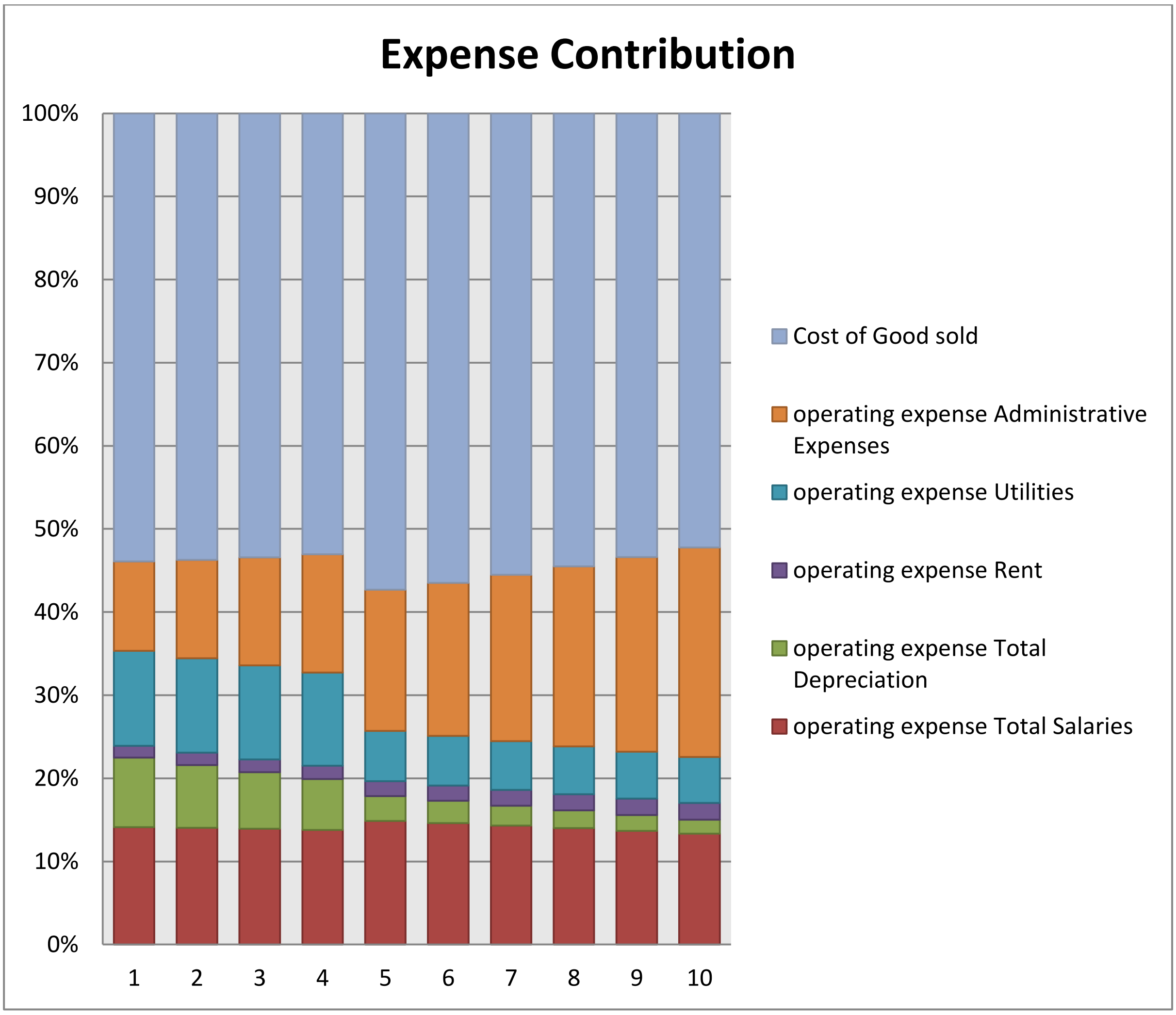


Figure V-51 Expense contribution in the income statement in percentage including revenues, expense and net profits

2. Step 2:

The second step is to increase and decrease the selected parameters by increments of 10% from -20% to +20%, i.e., -20%, -10%, **0% (original),** 10%, and 20%. The results are presented in Table V-3.

Table V-3 Sensitivity Analysis of major contributing expenses

Sensitivity Analysis	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
-10%										
COGS	4,082,400	4,502,887	4,966,685	5,478,253	12,085,026	13,329,784	14,702,752	16,217,135	17,887,500	19,729,913
Admin Expense	816,480	1,012,988	1,252,061	1,542,919	3,884,280	4,745,301	5,792,826	7,067,256	8,617,737	10,504,068
Salaries	1,070,280	1,177,308	1,295,039	1,424,543	3,133,994	3,447,393	3,792,133	4,171,346	4,588,480	5,047,329

-20%										
COGS	3,628,800	4,002,566	4,414,831	4,869,558	10,742,246	11,848,697	13,069,113	14,415,231	15,900,000	17,537,700
Admin Expense	725,760	882,966	1,074,225	1,306,911	3,180,000	3,868,817	4,706,837	5,726,380	6,966,766	8,475,830
Salaries	951,360	1,046,496	1,151,146	1,266,260	2,785,772	3,064,350	3,370,785	3,707,863	4,078,649	4,486,514
+10%										
COGS	4,989,600	5,503,529	6,070,392	6,695,643	14,770,588	16,291,958	17,970,030	19,820,943	21,862,500	24,114,338
Admin Expense	997,920	1,214,078	1,477,059	1,797,003	4,372,500	5,319,623	6,471,901	7,873,773	9,579,303	11,654,267
Salaries	1,308,120	1,438,932	1,582,825	1,741,108	3,830,437	4,213,481	4,634,829	5,098,312	5,608,143	6,168,957
+20%										
COGS	5,443,200	6,003,850	6,622,246	7,304,337	16,113,368	17,773,045	19,603,669	21,622,847	23,850,000	26,306,550
Admin Expense	1,088,640	1,324,449	1,611,337	1,960,367	4,770,000	5,803,225	7,060,256	8,589,571	10,450,149	12,713,745
Salaries	1,427,040	1,569,744	1,726,718	1,899,390	4,178,659	4,596,524	5,056,177	5,561,795	6,117,974	6,729,771
0%										
COGS	4,536,000	5,003,208	5,518,538	6,086,948	13,427,807	14,810,871	16,336,391	18,019,039	19,875,000	21,922,125
Admin Expense	907,200	1,103,708	1,342,781	1,633,639	3,975,000	4,836,021	5,883,546	7,157,976	8,708,457	10,594,788
Salaries	1,189,200	1,308,120	1,438,932	1,582,825	3,482,215	3,830,437	4,213,481	4,634,829	5,098,312	5,608,143

3. Step 3:

The third step is to plot all scenarios and observe the effect on the different results, such as expenses, profits and profit margin. The steps explained in Figure V-50 are to be applied only on the mobile type.

Table V-4 Sensitivity Analysis of the affected results (Total expense, net profit, profit margin)

-10%										
Total Expenses 800TPH -10%	5,781,760.00	6,202,175.68	6,688,744.14	7,253,209.71	14,488,967.39	13,057,707.78	14,683,812.26	16,598,782.84	18,858,558.06	18,715,488.19
Net Profit 800 TPH -10%	6,935,840.00	7,825,337.12	8,783,602.48	9,812,788.61	23,158,624.90	28,467,586.52	31,118,587.35	33,921,263.94	36,865,053.53	42,747,655.40
Profit margin -10%	41%	42%	43%	44%	47%	52%	51%	51%	50%	53%
% variation from original	11%	10%	10%	10%	8%	7%	7%	7%	8%	7%
-20%										
Total Expenses 800TPH -20%	5,916,640.00	6,235,684.00	6,587,829.04	6,976,550.78	13,390,459.71	11,376,756.55	12,261,770.36	13,239,390.28	14,319,469.87	12,697,934.66
Net Profit 800 TPH -20%	7,254,560.00	8,292,149.60	9,436,371.42	10,698,142.33	25,599,913.29	31,629,624.87	35,174,268.35	39,082,560.41	43,391,641.74	50,957,421.45
Profit margin -20%	43%	45%	46%	47%	51%	58%	58%	59%	59%	63%
% variation from original	16%	17%	18%	19%	20%	19%	21%	24%	27%	28%
+10%										
Total Expenses 800TPH +10%	6,201,040.00	6,664,890.45	7,201,528.61	7,823,858.65	15,673,630.48	14,398,117.26	16,205,583.04	18,332,266.14	20,839,786.14	20,987,315.52
Net Profit 800 TPH +10%	5,609,360.00	6,361,980.75	7,167,110.32	8,024,750.09	19,288,400.41	24,165,002.81	26,329,538.40	28,583,972.80	30,908,825.42	36,091,403.03
Profit margin +10%	33%	34%	35%	36%	39%	44%	44%	43%	42%	44%
% variation from original	-11%	-10%	-10%	-10%	-10%	-9%	-9%	-9%	-10%	-10%
+20%										
Total Expenses 800TPH +20%	6,410,680.00	6,906,073.22	7,479,699.88	8,145,505.08	16,419,352.03	15,264,763.04	17,215,285.75	19,511,546.58	22,220,463.05	22,607,608.58
Net Profit 800 TPH +20%	4,946,120.00	5,620,477.18	6,337,085.21	7,094,408.87	17,199,898.16	21,817,269.92	23,686,196.60	25,602,788.46	27,540,648.49	32,278,897.45
Profit margin +20%	29%	30%	31%	31%	35%	40%	39%	38%	37%	40%
% variation from original	-21%	-21%	-21%	-21%	-20%	-18%	-18%	-19%	-20%	-19%
0%										
Total Expenses 800TPH (Original)	5,991,400.00	6,423,707.68	6,923,357.34	7,502,212.23	14,927,908.93	13,531,471.48	15,195,880.33	17,152,985.71	19,459,109.23	19,367,022.47
Net Profit 800 TPH (Original)	6,272,600.00	7,103,484.32	7,997,135.43	8,955,091.31	21,376,902.66	26,512,735.71	28,972,880.20	31,565,157.15	34,277,002.35	39,903,908.60
Profit margin (Original)	37%	38%	39%	40%	43%	48%	48%	47%	47%	49%

