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# The Three-Stage Entrepreneurial Model to Empower Recycling Product Designers

A Thesis Submitted to  
the Graduate Programme in Sustainable Development,

In partial fulfilment of the requirements for the degree of:

Master of Science in Sustainable Development,  
Green Technologies Concentration

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**Cairo, December 2017**

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## Abstract

Two of every five Egyptian youth aged 20-24 suffer unemployment and abject poverty. And while 40% of Egyptians have entrepreneurial intentions only 2.9% manage to establish their businesses past the 3.5-year mark of regulated operation. The main reasons for this failure have been defined to be: the poor entrepreneurial education at all stages, the poor legal & commercial infrastructure, as well as lack of supportive government programmes. The proposed solution is a three-stage process; it begins with formulating a 'matrix model', which is a detailed workplan for the transfer of an entrepreneurial idea from concept to a sustainable business, then developing a successful alpha product line that would allow business operation & sustenance, and then giving room for research and development of new similar products by incubating entrepreneurial ideas that can be turned into profitable product lines later on. The matrix model is the product-customised version of "Egyptian Ecosystem Theory of Change" by Saeed et al, 2015. The alpha product proposed is a flooring tile created from cleaned and shredded trash at the AUC Sustainable Development labs by heat-pressing plastics as a binder and redbrick as a filler, to create an environmentally friendly product line, then the tile is set to be tested against relevant ASTM standards for flooring tiles. Then, the proposed business model is to use part of the revenue to sponsor research and development, provided it is based on the 'private incubator' model. The idea is seen to positively impact the society by providing employment for the young entrepreneurs, the economy by boosting production and investment opportunities, as well as the environment by encouraging a recycling economy. This conforms with sustainable development goal number 8.6 which promotes substantially reducing the proportion of youth not in employment, education or training.

### Key Words:

- Sustainable Development
- SDG 8
- Unemployment
- Product Design
- Entrepreneurship
- Recycling
- Business Plan
- Incubation



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# Chapter 1: Introduction

## 1.1 The Problem: Unemployment in Egypt

Three million six hundred thousand Egyptian bread earners are currently unemployed (**Error! Reference source not found.**) and incapable of providing even a basic salary to their dependents. Twenty-four million five hundred thousand Egyptians, consequently have an income below 5788 E£/year (**Error! Reference source not found.**), that means they earn less than \$ 0.9 daily, which is well below the UN absolute poverty line of \$ 1.5.

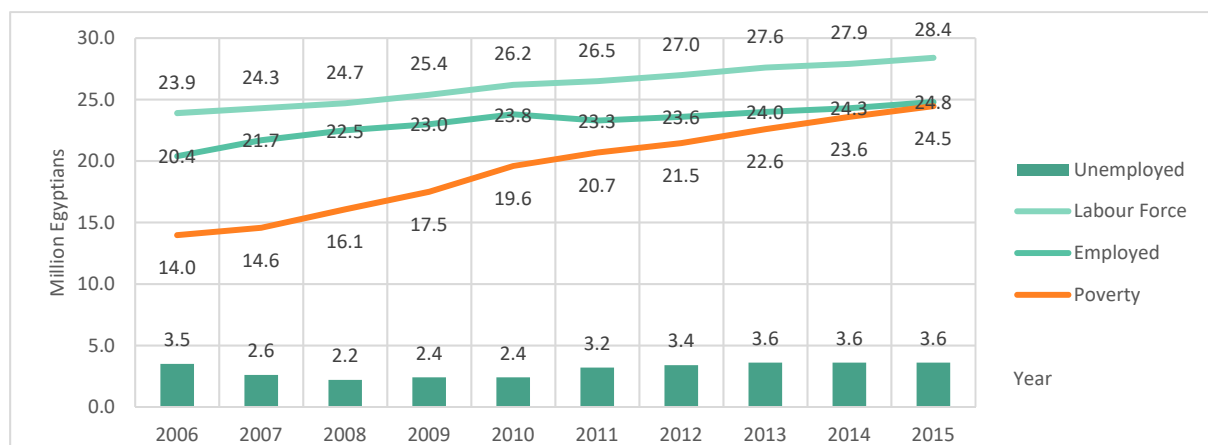


Figure 1.1: By Million Egyptians, the number of Egyptians in Employment, Unemployment and under Poverty. (CAPMAS, 2016) Among the millions of unemployed Egyptians, 80% are in the below 30 age group (Figure 1.3). This is an alarming indicator to the extent of the problem at hand, and consequently gives way to the prevalence of many socio-economic problems.