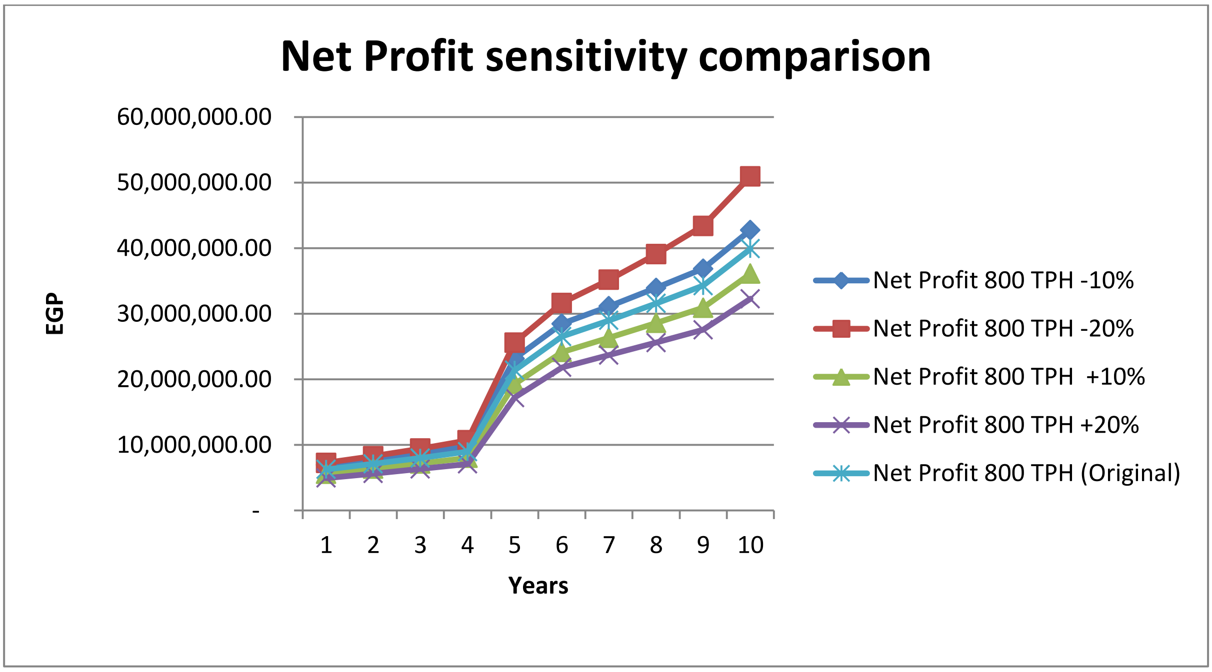


Figure V-52 Net profit sensitivity comparison

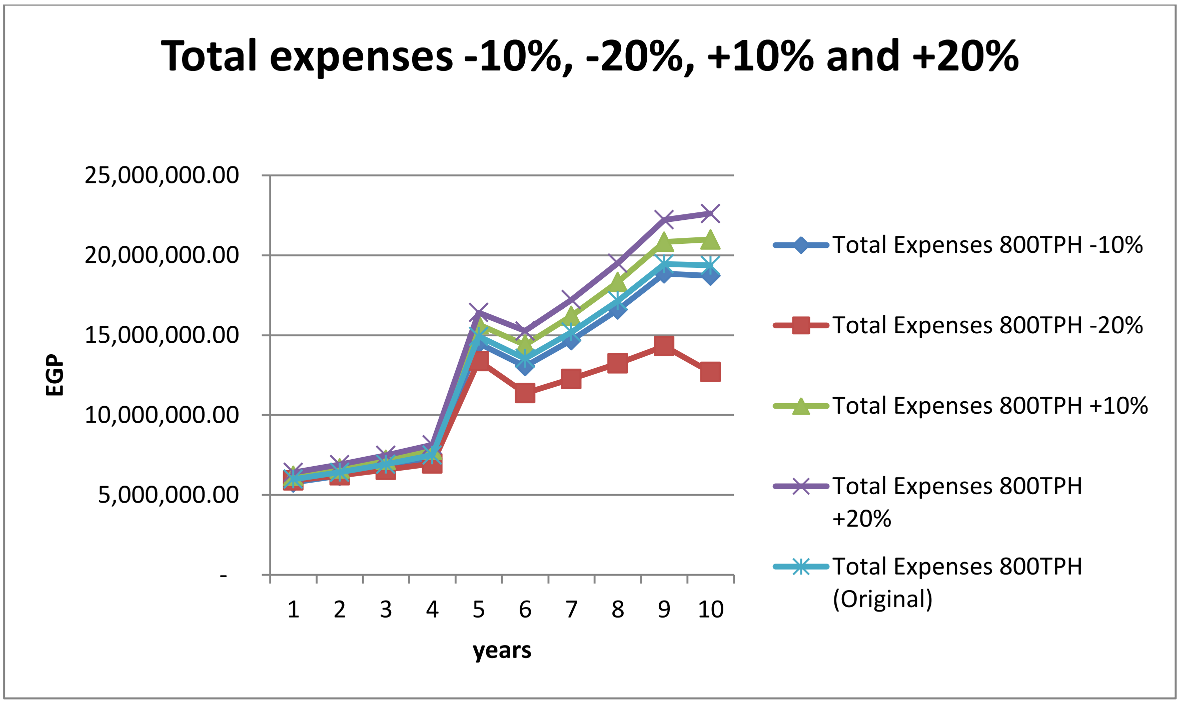


Figure V-53 Total expenses sensitivity comparison

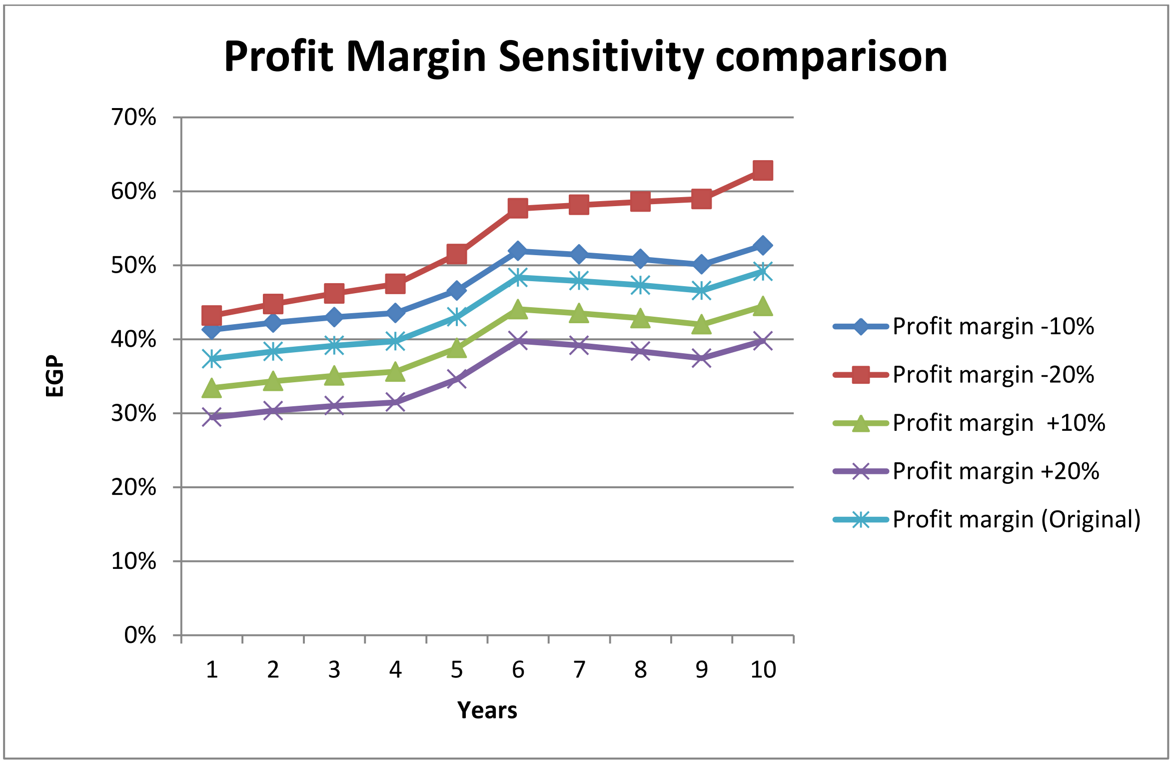


Figure V-54 Profit margin sensitivity comparison

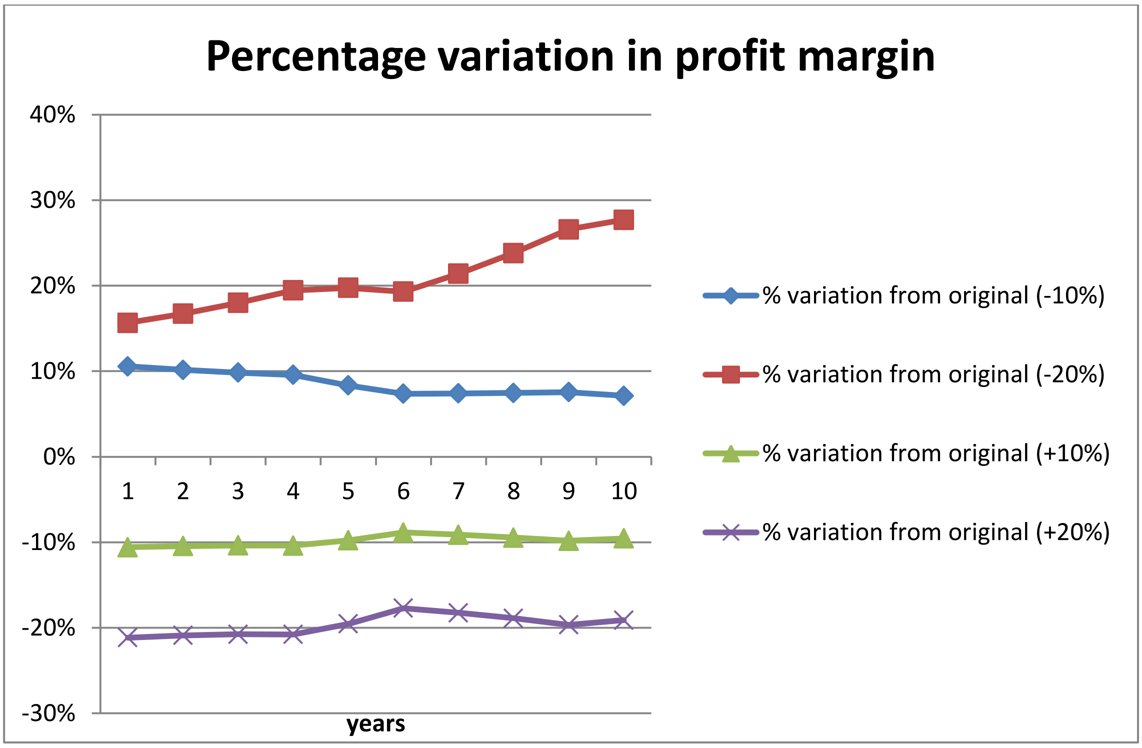


Figure V-55 Percentage variation in profit margin for -10%, -20%, +10% and +20% variations.

I. Model verification (Sensitivity Analysis Results)

The aim of this section is to verify all the calculations conducted in this model. The results should seem reasonable. The steps analyzed in section H of chapter 5, are testing the sensitivity analyses of the parameters having the most impact on the expenses. The expected outcome would be an increase in the profit margin when the expenses decrease and vice versa. According to Table V-4, the results indicated are the projections of the increase and decrease of the selected parameters over the 10-year analyses of the plant. In Figure V-52 and Figure V-53 show the plotted different results of expenses and profits. In Figure V-54 and Figure V-55 show the order of difference and percent variations relative to the original results, respectively. As noticed, when the expenses increase, the profit margin decreases and vice versa. For example, the -20% variation results in increase in profits by 16% in the first year and then it continuously increases to 28% in year 10 and the rest of the expected variations can be noticed in Figure V-55.

VI. Chapter 6: Case Study (Validation of the model)

This chapter illustrates the use of the developed tools through a real case study, and then a calculations' analysis is conducted to identify the impact of several factors on the profits, revenues and expenses on the plant.

The only available plant in Egypt that recycles concrete aggregates is the enhancement company which was described previously in this paper in chapter 2: review of the literature. The site is located in haram city in 6th of October. The plant area is 6 acres. The expenses and any other data were extracted through interviews with the CEO (Ghanem, 2013).

A. Data Input

The data needed to test the model are as follows:

- Rent fees: 10000LE/month , 120,000 LE/year
- Utility fees: 5000 LE/month, 60,000 LE/year
- Administrative expense: 15% of the total revenues , i.e., 123,750LE/year
- Crushing equipment bought: 150,000LE (manufactured locally)
- Vehicles (trucks) cost: 600,000LE if needed more they can rent
- Heavy hauling (loader): 700,000LE
- Years of installments: 5 years
- Highly skilled labor salary: 135 LE/day, i.e., .3500 LE/month
- Normal labor salary: 75LE/day, i.e., 2000LE/month
- Engineer salary: 4500LE/month
- Forman salary: 3000 LE/month
- The manning diagram for the recycling process in presented in Table VI -VI-1
- Working days per year: 250 days
- Working hours: 10 hours
- Efficiency: 60% (conservative)

- Plant production rate: 50TPH
- Cost of pre-handling: 2LE/ton
- Cost of post-handling (mix with other material to produce concrete blocks and curbstones: 8LE/ton
- Price of construction debris: 0 LE/ton (some case they get fees to follow LEED requirements.
- Price of aggregates sold in a forms of products: 60LE/ton
- Rent increase: 15% yearly
- Product inflation rate: 10.3% yearly
- Salary increase: 12%

Figure VI-3 Concrete curb stones produced from recycled concrete (Case study)

Figure VI-1 Concrete bricks produced from recycled concrete (Case study)

Figure VI-2 Crusher 50 TPH (case study)

Table VI -VI-1 manning process diagram for traditional type (Case study)

Activity	Haul-Input	Feeder	Manual Filtering	Primary Crusher	Secondary Crusher	Screen	Monitor	Post-Handling	Transportation
# of workers									
Highly Skilled Labor	1			1				1	1
Semi-Skilled Labor									
Normal Skilled Labor	1		2	1					1
Engineer							1		
Forman							1		

The results of the case study are analyzed with the same model introduced earlier in chapter 5: model framework and development. The forecasted results are to be compared with the actual data on site. As the profits were very confidential to the CEO of the enhancement company, the data extracted from the model is evaluated by the CEO of the company and comments are given.

B. Results

The results were conducted based on the data that was available on hand. Afterwards the relevant graphs were extracted from the model to show the profits, expenses and revenues. As shown in Table VI-2, the income statement is presented with all the expected results in the next 10 years. Afterwards, the results were compared with actual numbers provided by the company's CEO. The net profit is present in Figure VI-4. The net profit margin is 10.7% and increases to 13.7% in year 10. However the model is designed to have another plant operating in year 5. The maximum net profit margin is 16.3% in year 7.

Table VI-2 Forecasted Income statement for 50 TPH traditional plant (Case study)

50 TPH				
Income Statement	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Revenues	1,875,000.0	2,068,125.0	2,281,141.8	2,516,099.4

		0	0	8	9
Cost of Goods sold		750,000.00	827,250.00	912,456.75	1,006,439.80
Gross Profit 50TPH		1,125,000.00	1,240,875.00	1,368,685.13	1,509,659.69
operating expense					
	Total Salaries	342,000.00	383,040.00	429,004.80	480,485.38
	Total Depreciation	72,500.00	72,500.00	72,500.00	72,500.00
	Rent	120,000.00	138,000.00	158,700.00	182,505.00
	Utilities	60,000.00	66,180.00	72,996.54	80,515.18
	Administrative Expenses	112,500.00	136,868.51	166,515.46	202,584.21
	Initial Investment	290,000.00	290,000.00	290,000.00	290,000.00
				-	-
Total Expenses 50TPH		924,500.00	1,014,088.51	1,117,216.80	1,236,089.77
Net Profit 50 TPH		200,500.00	226,786.49	251,468.32	273,569.92
	Profit margin	10.69%	10.97%	11.02%	10.87%

Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
5,550,515.47	6,122,218.56	6,752,807.08	7,448,346.21	8,215,525.86	9,061,725.03
2,220,206.19	2,448,887.43	2,701,122.83	2,979,338.48	3,286,210.35	3,624,690.01
3,330,309.28	3,673,331.14	4,051,684.25	4,469,007.72	4,929,315.52	5,437,035.02

1,076,287.24	1,205,441.71	1,350,094.72	1,512,106.08	1,693,558.81	1,896,785.87
72,500.00	72,500.00	72,500.00	72,500.00	72,500.00	72,500.00
419,761.50	482,725.73	555,134.58	638,404.77	734,165.49	844,290.31
88,808.25	97,955.50	108,044.91	119,173.54	131,448.41	144,987.60
492,931.55	599,704.96	729,606.45	887,645.78	1,079,917.84	1,313,837.77
290,000.00					
290,000.00	290,000.00	290,000.00	290,000.00	290,000.00	
-					
2,657,788.54	2,675,827.90	3,032,880.67	3,447,330.17	3,929,090.56	4,199,901.55
672,520.74	997,503.24	1,018,803.58	1,021,677.55	1,000,224.96	1,237,133.47
12.12%	16.29%	15.09%	13.72%	12.17%	13.65%

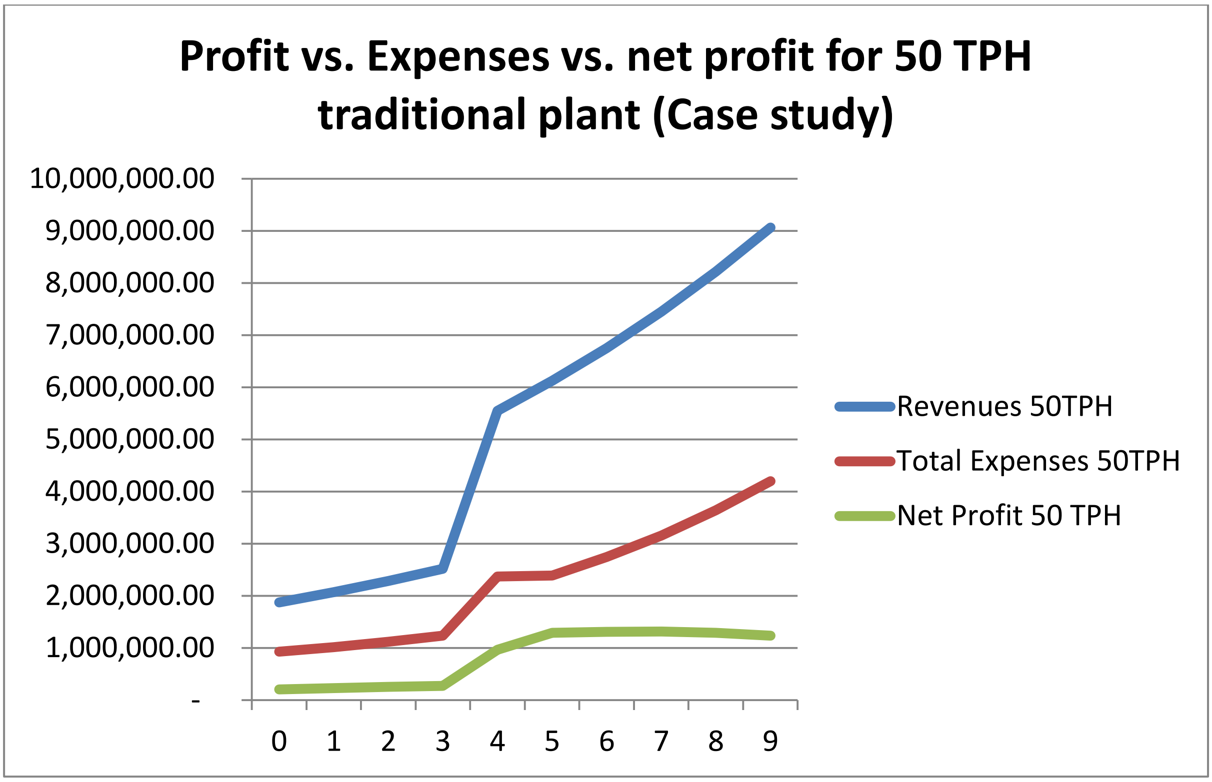


Figure VI-4 Profit, Expenses and net profit for 50 TPH traditional plant (Case study)

C. Model validation

According to the results in Figure VI-6 of the case study, the profit was relatively the same as the actual results for the first year of the company's operation (Ghanem 2014). The model illustrated as much possible the first 4 years, however, the several years afterwards are different since the model initiates another operating plant by year 5, which changes all the forecasted results. However, an alternative plan was proposed to forecast the results with only one operating plant throughout the 10 years, as shown in Table VI-2.

Nevertheless, there was something noticed in the graph trend in the case with only one operating plant as shown in Figure VI-5. The profit margin curve has a negative slope as it reaches year 10. After major analysis and study, it was noticed that the percentage increase of rent and salaries is higher than the inflation percentage increase of the selling price of the products. Therefore, another modification was done to adjust this problem. The modification is as follows:

- Rent increase: 10% yearly (instead of 15%)
- Product inflation rate: 10.3% yearly (no change)
- Salary increase: 10% (instead of 12%)

The results are plotted as shown in Figure VI-5. The slope is adjusted to a positive trend to ensure an increase in the profit margin. The variations of the model from the actual are indicated in percentage in Table VI-3 Model Variations from actual.

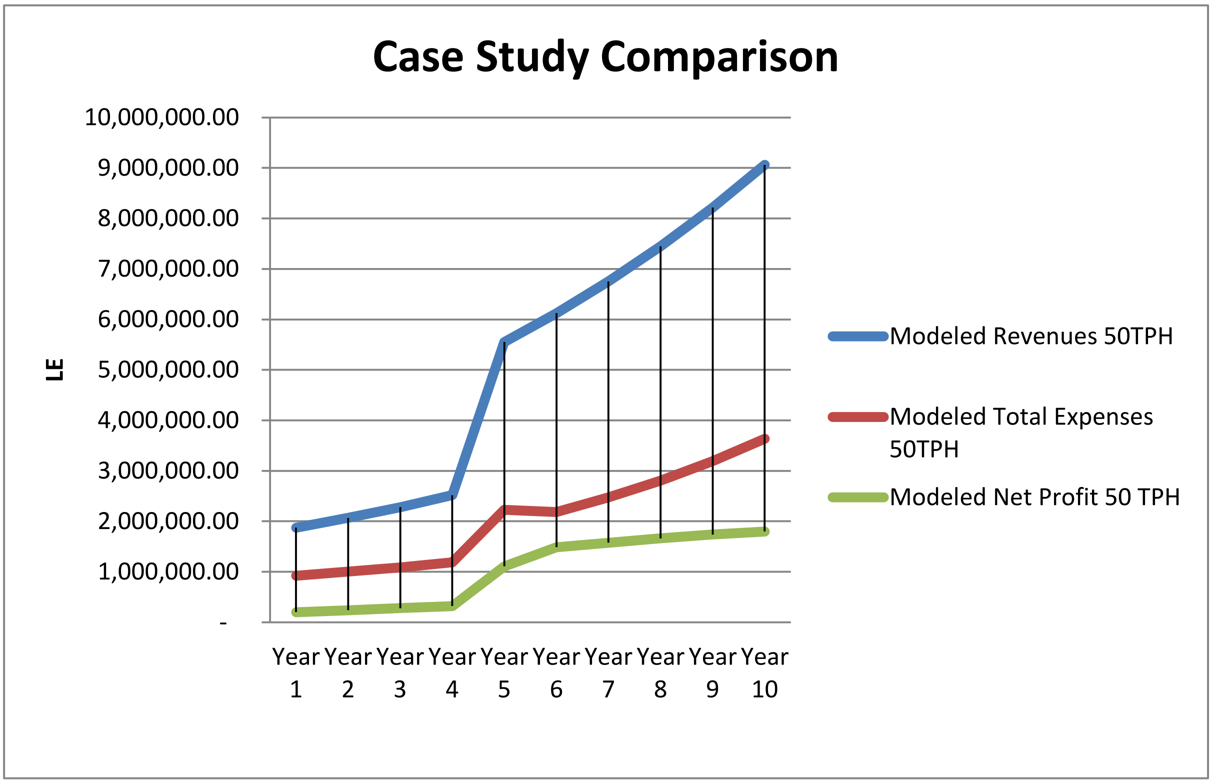


Figure VI-5 Profit, Expenses and net profit for 50 TPH traditional plant with single operating plant (Case study)

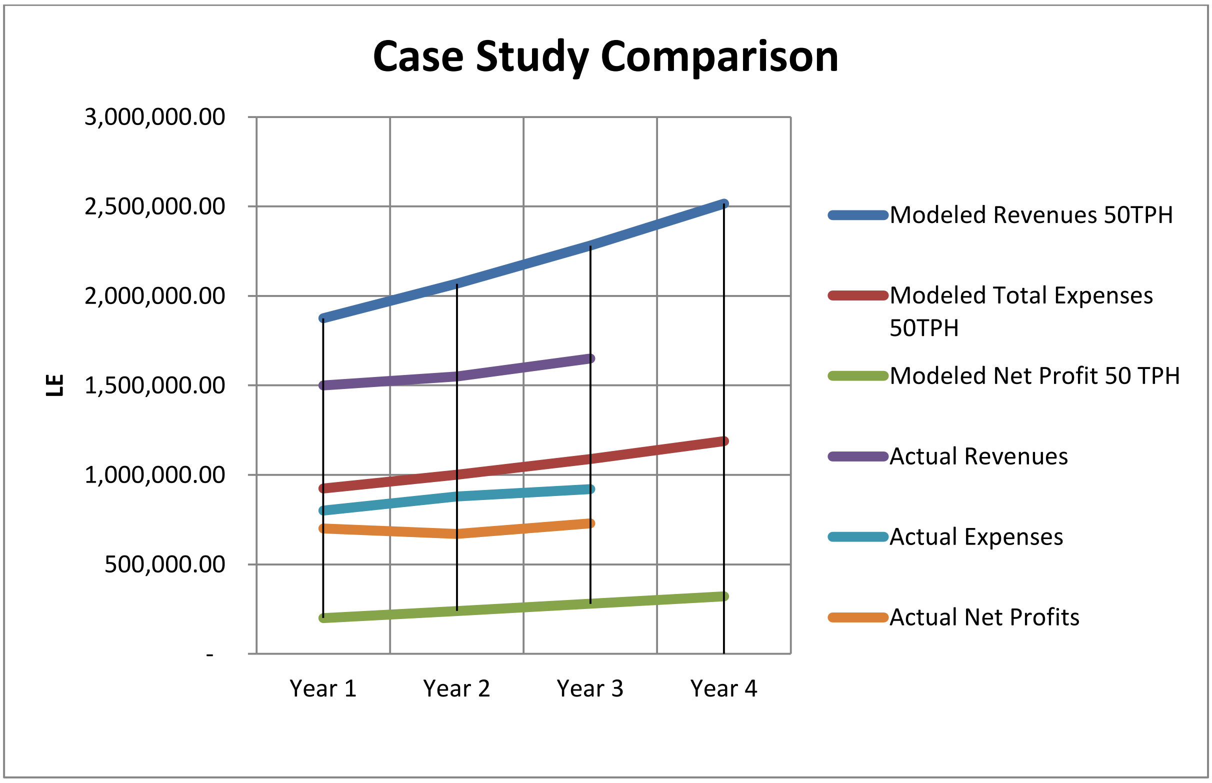


Figure VI-6 Modeled VS. actual Profit, Expenses and net profit for 50 TPH traditional plant (Case study)

Table VI-3 Model Variations from actual

		Year 1	Year 2	Year 3
Variations Relative to Actual Results	Revenues	25%	33%	38%
	Expenses	16%	14%	18%
	Net Profits	-71%	-64%	-62%

Variations

- Revenues: Increase in working days
- Expenses: Depreciation costs, Increase in rent and salaries

VII. Chapter 7: Conclusion, Recommendation and future work

A. Concrete as a material and its usage

Concrete is one of the most durable materials used in the construction industry and pavement activities for many decades. Concrete is the second most consumed material worldwide after water. In the construction industry, concrete is consumed in amounts twice as those of all the other materials consumed together, such as wood, steel, plastic, aluminum, etc. There is one cubic meter of concrete consumed per person every year.