In comparison to the Egyptian national average, Figure 1.4 shows that youth unemployment is more than the national double, and this doesn't just mean that they are unemployed, it also indicates their poverty and inability to provide for their families, if indeed they managed to build families.

### Poverty <5788 E£/year (2015)

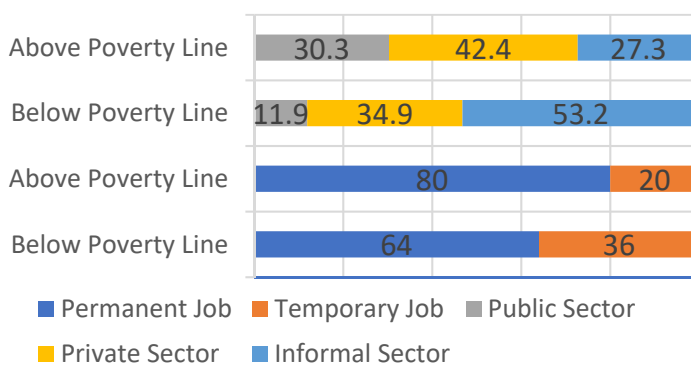


Figure 1.2: Poverty Levels Among Egyptians by Job Type

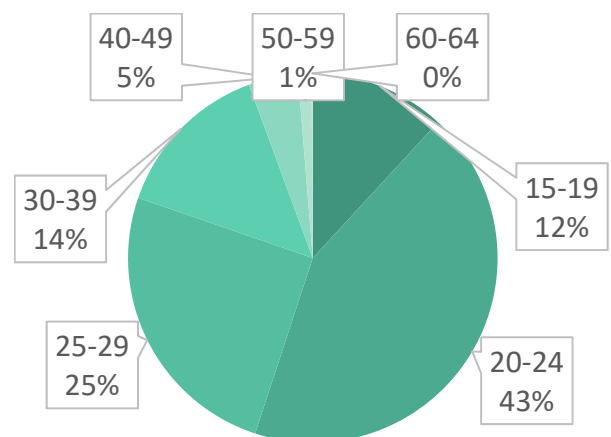


Figure 1.3: Unemployment Rates by Age Group. (CAPMAS, 2016)

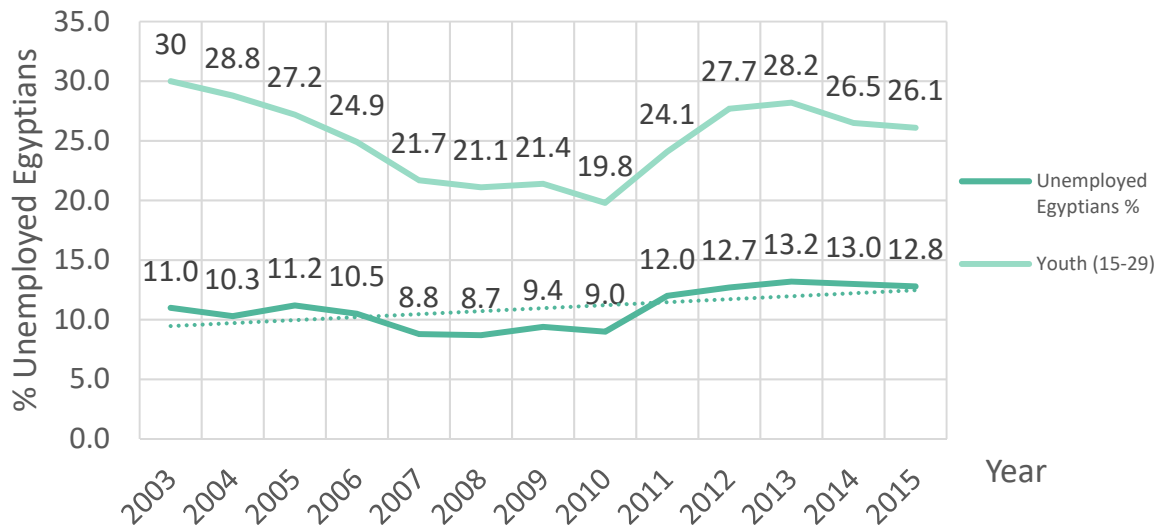


Figure 1.4: Rates of Unemployment of Youth VS National Average. (CAPMAS, 2016)

To understand the factions of the Egyptian society most needing of development based on their unemployment and poverty levels, regions where most unemployed Egyptians are can be indicated in Figure 1.5 where urban cities such as Cairo, Port Said and Suez have 21% of the unemployed Egyptians, and 49% are living in rural areas.