B. Concrete recycling applications worldwide and Egypt

As concrete is the second consumed material worldwide, it has a lifetime and expected disposal and this produces large quantities of waste and debris. Since many years ago, concrete waste was dumped in landfills and not reused. Several years ago, many countries started to adopt the recycling of concrete to be used as aggregates. In Europe and UK where most of the recycling of the world occurs, they have acquired experience in the recycling of concrete. The process is divided into wet and dry concrete aggregate recycling. The wet type is the recycling of returned or rejected concrete from a site to the batch plant through trucks. The dry method is the common on, which is the recycling of waste or demolished concrete. In Egypt, few applications are currently being implemented to follow the LEED requirements but there is no motive to recycle concrete for financial rewards.

C. Problem statement and objective

The problem in Egypt is that a large quantity of concrete waste is produced. There have been no attempts to quantify this kind of waste. The waste management, recycling knowledge and knowhow is minimal at this time. There are some attempts to recycle but only in the academic field. Moreover, the technical applications of recycling concrete are positively supported by many research conducted in Egypt and aboard.

The objective of this thesis is to present a complete technical plan and financial study for operating a zero construction waste traditional, mobile and stationary plants specialized in recycling concrete aggregates. In addition, the plant will manage all other kinds of waste and outsource their recycling processes to other specialized plants.

D. Methodology

The methodology is a critical part of this thesis as it contains the flow of the research and how it is conducted. The simple steps to reach the objective is by producing a literature review of all the past and current research conducted, gather and compile all required data from international and local sources, create model framework, further develop the model, verify the model through the sensitivity analysis, validate the model and finally the conclusion and recommendations.

E. Recycling of concrete aggregates status, nationally and internationally.

As mentioned in the literature review, the international status is ahead of the local one. In Germany, the dry recycling is very common as it saves 3-5% of all the fresh concrete wastes, which the average waste produced. Moreover, in France and the UK, the recycling of old concrete is very common. They use several types of equipment, such as stationary and mobile.

Since many countries started to implement governmental guidelines and regulations, many private companies started to open their own businesses. In the US LEED is the regulations and certification followed in the construction field. However, in UK, the BREAM is the main regulations and certification. It is found profitable to operate the recycling plant under these guidelines, as the party having the waste has to pay a large amount to dispose the waste in landfills or recycle them by paying a less amount.

In Egypt, there is research that was conducted for the technical aspects of recycling concrete aggregates and comparing them with virgin one. The studies focused on the recycling of old concrete aggregates and using them in new mixes, and then they were compared with mixes with virgin aggregates. After some physical research and looking for recycling plants in Egypt, there was one plant in 6th of October found. The plant was offering a service for contractors who are obliged to follow the LEED requirements. The plant takes all the concrete debris and recycles it to produce new products like coarse aggregates, curbstones and interlocks. All the information was extracted through physical interviews and site visits, whether locally or internationally.

F. Model development and results

The model was developed through stages. The first one is the layout and calculation design to produce the most accurate results possible. The next stage is data input and duplicating the model for several types and capacities and then entering the data for all models. The models are created to compare the revenues, expenses and net profits for stationary, mobile and traditional types with capacities 200, 400, 800 TPH each. The results are presented in Table VII-1, Table VII-2, Table VII-3 and Table VII-4. According to Table VII-1, the plants having the highest net profits are mobile 800 TPH and 400 TPH, and traditional 800 TPH and 400 TPH plants. According to Table VII-2, the highest revenues are produced from traditional 800 TPH, stationary 800 TPH and mobile 800 TPH plants, from highest to lowest respectively. According to Table VII-3, profit margin is highest in mobile 800 TPH, mobile 400 TPH, mobile 200 TPH, then the traditional and stationary from highest to lowest respectively. According to Table VII-4, the total expenses are highest in stationary 400 TPH, 800 TPH, traditional 800 TPH, mobile 800 TPH and then the rest, from highest to lowest respectively.

Table VII-1 Comparison of all plant types according to net profits

Net Profits		1	2	3	4	5	6	7	8	9	10
800	Stationary	(3,637,700)	(4,389,799)	(4,840,709)	(5,414,241)	(10,858,312)	(9,154,348)	(11,282,277)	(13,964,356)	(17,330,501)	(18,156,062)
	Mobile	6,272,600	7,103,484	7,997,135	8,955,091	21,376,903	26,512,736	28,972,880	31,565,157	34,277,002	39,903,909
	Traditional	8,896,000	7,908,144	8,396,095	8,868,346	20,040,760	21,060,299	21,855,702	22,456,075	22,784,433	22,833,965
400	Stationary	(18,661,900)	(19,021,556)	(19,339,030)	(19,727,078)	(39,692,034)	(23,174,853)	(24,508,981)	(26,147,431)	(28,157,924)	(13,020,563)
	Mobile	529,400	1,314,560	1,642,173	1,992,636	5,442,421	8,667,104	9,581,912	10,543,686	13,907,165	14,944,382
	Traditional	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200	4,061,200
200	Stationary	(1,291,550)	(2,224,916)	(2,430,294)	(2,352,042)	(5,572,968)	(5,248,782)	(6,033,462)	(6,975,399)	(8,107,521)	(8,491,038)
	Mobile	189,325	372,877	540,729	1,043,904	2,188,728	4,088,645	4,576,075	5,096,539	5,649,853	7,680,181
	Traditional	2,083,600	1,146,007	1,174,108	1,510,261	2,722,631	2,737,710	2,658,123	2,503,171	2,252,367	1,916,637

Table VII-2 Comparison of all plant types according to revenues

	Reven s	1	2	3	4	5	6	7	8	9	10
800	Stationary	22,500,000	24,817,500	27,373,703	30,193,194	66,606,186	73,466,623	81,033,685	89,380,154	98,586,310	108,740,700
	Mobile	16,800,000	18,530,400	20,439,031	22,544,251	49,732,619	54,855,078	60,505,151	66,737,182	73,611,112	81,193,056
	Traditiona	25,000,000	27,575,000	30,415,225	33,547,993	74,006,873	81,629,581	90,037,428	99,311,283	109,540,345	120,823,000
400	Stationary	12,500,000	13,787,500	15,207,613	16,773,997	37,003,436	40,814,790	45,018,714	49,655,641	54,770,172	60,411,500
	Mobile	7,000,000	7,721,000	8,516,263	9,393,438	20,721,924	22,856,283	25,210,480	27,807,159	30,671,297	33,830,440
	Traditiona	12,500,000	13,787,500	15,207,613	16,773,997	37,003,436	40,814,790	45,018,714	49,655,641	54,770,172	60,411,500

200	Stationary	6,250,000	6,893,750	7,603,806	8,386,998	18,501,718	20,407,395	22,509,357	24,827,821	27,385,086	30,205,750
	Mobile	3,500,000	3,860,500	4,258,132	4,696,719	10,360,962	11,428,141	12,605,240	13,903,580	15,335,648	16,915,220
	Traditiona	6,250,000	6,893,750	7,603,806	8,386,998	18,501,718	20,407,395	22,509,357	24,827,821	27,385,086	30,205,750

Table VII-3 Comparison of all plant types according to profit margin

Profit Margin		1	2	3	4	5	6	7	8	9	10
800	Stationary	-16.17%	-17.69%	-17.68%	-17.93%	-16.30%	-12.46%	-13.92%	-15.62%	-17.58%	-16.70%
	Mobile	37.34%	38.33%	39.13%	39.72%	42.98%	48.33%	47.88%	47.30%	46.56%	49.15%
	Traditional	35.58%	28.68%	27.60%	26.43%	27.08%	25.80%	24.27%	22.61%	20.80%	18.90%
400	Stationary	-149.30%	-137.96%	-127.17%	-117.61%	-107.27%	-56.78%	-54.44%	-52.66%	-51.41%	-21.55%
	Mobile	7.56%	17.03%	19.28%	21.21%	26.26%	37.92%	38.01%	37.92%	45.34%	44.17%
	Traditional	32.49%	24.39%	23.45%	22.42%	23.22%	22.15%	20.80%	19.33%	17.73%	16.09%
200	Stationary	-20.66%	-32.27%	-31.96%	-28.04%	-30.12%	-25.72%	-26.80%	-28.10%	-29.61%	-28.11%

	Mobile	5.41%	9.66%	12.70%	22.23%	21.12%	35.78%	36.30%	36.66%	36.84%	45.40%
	Traditional	33.34%	16.62%	15.44%	18.01%	14.72%	13.42%	11.81%	10.08%	8.22%	6.35%

Table VII-4 Comparison of all plant types according to total expenses

Total Expenses

800	**Stationary**	8,992,700	10,296,364	11,355,650	12,600,221	26,710,584	26,639,404	30,568,294	35,236,833	40,794,043	44,036,349
	Mobile	**5,991,400**	6,423,708	6,923,357	7,502,212	14,927,909	13,531,471	15,195,880	17,152,986	19,459,109	19,367,022
	al	4,104,000	6,430,856	7,419,822	8,576,610	18,442,814	21,387,083	24,963,760	29,185,792	34,176,546	39,993,996
400	**Stationary**	21,261,900	21,889,356	22,502,213	23,216,069	47,388,749	31,664,329	33,872,873	36,475,804	39,550,120	25,586,155

	Mobile	4,580,600	4,321,770	4,574,699	4,864,574	9,684,584	8,017,982	8,821,739	9,755,540	8,482,881	9,751,839
	al	2,438,800	3,806,078	4,341,519	4,961,418	10,650,183	12,183,306	14,046,282	16,222,913	18,770,114	21,691,723
200	Stationary	2,591,550	3,658,816	4,011,886	4,096,537	9,421,326	9,493,520	10,715,408	12,139,586	13,803,619	14,773,834
	Mobile	2,365,675	2,445,288	2,567,707	2,384,701	5,374,774	4,253,898	4,625,750	5,053,074	5,545,170	4,667,930
	al	1,166,400	2,438,743	2,779,871	2,850,978	6,898,262	7,874,135	9,046,743	10,407,296	11,987,878	13,790,354

G. Case study and sensitivity analysis to validate and verify model

In order to create a reliable model, the validating and verifying exercises are done. The validations are done using the model to forecast the results of a case study then these results are compared with the actual ones on site. The verification is conducted by a sensitivity analysis to give the reader a sense of the critical parameters of the model and to verify that all the results are logical when changing the parameters. As noticed, when the expenses increase, the profit margin decreases and vice versa. For example, the -20% variation results in increase in profits by 16% in the first year and then it continuously increase to 28% in year 10 and the rest of the expected variations can be noticed in Figure V-55.

The case study was similar to the actual data at hand from the local concrete recycling aggregates plant of a traditional type. According to the results of the case study, the profit was relatively the same as the actual results for the first year of the company (Ghanem 2014). The model illustrated as much as possible the first 4 years, however, the several years afterwards are different since the model initiates another operating plant by year 5, which changes all the forecasted results.

H. Future use of the model

The model is designed to be very user-friendly. The excel workbook is protected of any editing however; parts of the sheets are editable to allow data input. As commonly known, the research is always in advance of the practical life. Therefore, the model is expected to be used later after many years and it is flexible to adopt the research and market changes, by allowing users to edit specific inputs of data.