Illiterate and barely literate Egyptians are the ones most suffering from unemployment, constituting 55% of the unemployed population. As the education level rises, employment drops, as shown in Figure 1.6.

Generally speaking, it can be concluded that factions most in need of intervention are unskilled youth in their 20s', with lower than General Secondary degree.

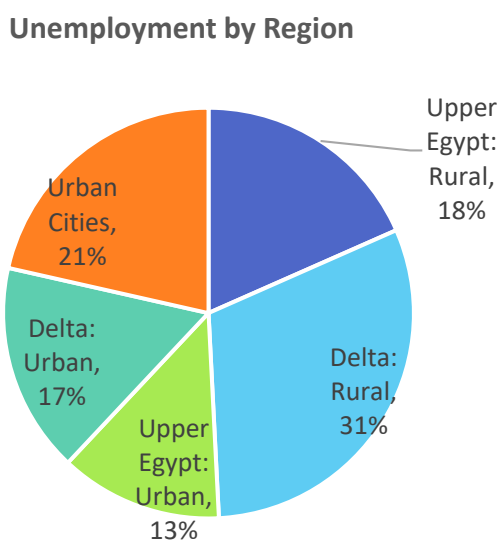


Figure 1.5: Rates of Unemployed by Region. (CAPMAS, 2016)

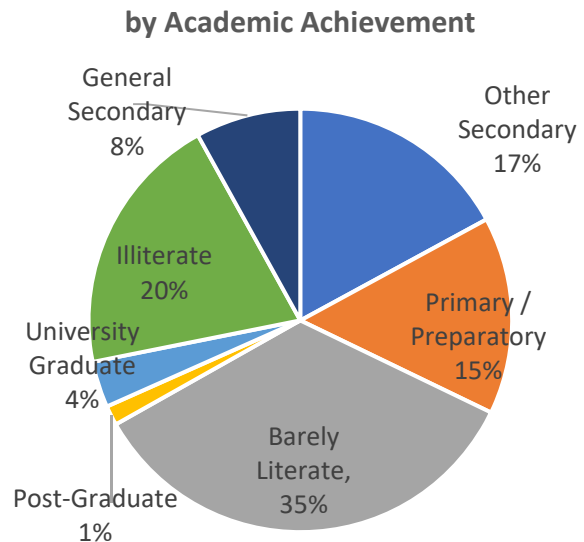


Figure 1.6: Rates of Unemployment by Academic Achievement (CAPMAS, 2016)

## 1.2 The Proposal: Empowering Entrepreneurship in Egypt

The failure of both public-sector opportunities and private corporates to accommodate the rising demand for decent jobs means that new doors need to be opened; private entrepreneurial ventures.

Entrepreneurship is the innovation through the creation of new products or new ways to fulfil market needs and create new sources of revenue for their organisations (Schumpeter & al., 2005). According to the GEM report, enthusiastic Egyptian entrepreneurs lack education, infrastructure & supportive programmes. Consequently, this study aims to bridge the gap & increase the success rates of entrepreneurial ventures by creating win-win situations for business owners & entrepreneurs.

To understand the core concept that makes recycling favourable, the typical process of production, consumption and disposal of materials is depicted in Figure 1.7; recycling reduces the reliance on inputting natural resources to the system, as well as outputting waste. Not only does recycling help the environment, but it also makes economic sense on the long-term when the resources have depleted to have the technology and expertise to recycle. Also, recycling can help create many job opportunities which is what this research is mainly addressing. (E. Worrell & M. A. Reuter, 2014)

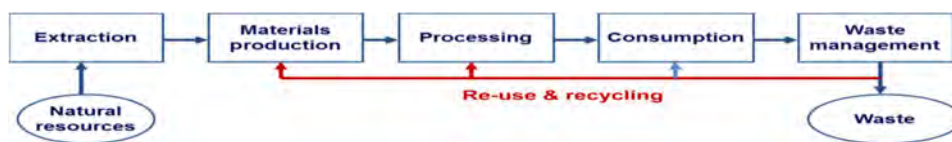


Figure 1.7: Recycling helps close the loop to create a circular economy. (E. Worrell & M. A. Reuter, 2014)

## 1.3 The Hypothesis: Three-Stage Entrepreneurial Model

The main aim of this study is to create a followable process for entrepreneurs with innovative ideas of sustainable products to guide the transition of an idea to become a good prototype and thence a successful business product line. The hypothesis takes into consideration previous models of incubators in the USA & Europe, as well as the recently developed Egyptian entrepreneurial models for the empowerment of entrepreneurs.