I. Future recommended research work

- This thesis is not a comprehensive study in all aspects of the construction debris recycling. Therefore, it is recommended to study further the quantities of waste generated in Egypt. A formula or a survey may help in this investigation.
- It is recommended to investigate the financial possibilities to recycle other materials in specialized plants with profitable objectives.
- Adopting a sustainability code (currently under investigation many research and experts engineers) is a possible research area for advancing with the sustainable guidelines in Egypt and the Middle East.
- Studies on behavior of contractors and other parties towards recycling and social resistance in Egypt can be investigated to find solutions to motivate contractors and building owners to recycle all their waste during construction and operations.

VIII. References

52.5 (n.d.).

Abou-Zeid, Mohamed, et al. "Reincarnation of Concrete." *Concrete International* February 2005: 1-7.

Batayneh M., Marie I., Asi I. "Use of selected waste materials in concrete mixes." *Waste Management* 27 (2007): 1870–1876.

Boesman, B. "Crushing and Separating Techniques for Demolition Material." *Re-Use of Concrete and Brick Materials* 2 (1985).

Concrete recycling. n.d. 10 9 2013. <http://www.concreterecycling.org/plants.html>.

Del Barrio, Jaview De Pinto. *Personal Interview: Visiting and investigating a stationary concrete recycling plant* Omar Farahat Hassanein. South Madrid, 9 January 2014.

Department for Enviroment, food and rural affairs. "Defra Archive." 8 Feb 2008. *Archive: Construction waste.* 1 July 2013. <http://www.legislation.gov.uk/uksi/2008/314/contents/made>.

Edge Enviroment Rty Ltd . "Australia Enviroment." 17 Jan 2012. *Construction and Demolition waste guide - recycling and re-use across the supply chain.* 2 July 2013. <http://www.environment.gov.au/wastepolicy/publications/pubs/case-studies.pdf>.

Garas, Gihan, Ahmed Anis and Adel Gammal. “Material waste in the Egyptian construction industry.” n.d. 2013 йил 19-june. <http://cic.vtt.fi/lean/singapore/Garasetal.pdf>.

Gayed, Eng Roufael. *Aggregate price survey* Omar Farahat Hassanein. New Cairo, 05 September 2013.

Ghanem, Ayman. *CEO of the Enhancement for waste management* Omar Hassanein. Nov 2013.

Gutierrez, Pilar Alaejos. *Recycled Concrete Testing in CEDEX Research Center* Omar Farahat Hassanein. Madrid, 19 January 2014.

Haggar, Salah El. *Sustainable Industrial Design and Waste Management: Cradle-to-Cradle for Sustainable Development*. Academic Press; 1 edition, 2007.

Hansen, T.C. *Recycling of Demolished Concrete and Masonry*. Ipswich: Rilem, 1992.

Hardy, Christophe. *Personal Interview: Wet and dry concrete recycling investigation in Lafarge, Paris* Omar Farahat Hassanein. Paris, 28 December 2013.

Hassanein, Omar Farahat and A Ezeldin. "Concrete Recycling in Egypt for Construction Applications: A Technical and Financial Feasibility Model." Vol. 7. Paris: International Science, 2013. 1206-1212.

History of Leed. n.d. 1 july 2013. <http://www.businessrecovery.ws/leed-certification/history-of-leed>.

Kamel, Ahmed Moustafa Aly. "Guidelines for The application of recycled concrete aggregate in the Egyptian construction industry." Thesis Project. 2007.

Krause. "Built to last." n.d. *Krause Manufactering.* 1 july 2013. <http://www.krausemanufacturing.com/wp-content/uploads/_brochure_file/2075-1d376c44.pdf>.

Lu, W and H Yuan. "A framework for understanding waste management." *Waste Mangement* (2011): 1252-1260.

Marie, Iqbal and Hisham Quiasrawi. "Closed-loop recycling of recycled concrete aggregates." *Journal of Cleaner Production* 37 (2012).

Marmash, Basem Ezzat. "The Properties of Recycled Precast Concrete Hollow Core Slabs for Use as Replacement Aggregate in Concrete." Nottingham, January 2010.

pilar. *comncrete* omar. 28 dec 2013.

SRJ Ltd-Construction Waste Recycling. "Construction Waste Recycling System- A Predicted Life Cycle of Construction Waste." n.d. http://www.suomenrakennusjate.fi/eng/index.html.

Tam, Vivian W.Y. "Economic comparison of concrete recycling: A case study approach." *Resources Conservation and Recycling*. Science Direct, 2007. 821-828.

The Cement Sustainability Iniative. *Recycling Concrete* . Industry Report. Geneva: World Business Council for Sustainable Development , 2009.

YIFAN. *Zhengzhou Yifan Machinery Co., LTD*. 2012. 16 9 2013. <http://www.concreterecovery.net/products/concrete-recovery-plant.html>.

IX. Appendix I:

1. Interview questions:

The interview questions are divided into two sections. First one is the background and the purpose of the interview. The second is the interview questions conducted directly with the interviewee.

Background questions:

- What is the purpose of the visit?
- Where is the interview conducted, office, site or else? Which country?
- What is the scale of production and their recycled material type?
- What is the post and expertise of the interviewee, professors, engineer, field, research, etc.?

Direct interview questions:

- What is the type of crushing equipment at hand?
- What is the process used to recycle concrete? Dry or wet method?
- What type of equipment used, mobile, traditional or stationary? What is the type of crusher?
- What are the main sources of revenues and expenses?
- What are the challenges faced that result from corporate and government policies?
- What is the number of labor and their skills?
- Are the expenses and revenue in the model realistic? If not please modify it based on your experience.
- What are the advantages and disadvantages you are facing o recycle concrete in your country?
- What is the revenue model of the plant?
- Is the recycling operation executed as a service for other companies or for yourself as product oriented model?
- How does the contractor and owner relate to the idea of recycling materials?

- Can you evaluate the following model and give me your feedback? (proposed thesis model given)
- Do you conduct any research to develop your products? What are the results of them?

X. Appendix II:

1. Summary sheets and comparison graphs (Soft copy as Excel sheets)

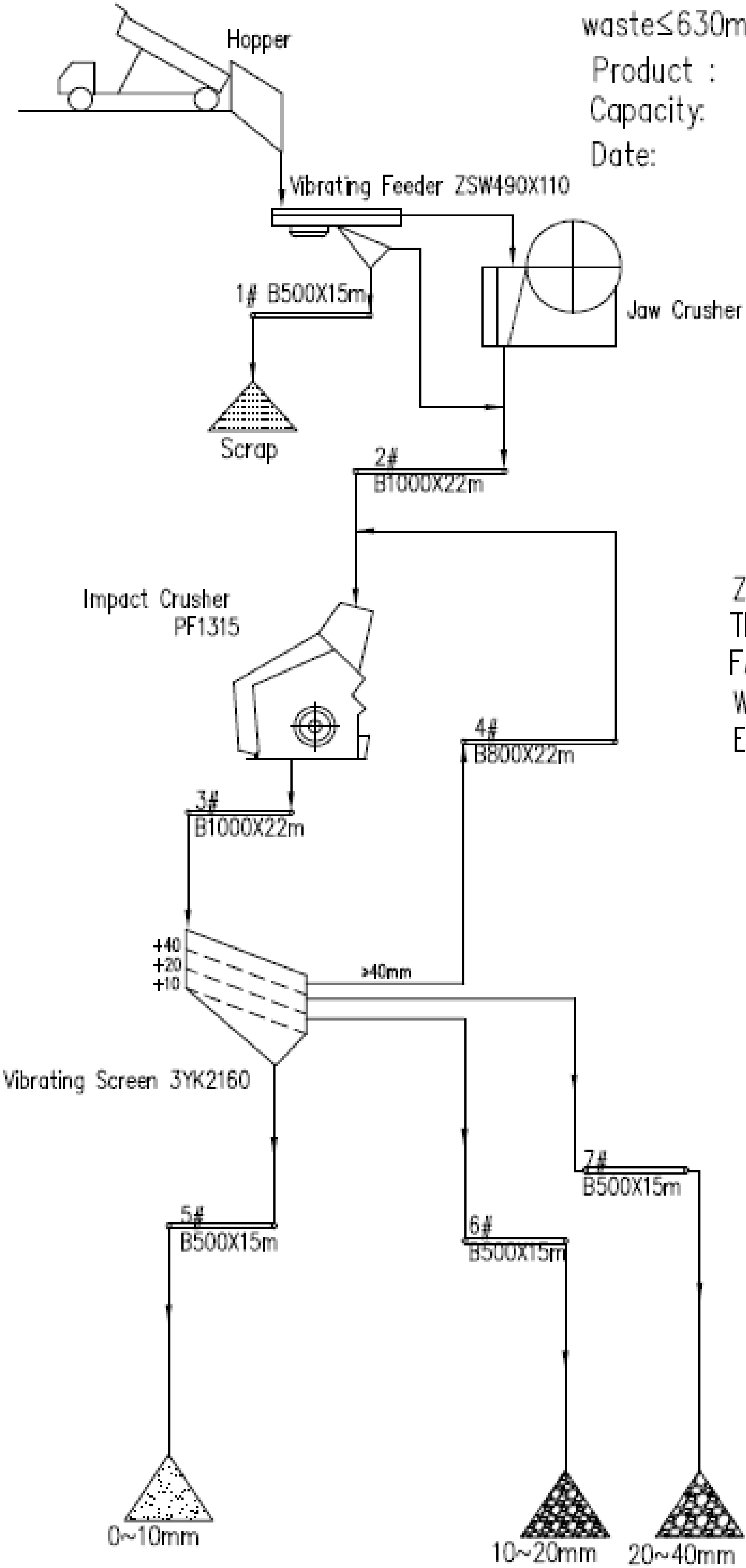
XI. Appendix III:

1. Manufacturers data specifications

Crushing & Screening Flow Chart

Raw Material : construction waste≤630mm

Product : 0~10,10~20,20~40mm
Capacity: 200 t/h
Date: 2013.09.24



ZHENGZHOU YIFAN MACHINERY CO.,LTD.
TEL:+86-371-64963352
FAX:+86-371-64628872
Web: http://www.yfcrusher.com
Email: sale01@yfmac.com

Equipment List

Name	Model	Unit	Num	Power (kW/unit)
Vibrating Feeder	ZSW490X110	Set	1	15
Jaw Crusher	PE750x1060	Set	1	90
Impact Crusher	PF1315	Set	1	200
Vibrating Screen	3YK2160	Set	1	30
Belt Conveyor	B500x15m	Set	4	4
	B1000x22m	Set	2	11
	B800X22m	Set	1	7.5
Electrical Cabinet				
Total				276.5

Vibrating feeder

+ ZSW series vibrating feeder is mainly used to feed material into the primary crusher homogeneously and continuously. Meanwhile, it can screen the fine material and make the crusher more powerful.

«} Features and Benefits:

+ Smooth vibrating
+ The special fence can prevent the block of raw material
+ The distance between bars is adjustable
+ Frequency conversion motor can be equipped to facilitate feeding control, and frequent startup of motor is avoided.

+ Technical data:

Model	Max Feed Size (mm)	Capacity (t/h)	Motor Power (kW)	Size of Funnel (mm)	Overall Dimensions (mm)	Weight (kg)
ZSW-490×110	580	120-280	15	4900×1100	4957×2400×2150	5320

Impact Crusher

+ PF Series Impact Crusher is mainly used in secondary crushing and can crush material whose crushing compression strength is not more than 320 Mpa. It is suitable to produce aggregate for highway, hydroelectric and building material industry, etc.

+ Features and Benefits:

«} Many cavities to crush, suitable for crushing hard rocks

«} Reasonable design of leveling plate making charger finer and cubic without interior crack

«} Low and big feeding opening makes it easy to arrange the production line and increase the size Of feeding material

«} Use the hydraulic to open, easy to maintain and change wear parts

«} New anti-abrasive material makes longer service life of impact bar, impact plate and liner.

+ Technical data:

Model	Feed Opening Size (mm)	Max Feeding Edge (mm)	Capacity (t/h)	Motor Power (kw)	Overall Dimensions (mm)	Weight (kg)
HCP359 (PF-1315)	1320x1500	500	160~250	200	3096×3273×2667	19,300

Vibrating screen

+ YK Series incline vibrating screen absorbs Germany technology, and is special designed to sieve different sizes of aggregate. It is also applied to coal dressing, ore dressing, building material, electric power and chemical industries.