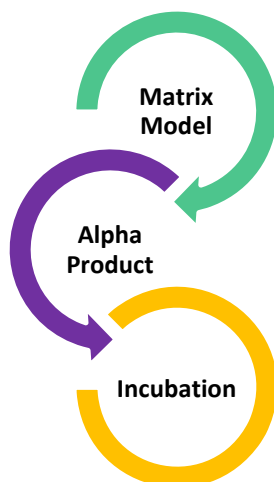


Figure 1.8: The Three-Stage Entrepreneurial Model

- Matrix Model:

Customising the Egyptian Entrepreneurial Ecosystem Theory of Change to generate a guiding plan for the conception, design, and manufacture of a product, while creating a business structure.

- Alpha Product:

The first product line that is created in accordance with the Matrix Model is expected to help sustain the business operation & growth.

- Incubation:

Following the success of the Alpha Product, the business will now sustain the R & D sector that incubates ideas by young entrepreneurs.





## 1.4 The Sustainable Development Context

The latest UN conventions have determined that the most fitting way to develop our world is through individually and collectively achieving the 17 goals of sustainable development, mentioned in *Figure 1.9*, and 169 targets along with their indicators.

The main aim of the international convention was to ‘free the human race from the tyranny of poverty and want, and to heal and secure our planet.’ (A/RES/70/1, 2016)

This is mainly achieved by the combined efforts of international institutions, governments, local authorities, academic institutions, philanthropic organisations, volunteer groups, among other stakeholders on the national public and private level. All stakeholders work under the common primary aim of eradicating poverty, seeing it as the only way to advance our world into a more developed and equitable future for future generations.



*Figure 1.9: The 17 Goals of Sustainable Development. (A/RES/70/1, 2016)*

### Goal 8. Good Jobs & Economic Growth

Relevant to the study and proposed model, Goal 8 is one that would substantially improve the livelihood of many Egyptian families. The goal is divided into several targets, of which, targets 8.3 and 8.6 are most relevant. (UN Economic & Social Council, 2016)

**8.3:** “Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services” (A/RES/70/1, 2016)

This is measured by the “Proportion of informal employment in non-agriculture employment, by sex” as an agreed indicator to the level of achievement of the target.

**8.6:** “By 2020, substantially reduce the proportion of youth not in employment, education or training” (A/RES/70/1, 2016)

This is measured by the “Proportion of youth (aged 15-24 years) not in education, employment or training” as an agreed indicator to the level of achievement of the target.



## 1.5 The Methodology

Based on the previously explained narrative, works on developing the programme require achieving a careful understanding of the de-facto state of the Egyptian problem (CAPMAS Reports), as well as the entrepreneurial ventures in Egypt (GEM Report), and problems that face entrepreneurs. Then, understanding what makes entrepreneurial ventures in developed nations succeed, namely incubators, and seeing how they are working in the Egyptian economic environment.

The literature reviewed above has resulted in formulating the three-stage entrepreneurial model in Figure 1.8. It is verified as follows:

**Matrix Model:** It is formulated by customising the Egyptian Entrepreneurial Ecosystem of Change model, then followed throughout the study. The success of the product development phase will show the accuracy of the tasks.

**Alpha Product:** It is developed by following the tasks of the product development attribute through the different stages. The aim is successful transformation of an entrepreneurial idea into a product line.

**Incubation:** This stage may only be reached upon the achievement of a sustainable business with at least one product line, so a business model for a private incubator will be setup.

## 1.6 Thesis Outline

Figure 1.10 is a summary of the work breakdown structure that showcases work categories and processes required to achieve the ends of research.