+ Features and Benefits:
  - «} Famous brand Bearing
  - «} Motor: Siemens-Beide Brand
  - «} Adopt tire coupling, soft connection makes operation smooth;
  - «} High vibrating force with unique eccentric structure;
  - «} The beam and case of the screen are connected with high strength bolts without welding;
  - «} Simple structure, easy maintenance;
  - «} High efficiency, high capacity and durable.

+ Technical data:

Model	Screen Deck	Installation Slope (°)	Deck Size (㎡)	Frequency (r/min)	Capacity (t/h)	Motor Power (kW)	Overall Dimensions (mm)	Weight (kg)
3YK2160	3	20	12.6	970	180-240	30	5966×3958×4400	9112

Control Panel

Features and Benefits:

- Special design , ISO quality standard
- Quality electrical component, linkage performance

- If customer have special requirement, it could be soft start controlled. Protect the machine well.

A corner scene in our workshop

Spare parts for packing

Shipping of goods

Mobile crusher

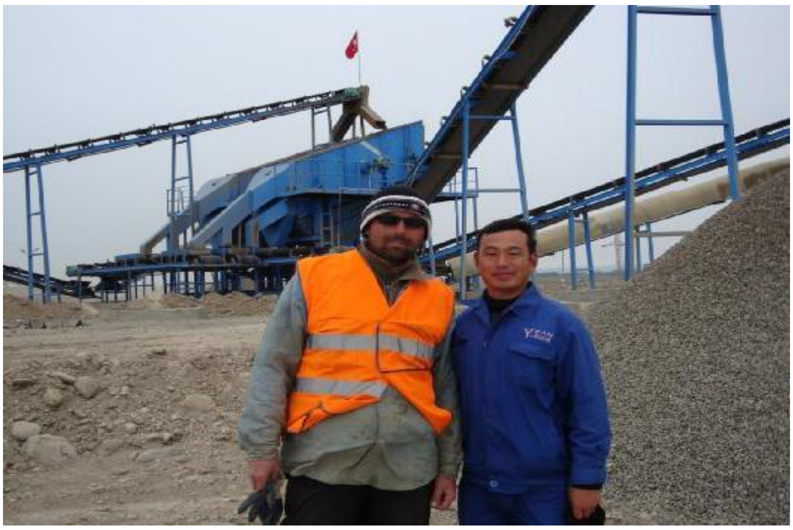
plant

Mobile crusher transportation

Truck transportation

Train Transportation

Container transportation



YIFAN engineer in Turkey

YIFAN engineer in Nigeria

Part 6 Customer's reference

720t/h granite stationary crushing plant in Saudi Arabia

250t/h basalt stone crushing plant in Saudi Arabia

200t/h Cobble stationary crushing plant in Turkey

200-250t/h Limestone crushing plant in Sri Lanka

300t/h Granite stationary crushing plant in New Zealand

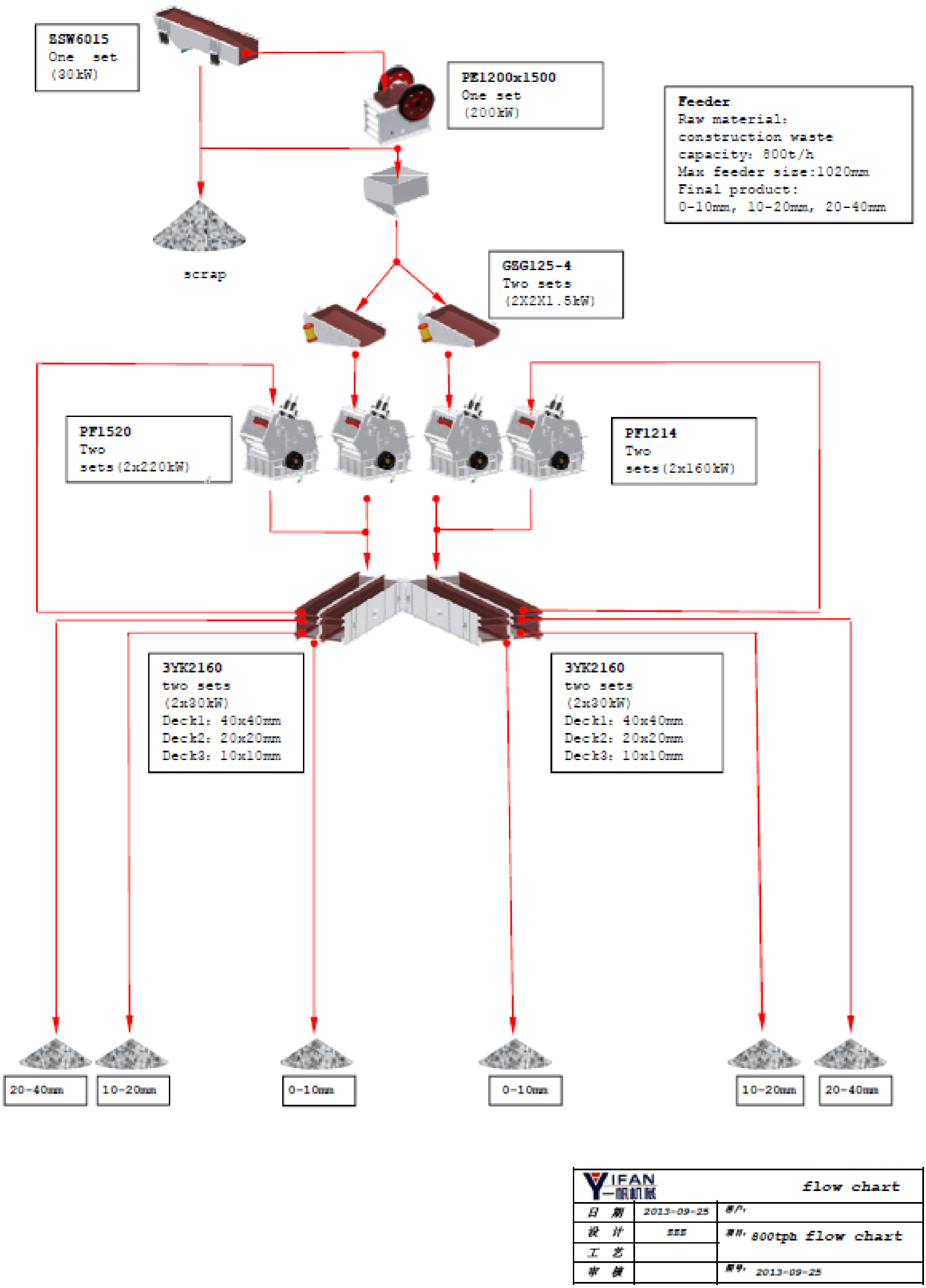
200t/h Granite stationary crushing plant in Algeria

150-200t/h granite crushing plant in Nigeria-1

150-200t/h granite crushing plant in Nigeria-2

400-450t/h limestone crushing plant is working well in China-1

400-450t/h limestone crushing plant is working well in China-2


ESW6015
One set
(30kW)
PE1200x1500
One set
(200kW)
Feeder
Raw material:
construction waste
capacity: 800t/h
Max feeder size:1020mm
Final product:
0-10mm, 10-20mm, 20-40mm
scrap
GZG125-4
Two sets
(2X2X1.5kW)
PF1520
Two
sets(2x220kW)
PF1214
Two
sets(2x160kW)
3YK2160
two sets
(2x30kW)
Deck1: 40x40mm
Deck2: 20x20mm
Deck3: 10x10mm
3YK2160
two sets
(2x30kW)
Deck1: 40x40mm
Deck2: 20x20mm
Deck3: 10x10mm
20-40mm
10-20mm
0-10mm
0-10mm
10-20mm
20-40mm
flow chart
日 期
2013-09-25
工 艺
800tph flow chart
2013-09-25

J. Part 3 Specification of all the machine

Vibrating feeder

+ ZSW series vibrating feeder is mainly used to feed material into the primary crusher homogeneously and continuously. Meanwhile, it can screen the fine material and make the crusher more powerful.

«} Features and Benefits:

+ Smooth vibrating
+ The special fence can prevent the block of raw material
+ The distance between bars is adjustable
+ Frequency conversion motor can be equipped to facilitate feeding contr l, and frequent startup of motor is avoided.

«} Technical data:

Model	Max Feed Size (mm)	Capacity (t/h)	Motor Power (kW)	Size of Funnel (mm)	Overall Dimensions (mm)	Weight (kg)
ZSW-600×150	1000	460~660	30	6000×1500	6627×2350×3068	9,295

Jaw crusher

PE series single toggle jaw crusher has the features of great crushing ratio, uniform size of product. It can be used to crush material its compressive resistance not more than 320 Mpa.

+ Features and Benefits:
  - «} Famous brand Bearing
  - «} Motor: Siemens-Beide Brand
  - «} Eccentric shaft forged by Cr40. More durable
  - «} Wearing parts contain high manganese cast steel
  - «} Simple structure and reliable operation;
  - «} Convenient maintenance and low operation cost;

+ Technical data:

Model	Feed Opening (mm)	Max Feed Size (mm)	Discharge Range (mm)	Capacity (m^3/h)	Motor Power (kW)	Weight (kg)
PE-1200×1500	1200×1500	1020	100~200	250~500	200	88,500

2. Impact Crusher

+ Impact crusher is designed and made through absorbing world advanced crushing technology. It is widely used in metallurgical, aggregate, building material industries. It is suitable for crushing varies of mid-hard ores and rocks.
+ Features and Benefits:
  - Many cavities to crush
  - Low and big feed opening make the production line easy to arrange and increase the size of feeding material
  - New anti-abrasive material makes longer service life of impact bar, impact plate and liner.
  - Technical data:

Model	Max Feeding Size (mm)	Feed Opening Size (mm)	Capacity (t/h)	Motor Power (kW)	Overall Dimensions (mm)	Weight (kg)
PF1214	350	400*1430	130~180	160	2640×2370 ×2890	17100
PF1520	700	830*2050	300-550	2*200	3581×3560 ×3265	38700

3. Vibratingscreen

+ YK Series incline vibrating screen absorbs Germany technology, and is special designed to sieve different sizes of aggregate. It is also applied to coal dressing, ore dressing, building material, electric power and chemical industries.
+ Features and Benefits:
  - Famous brand Bearing
  - Motor: Siemens-Beide Brand
  - Adopt tire coupling, soft connection makes operation smooth;
  - High vibrating force with unique eccentric structure;
  - The beam and case of the screen are connected with high strength bolts without welding;
  - Simple structure, easy maintenance;
  - High efficiency, high capacity and durable.

+ Technical data:

Model	Screen Deck	Installation Slope (°)	Deck Size (㎡)	Frequency (r/min)	Capacity (t/h)	Motor Power (kW)	Overall Dimensions (mm)	Weight (kg)
3YK2160	3	20	12.6	970	100-200	22	5966×3958×4400	9112

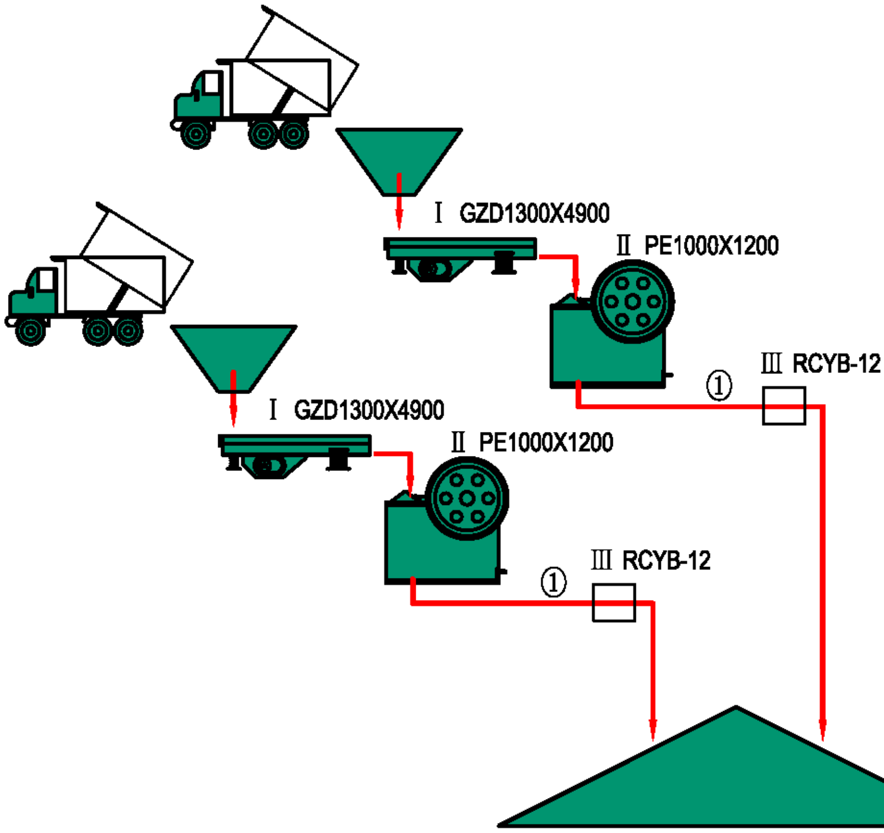
Control Panel

+ Features and Benefits:

«} Special design , ISO quality standard

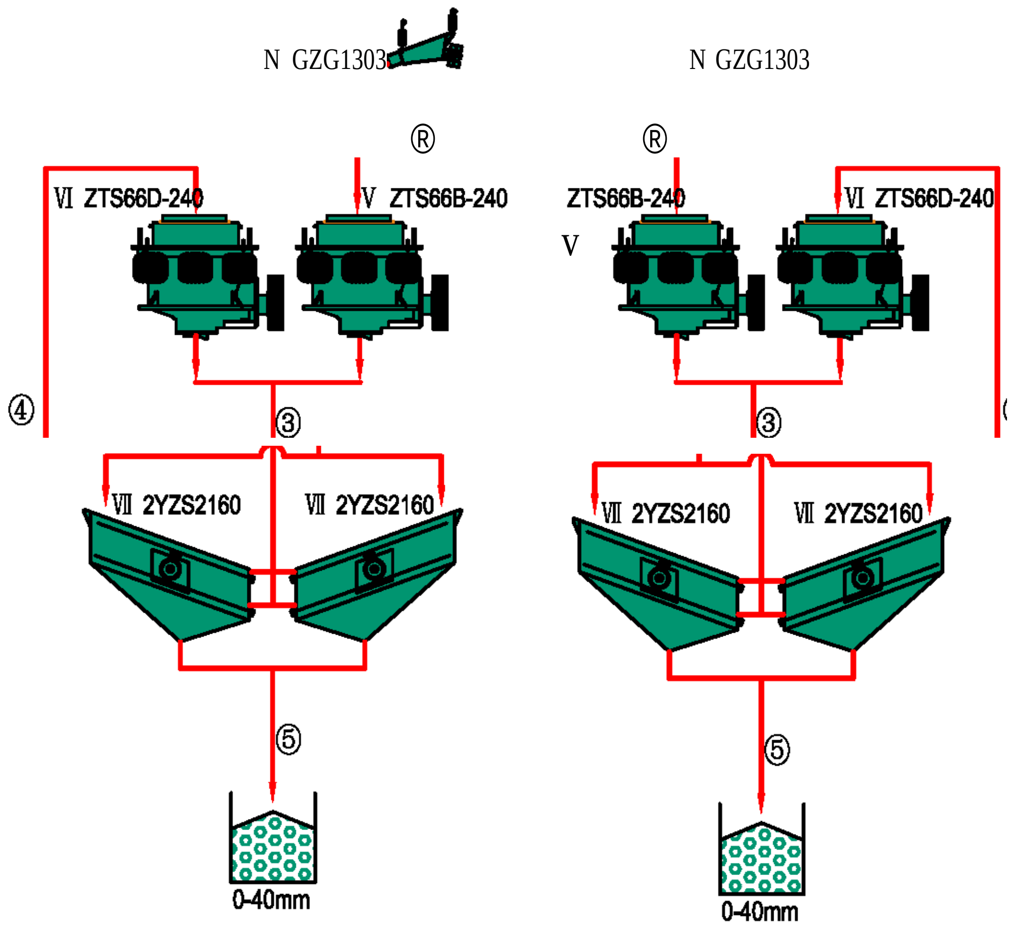
«} Quality electrical component, linkage performance

«} If customer have special requirement, it could be soft start controlled. Protect the machine well.



Equipment List

NO.	EQUIPMENT	MODEL	QTY.
I	Vibrating Feeder	GZD1300X4900	2
n	Jaw Crusher	PE1000X1200	2
m	MagnBiic Separator	RCYB-12	2
N	Feeder	GZG1303	2
V	Cone Crusher	ZTS66B-240	2
VI	Cone Crusher	ZTS660-240	2
Vll	Vibrating Screen	2YZS2160	4
(!)	Belt Conveyor	B1200X25M	2
®	Belt Conveyor	B1200X25M	2
®	Belt Conveyor	B1200X(8M+26M)	2
@	Belt Conveyor	B800X(7M+24M)	2
@	Belt Conveyor	B1200X25M	2



To: Omar ***Date:Sept 27th , 2013***

700TPH Quarry Crushing Plant Solution & Quotation

Content :

2. The steel of the main structure (not the alloy and special steel) is the Q235 (UK standard is 4360-40B (C), and USA K02502).

3. Terms of payment: 30% of the total amount should be paid in advance(T/T) as earnest money,70% of the total amount should be paid by T/T or LC before the goods leave our factory.

4.Delivery time: 35-40 working days after we receipting the earnest money.

5. Technical supports: We will send you the technical documentary in 5days after receipting the earnest money , also with the operating instruction and all relative drawing. 6.The guarantee period of the machine is one year, exclude the quick wear parts. 7.Installation: We can also responsible for civil engineering, accessorial material, chain block. However the fee for our engineer(include airplane ticket for come and go, the cost for house and food, the income (50 USD/Day for the engineer) ,light and power should be supply

2、Detailed Information

Vibrating Feeder

Model	Feeding Chute Size (mm)	Max. Feeding Size (mm)	Capacity (t/h)	Motor Power (kw)	Weight (kg)	Overall Dimension (mm)

GZD-1300×4900	1300×4900	650	450-600	22	5200	5200×2350×1750

Jaw Crusher

Model	Feed Opening Size (mm)	Max. Feeding Size (mm)	Adjustable Range of Output Size (mm)	Capacity (t/h)	Motor Power (kw)	Weight (t)	Overall Dimension (mm)
PE1000×1200	1000×1200	850	105-185	180-400	160	56.5	3900×3320×3280

ZTS Cone Crusher

Model	Cavity Size	Max Feeding Size (mm)	Adjusting Range of Output Size (mm)	Capacity (th)	Motor Power (kw)	Weight (t)	Overall Dimension (mm)
ZTS66B	Fine	178	16~38	181~327	220	51	3941×2954×3771
	Medium	205	22~51	258~417			
	Coarse	228	25~64	299~635			
	Extra Coarse	313	38~64	431~645			
ZTS66D	Fine	60	5~13	90~209		52	
	Medium	76	6~19	136~281			
	Coarse	113	10~25	190~336			
	Extra Coarse	125	13~25	253~336			

Vibrating Screen

Model	Screen Cloth Size (mm)	Screen Decks	Screen Opening Size (mm)	Max. Feeding Size (mm)	Capacity (t/h)	Motor Power (kw)	Weigh t (t)	Overall Dimension (mm)
2YZS2160	6000×2100	2	3-100	400	81-720	22	8.48	7130×2990×1760

Belt Conveyor

Belt Width (mm)	Conveying Length(m)/Power(kw)			Transporting Speed m/s)	Capacity (t/h)
1200	≤10/7.5	10-20/7.5-15	20-40/15-30	1.25-2.0	290-480

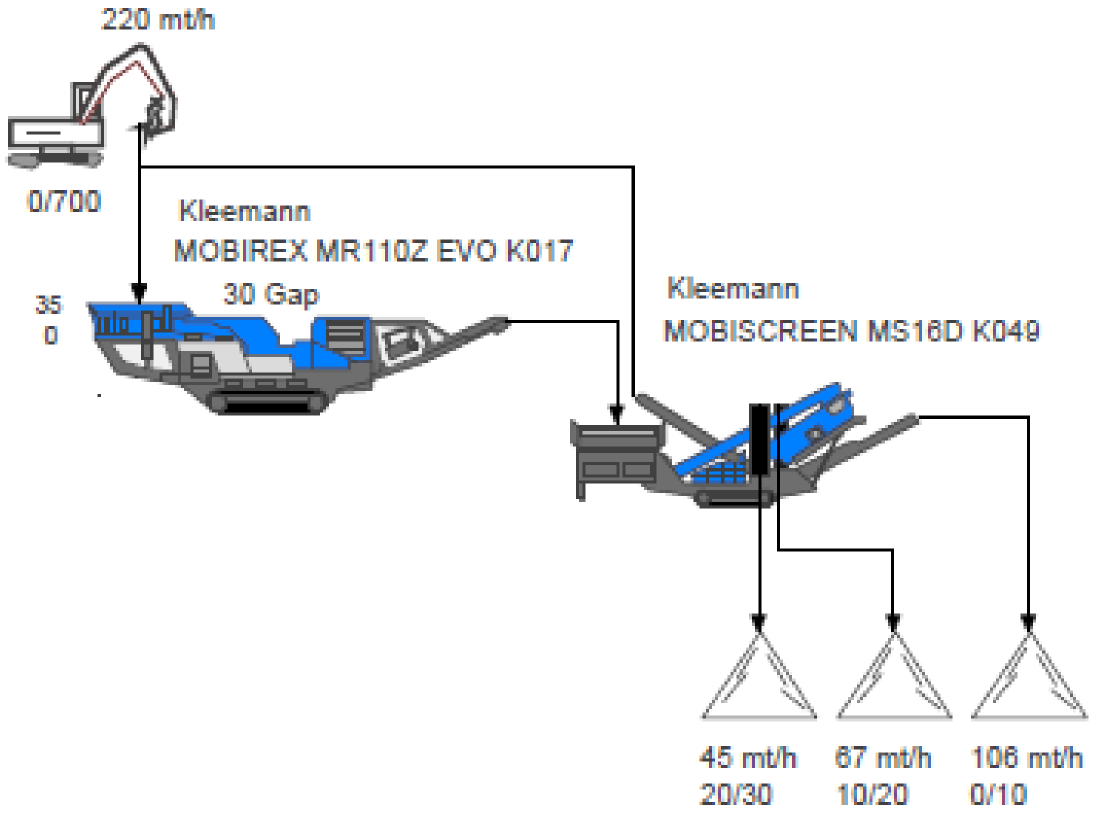
K. 3、Our Customers' worksites

Assumed Feed Material:
Concrete Recycling
High amount of fines
Longest dimension 700mm

Feed Curve:

Size (mm)	Pass. (%)
700	100
256	77
128	59
64	43
32	31
16	22
8	16
4	12
2	8
1	6

Flowsheet shows peak perfomance,
not taking into account
any efficiency calculations



Calculation results may differ due to variations in operating conditions and application of crushing and screening equipment. This information does not constitute an express or implied warranty, but shows results of calculations based on information provided by customers or equipment manufacturers. Use this information for estimating purposes only. ***All calculations performed by AggFlow. http://www.AggFlow.com***	Kleemann Omar Hassanein, Concrete Recycling 0-700mm, MR110Z EVO+MS16D Jens Behn Project #: 4657 Version #: 9131 Date: 5/November/2013

WIRTGEN GROUP Kleemann

CONTRACTOR LINE

XII. MOBIREX MR 110 Z EVO

TECHNICAL SPECIFICATIONS

TRACK-MOUNTED IMPACT CRUSHER

Top view

Side view MR 110 Z transport position

Feeding unit	
Feed capacity up to approx. (t/h) [1]	350
Feed size max. (mm)	900 x 600
Feed height (mm)	4,175
Hopper capacity (optional) (m^3)	4 (7)
Vibrating feeder	
Width x length (mm)	900 x 2,800
Primary screening	
Type	double-deck heavy-duty screen
Width x length (mm)	1,000 x 2,200
Fines conveyor (optional)	
Width x length (mm)	650 x 4,000 (6,000)
Discharge height approx. (mm)	2,700 (3,500)
Crusher	
Impact crusher type	SHB 110-080
Crusher inlet width x height (mm)	1,120 x 800
Crusher weight approx. (kg)	12,800
Rotor diameter (mm)	1,100
Crusher drive approx. (kW)	direct, 180
Impact toggles adjustment	infinitely variable fully hydraulic
Crushing capacity concrete rupture up to approx. (t/h)	250 [2]
Crushing capacity rubble up to approx. (t/h)	300 [3]
Crushing capacity asphalt up to approx. (t/h)	250 [4]
Crushing capacity limestone up to approx. (t/h)	300 [5]
Vibrating discharge chute	
Width x length (mm)	1,200 x 2,600