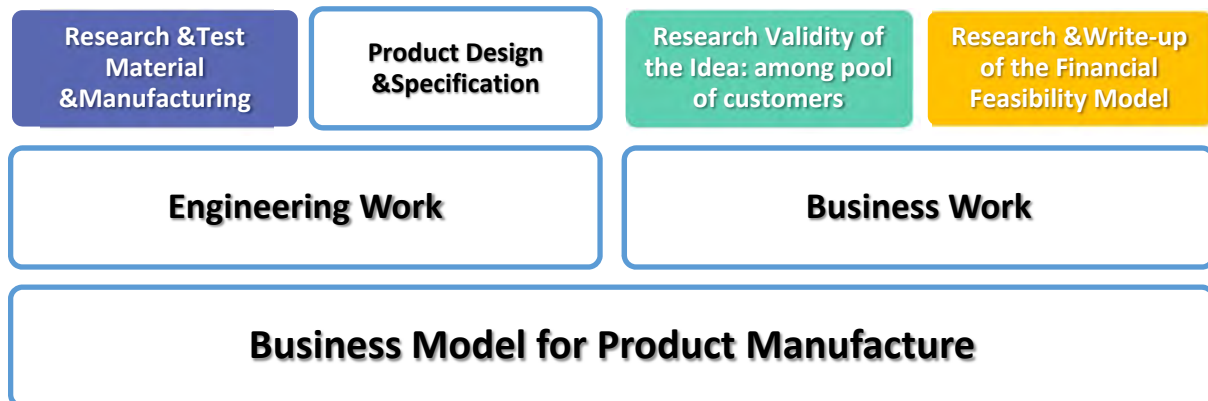


Figure 1.10: Thesis Work Breakdown Structure.



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## Chapter 2: Literature Review

### 2.1 Review of: Global Entrepreneurship Monitor Report

The Global Entrepreneurship Monitor 2015/2016 report (GEM, 2016) has surveyed 62 economies worldwide to identify different measures of entrepreneurial activity, covering indicators for influences (personal, societal, governmental), performance (quality, profitability, innovation), and sustainability of the businesses following the chart presented in Figure 2.1.

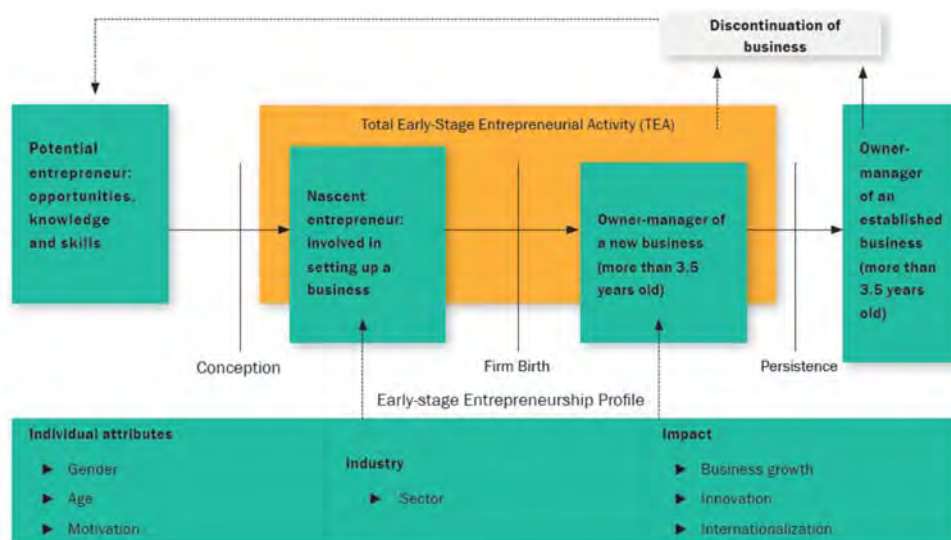


Figure 2.1: Model of Business Phases and Entrepreneurship Characteristics Represented in (GEM, 2016)

The performance of different countries on the different aspects of entrepreneurial activity is assessed based on the understanding of “Conception – Firm Birth – Persistence” phases of an entrepreneurial firm, as per Figure 2.1.

Surveys were performed on a minimum of 2000 randomly selected adults ageing 18-64, as well as expert opinions on the entrepreneurship eco-system.

The Egyptian economy was categorised as a factor-driven economy according to the World Economic Forum (WEF), the least developed economic form, where there is heavy reliance on agriculture & extraction, as well as on a majority of unskilled labour.

There are several factors related to the issue of entrepreneurial activity in Egypt; some can only be analysed through information gathered by surveying the population themselves as reported by the Global Entrepreneurship Monitor Report.

#### Self-Perceptions about Entrepreneurship

Entrepreneurship stems from a person’s creativity and persistence to pursue their ideas and turn them into achievable tasks and goals. When the person feels an entitlement to their own ideas, and has confidence in his/her capabilities to achieve them, a person is more likely to actually take the necessary initiative and overcome obstacles.

In Egypt, surveys show that apparent self-perceptions are relatively above average, where 40% perceive opportunities (rank 27/60), and the same percentile have entrepreneurial intentions (rank 11/60), with a fear of failure among only 30% (rank 16/60). The only drawback would be the perceived capabilities where only 40% find themselves capable of handling the pressure and risks associated with entrepreneurship. This can be attributed directly to the poor education system, specifically in the field of entrepreneurship, where experts rate Egypt the worst in this domain at school and post school stages (rank 62/62).

## Societal Values about Entrepreneurship

Just the same way that self-perceptions influence people's decisions, societal pressures and influences also have direct effects on a person's will.

In Egypt, surveys show that societal perceptions on entrepreneurship are quite positive, where 80% give a high status to entrepreneurs (rank 11/60) and 74% perceive entrepreneurship as a good career choice (rank 10/60). This, however, when coupled with the expert ranking of cultural and social norms (rank 48/62) sets a question of how society may be welcoming yet unsupportive of entrepreneurial initiatives, and that can also be attributed to the mentioned education failure.

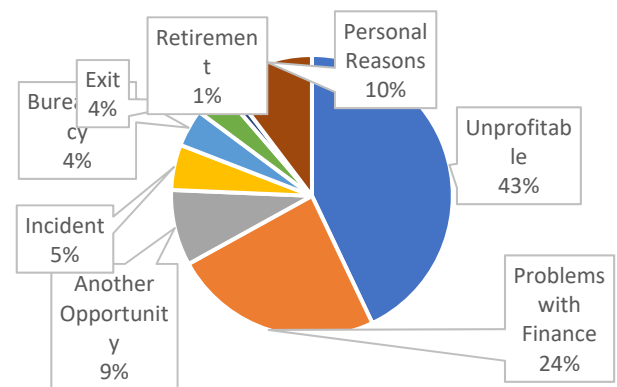


Figure 2.2: Reasons for Discontinuance of Ventures (GEM, 2016)

## Motivation for Early-Stage Entrepreneurial Activity

Identifying an entrepreneurs' motives to go through with their ventures may give an indication on the general economic state.

In Egypt, surveys show that 42.4% of entrepreneurial activity is motivated by necessity as opposed to 33.5% by a want to improve which shows a very low motivation index score of 0.8 (rank 59/60). The poor performance of the Egyptian economy, coupled with high rates of unemployment (26% of Egyptians under 30 years old (CAPMAS, 2016),) has forced many to think out of the frameworks of standard corporate or government jobs and create their own ventures.

## Stages of Entrepreneurial Activity



Figure 2.3: Stages of Entrepreneurial Activity (Egyptian rankings) (GEM, 2016)

Referring to Figure 2.3, Egyptian rankings along the stages of entrepreneurial activity show a generally lower than average rate of entrepreneurial activity, and a particularly low rate of established business ownership, meaning that most start-ups fail before continuing 3.5 years, hardly enough time to consider the payback sustainable.

## Discontinuance

Sometimes people are incapable or unwilling to pursue their entrepreneurial ventures. This may be due to many reasons, see Figure 2.2, but because of this, they and their societies miss out on the wide range of opportunities that such businesses may offer.

In Egypt, surveys have shown that 6.6% of the adult population have had to discontinue their entrepreneurship ventures (rank 14/60), mostly due to lack of profitability (43%, rank 13/60) indicating inability to study feasibility beforehand, secondly due to problems with finance (24%, rank 8/60). This high level of discontinuance signifies the inability of the entrepreneurs' ability to create sustainable businesses, due to their lack of skill, or an unsupportive environment, both of which valid reasons in the Egyptian context as per expert ratings.

## Industry Sector Participation

Figure 2.4 shows the classification of entrepreneurial ventures by industry in Egypt, where it can be clearly seen mostly dominated by wholesale and manufacturing industries.

It is worth mentioning that the rates of entrepreneurial ventures in the manufacturing industry in Egypt is the highest of all surveyed countries (1/60), which signifies the strong market gap that needs filling, as perceived by 22% of the entrepreneurs. Egypt's consumer service ranks 11<sup>th</sup> of 60, and wholesale ranking is 18<sup>th</sup> of 60.

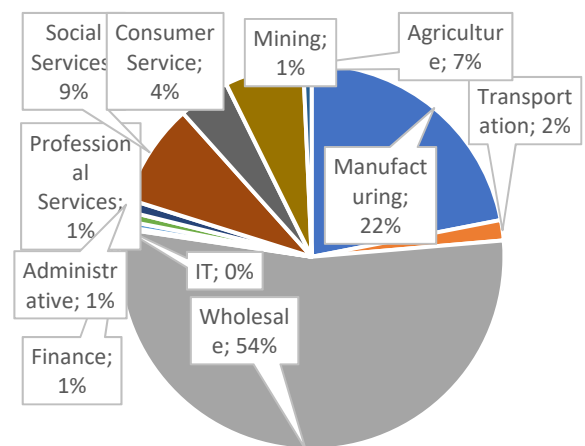


Figure 2.4: Entrepreneurial Classification by Industry (GEM, 2016)

## Job Creation Projections

Not only do entrepreneurs find jobs for themselves, but they also may have others at their employment which would generally aid in improving the employment rates.