Main discharge conveyor	
Width x length (mm)	1,200 x 9,400
Discharge height approx. (mm)	3,500
Crawler chassis	
Type	B60
Drive	
Drive concept	diesel-direct drive
Engine power (kW)	371
Generator (kVA)	125
Screening unit (optional)	
Type	single-deck vibrating screen
Width x length (mm)	1,350 x 4,500
Discharge height oversize conveyor approx. (mm)	4,300
Discharge height fines conveyor approx. (mm)	3,400
Transport	
Transport height approx. (mm)	3,600 [6]
Transport length without (with) screening unit approx. (mm)	16,940 (20,420)
Transport width without (with) screening unit (mm)	3,000 (3,000)
Transport weight without (with) screening unit (kg)	45,500 (53,500) [7]

[1] depending on the kind and composition of feeding material, feeding size, kind of primary screening and size of end product
[2] final grain size 0-45 mm with approx. 10-15% oversize
[3] final grain size 0-45 mm with approx. 10-15% oversize
[4] final grain size 0-32 mm with approx. 10-15% oversize
[5] final grain size 0-45 mm with approx. 10-15% oversize
[6] without flat bed trailer
[7] without options

Basic equipment: Hydraulically folding hopper walls / Vibrating feeder with variable speed drive / Remote control / PLC control system with touch panel and menu navigation / Electrical cabinet double dust protected, lockable, air-suspended, with overpressure system

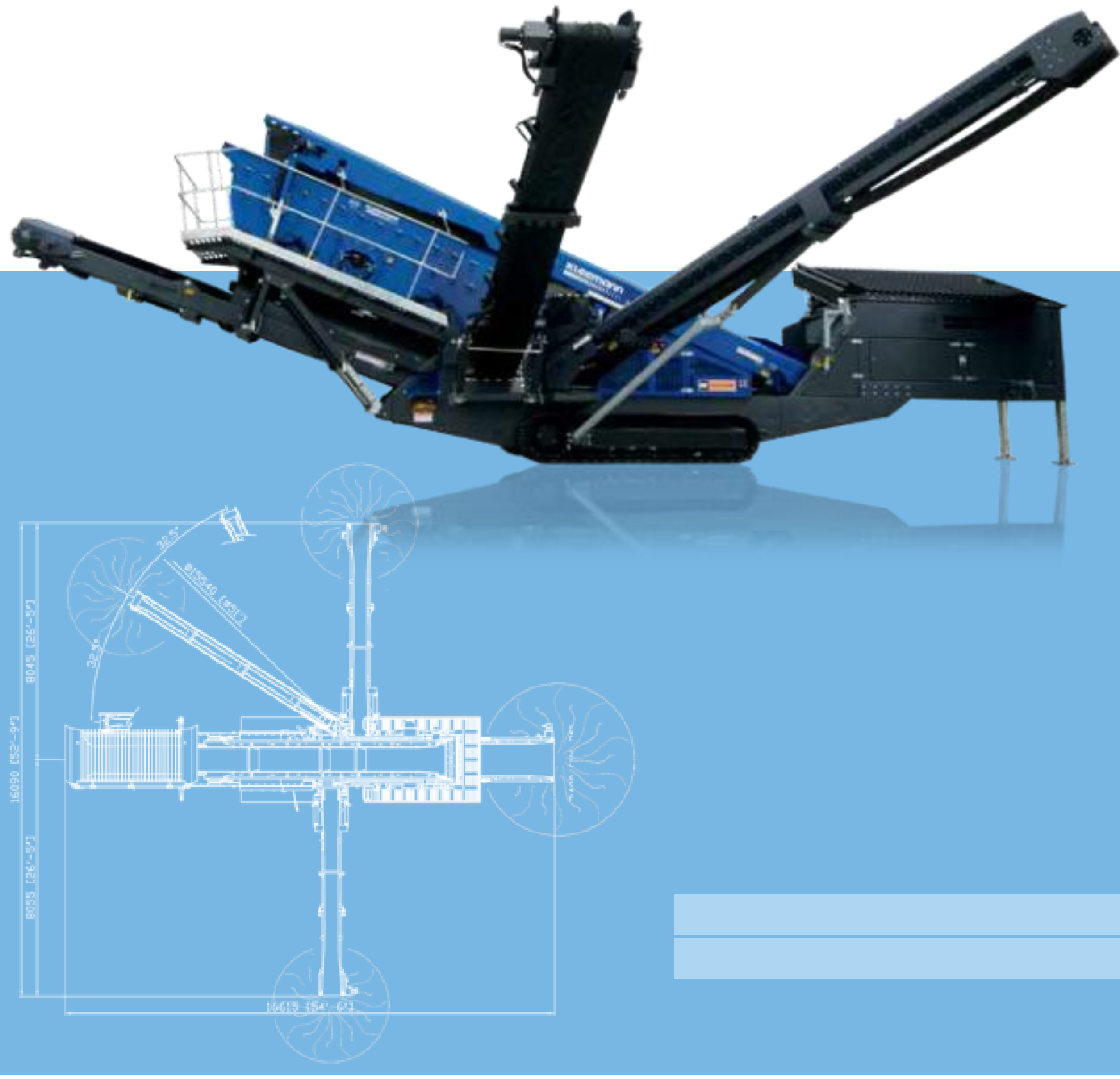
Options: Hopper extension / Lateral fines conveyor / Swivelling arm to change blow bars / Electric magnetic separator / Permanent magnetic separator / Preparation for magnetic separator / Low pressure spraying system / Preparation for belt weigher / Belt covers out of aluminium or canvas / Remote maintenance system via GSM-Modem

CONTRACTOR LINE

XIII. MOBISCREEN MS 16 D

TECHNICAL SPECIFICATIONS

TRACK-MOUNTED SCREENING PLANT



TECHNICAL SPECIFICATIONS MS 16 D

Feeding unit	
Feed capacity up to approx. (t/h)	350
Feed size max. (mm)	150 x 150
Feed height (mm)	3,635
Hopper capacity (m^3)	8
Belt conveyor feeder	
Width x length (mm)	1,200 x 3,500
Type (optional)	variable speed
Feeding belt conveyor screen	
Width x length (mm)	1,050 x 9,600
Screening unit	
Type	triple-deck vibration screen
Top deck width x length (mm)	1,520 x 4,270
Middle deck width x length (mm)	1,520 x 4,270
Bottom deck width x length (mm)	1,520 x 3,660
Bottom deck underflow discharge conveyor (fine fractions)	
Width x length (mm)	1,200 x 6,300
Discharge height approx. (mm)	3,900

Bottom deck overflow discharge conveyor (medium fractions 1)	
Width x length (mm)	650 x 9,100
Discharge height approx. (mm)	4,600
Middle deck overflow discharge conveyor (medium fractions 2)	
Width x length (mm)	650 x 9,100
Discharge height approx. (mm)	4,600
Belt conveyor oversize fractions	
Width x length (mm)	650 x 1,800
Top deck overflow discharge conveyor (oversize fractions)	
Width x length (mm)	500 x 8,500
Discharge height approx. (mm)	4,900
Crawler chassis	
Type	D3
Diesel-hydraulic drive	
Engine power (kW)	75
Transport	
Transport height approx. (mm)	3,450
Transport length approx. (mm)	15,610
Transport width approx. (mm)	3,100
Transport weight approx. (kg)	29,000

www.kleemann.info

XIV. Appendix IV:

1. Anonymous detailed quotations of the crushing equipment

Removed for confidentiality

L. Part 1 Requirement

1. Material: construction waste

2. Capacity: 200t/h

3. Final Product: 0-10,10-20,20-40mm

M. Part 2 Quotation of Main Machine

Name	Removed for confidentiality	Qty	Unit	FOB (USD)		Remark
				Unit Price	Total Price	
Vibrating Feeder		1	set	15,110	15,110	with motor
Jaw crusher		1	set	58,310	58,310	with motor
Impact crusher		1	set	52,450	52,450	with motor
Vibrating Screen		1	set	25,330	25,330	with motor
Belt conveyor		2	set	13,030	26,060	Total about 44 meters
		4	set	5220	20,880	Total about 60 meters
		1	set	9,620	9,620	Total about 22 meters
control panel		1	set	9,820	9,820	
FOB SHANGHAI		USD217,580				
Sea freight		USD 14,200				
USD 231,780, CFR Alexandria/Port Said						

3. Term of Payment:

Part 3 Item of the quotation

1. SHIPMENT: PORT OF SHIPMENT: TIANJIN/SHANGHAI/QINGDAO，CHINA
2. Time of delivery:

45 days after receipt of advance payment of 30% of total sum.

30% of total sum, as advance payment shall be paid by T/T, 70% of total sum shall be paid before shipment by T/T.

4. Installation: If the buyer requires the seller send the engineer to guide to install the machine, take trial run, the buyer should prepare the materials needed. The actual expenses incurred for accommodation, to and fro travel for the engineer, insurance, and labor charge should be borne by the buyer. The labor charge for the engineer is US$50 per day.

5. Warranty:

100% brand new when leaving the factory. The seller guarantee quality of the machines for a period of one year from the date of trial run finish, but not to exceed thirteen months from date on which machines away to the delivery port. If any parts (excluding easily damaging parts) are found defective in quality in the first year, the seller should replace free-of-cost. After one year, parts can be replaced on favorable payment basis.

Part 4 Specification of all the machine

Removed for confidentiality

Part 1 Quotation of Main Machine

Name	Removed for confidentiality	Qty	Unit	FOB (USD)		Remark
				Unit Price	Total Price	
Vibrating Feeder		1	set	33,420	33,420	with motor
Jaw Crusher		1	set	273,780	273,780	with motor
Impact Crusher		2	set	114,320	228,640	with motor
Impact Crusher		2	set	48,360	96,720	with motor
Feeder		2	set	3,200	6,400	with motor
Vibrating Screen		4	set	25,330	101,320	with motor
Belt conveyor		1	set	23,040	23,040	Total about 30 meters
		2	set	18,900	37,800	Total about 60 meters
		4	set	9,620	38,480	Total about 88 meters
		2	set	10,900	21,800	Total about 16 meters
		2	set	18,100	36,200	Total about 56 meters
		6	set	7,190	43,140	Total about 120 meters
		1	set	5,220	5,220	Total about 15 meters
control panel		1	set	34,450	34,450	

Steel structure				23,800	23,800	Include the input and output chute of each machine
FOB SHANGHAI		USD1,004,210				

Part 2 Item of the quotation

1. SHIPMENT: PORT OF SHIPMENT: TIANJIN/SHANGHAI/QINGDAO，CHINA

Removed for confidentiality

2. Time of delivery:

   45 days after receipt of advance payment of 30% of total sum.

3. Term of Payment:

   30% of total sum, as advance payment shall be paid by T/T, 70% of total sum shall be paid before shipment by T/T.

4. Installation: If the buyer requires the seller send the engineer to guide to install the machine, take trial run, the buyer should prepare the materials needed. The actual expenses incurred for accommodation, to and fro travel for the engineer, insurance, and labor charge should be borne by the buyer. The labor charge for the engineer is US$50 per day.

5. Warranty:

   100% brand new when leaving the factory. The seller guarantee quality of the machines for a period of one year from the date of trial run finish, but not to exceed thirteen months from date on which machines away to the delivery port. If any parts (excluding easily damaging parts) are found defective in quality in the first year, the seller should replace free-of-cost. After one year, parts can be replaced on favorable payment basis.

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Part 1、Price List of Main Unit-(700TPH)

Name	Removed for confidentiality	Power (kw)	Unit Price (USD)	Qty (Set)	Total Price (USD)
Hopper		/	5,374	1	**5,374**
Vibrating Feeder		22	16,393	2	**32,786**
Vibrating Feeder		2x1.5	7,213	2	**14,426**
Jaw Crusher		160	116,000	2	**232,000**
Cone Crusher		240	177,049	2	**354,098**
Cone Crusher		240	177,049	2	**354,098**
Magnetic Separator		/	4,000	2	**8,000**
Vibrating Screen		22	22,033	4	**88,132**
Belt Conveyor		22	13,115	6	**78,690**
		41	17,836	2	**35,672**
		20.5	10,570	2	**21,140**
Electric controller with panel(1,673 kw)					**24,684**
Total Favorite Price (FOB Shanghai)(USD)					**1,249,100**
Note: all the above price include motors, which voltage are required 380V,50HZ.,it can be adjusted according to our clients' request.					