The Egyptian economy is less developed, so it is easier to find people to hire due to the lack of alternatives and the fewer regulations. 22% of entrepreneurial ventures provide 1 to 5 jobs in the first five years (rank 58/60), and another 26% provide +6 jobs in the same period (rank 19/60), the remaining 51% provide no jobs at all (rank 14/60). This makes sense given the aforementioned high level of discontinuance rate, and the low sustainability of businesses, and is a logical outcome to the failed education and economic structure.



## The Entrepreneurship Ecosystem

Egypt, as per Figure 2.5, has shown some very clear shortcomings (ranking in lowest 10 economies) in its average performance on the following aspects:

- Entrepreneurship education at school stage. (62/62)
- Entrepreneurship education at post-school stage. (62/62)
- R&D transfer. (55/62)
- Commercial & legal infrastructure. (54/62)
- Government entrepreneurship programmes. (53/62)
- Government policies: support & relevance. (52/62)

On the other hand, Egypt only scored average to below average on:

- Internal market dynamics. (28/62)
- Physical infrastructure. (37/62)
- Internal market burdens or entry regulations. (43/62)
- Cultural & social norms. (48/62)
- Entrepreneurial finance. (49/62)
- Government policies: taxes & bureaucracy (50/62)

This has resulted in Egypt achieving very poor rankings according to the World Bank:

- Doing Business: 131/189
- Starting a Business: 73/189
- Competitiveness: 116/140

### Expert Ratings of the Entrepreneurial Eco-system (rank out of 62 recorded in brackets)

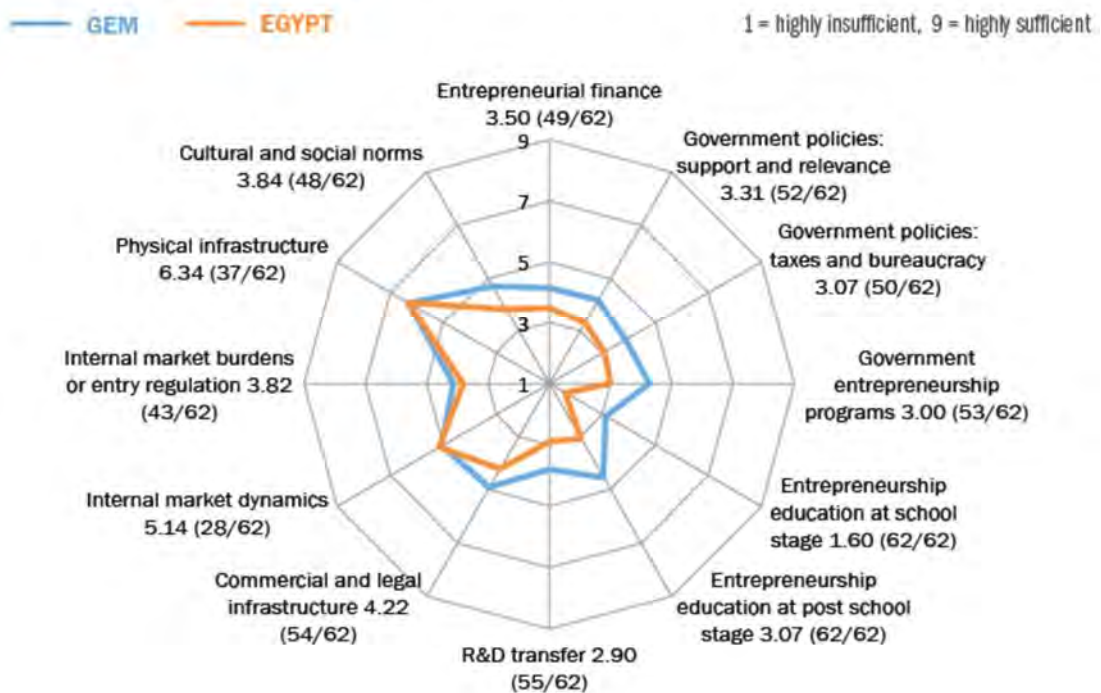


Figure 2.5: Expert Ratings of the Egyptian Entrepreneurial Eco-system. (GEM, 2016)



## GEM Recommendations in the Egyptian Context

According to the stated facts presented in expert opinions, it can be concluded that the most prominent issues are education, transfer of knowledge and government policies. Action in those areas is required in order to improve the Egyptian economy's performance in the field of entrepreneurship.

- \* Education systems at all levels must introduce the principles of entrepreneurship and business administration to students of all ages.
- \* Core skills of organisation, proactivity and resourcefulness must be instilled in youth to encourage them to pursue their ideas. This can be done through training centres and incubators that are made accessible to those interested.
- \* Innovation capabilities, namely research institutes and laboratories need to be made accessible for anyone with ideas that may be developed into a product.
- \* Acquiring business trainings in the business management fields of marketing, human resources and finances is key to learn how to make a business sustainable and allow it a chance to grow



## 2.2 Review of: Business Models and Start-up Frameworks

In order to understand the manner by which entrepreneurial ventures can be helped to survive past the 3.5 years mark, reference should be made to the very important role that business incubators play in the empowerment of entrepreneurial ventures and start-ups.

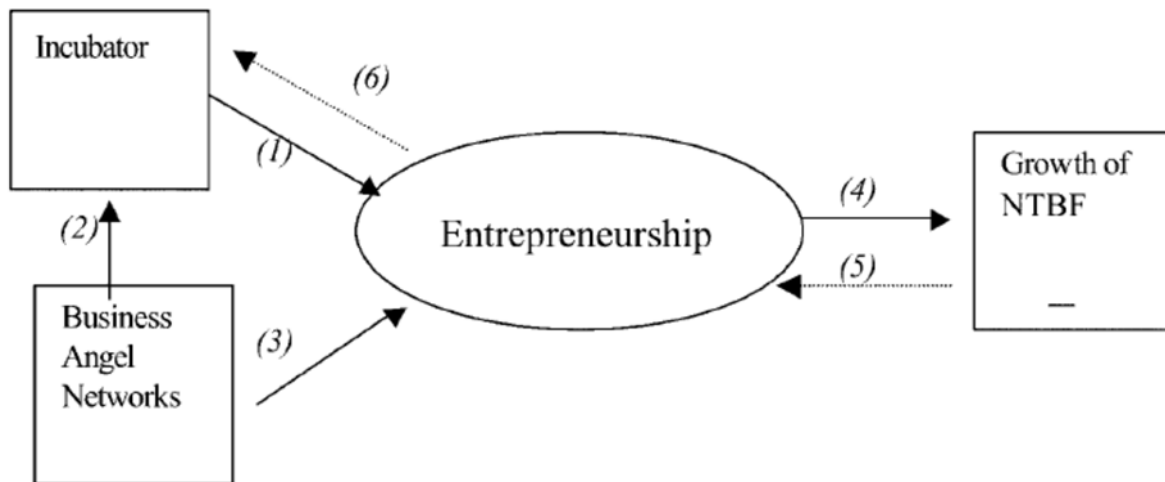


Figure 2.6: The dynamic process of entrepreneurship, incubation and business angel networks. (Aernoudt, 2004)

According to the model proposed by (Aernoudt, 2004), Figure 2.6, entrepreneurship is primarily empowered by incubators and its success leads to the growth of new Technology Based Firms (NTBF's). Directly, and indirectly (by supporting incubators), business angel networks empower entrepreneurship. Back again, the growth of NTBF's reflects on gained entrepreneurial experience and community support which boosts entrepreneurship wholly, which in turn allows incubators to work on the best-practice models and methodologies in entrepreneurial support. This healthy cycle can be seen in the American incubators, and assuming they are state sponsored, they can provide very good value for public money expenditure. This may be a profitable investment by the government, where it has been reported by (Sentana, González, Gascó, & Llopis, 2017) that in Spain, 2.8 Euros are collected as taxes for every 1 Euro invested in business incubation.

The process of Entrepreneurship goes through a number of phases according to (Peters, Rice, & Sundararajan, 2004):

1. Generating the Idea
2. Deciding to Pursue the Idea
3. Gathering Resources (Info., Money, Equipment, People)
4. Launching the Venture
5. Sustaining a Successful Business

Entrepreneurship is chiefly affected by factors on several levels: individual, group & society. (Peters, Rice, & Sundararajan, 2004)

- \* Individual: Skills, Motives, Characteristics
- \* Group: Ideas, Input, Effectiveness of Interactions with stakeholders
- \* Society: Government Policies, Economic Conditions, Technology



The process of Incubation, according to (Peters, Rice, & Sundararajan, 2004) includes five main tasks that the incubator managers must oversee in their operations:

- \* Setting Success Standards
- \* Leading Entrepreneurs by Example
- \* Developing a Selection Process
- \* Delivering Services
- \* Enabling Access of Incubated Businesses to Resources

## Business Incubators Definition

With regards to the issue of entrepreneur empowerment, the oldest found publications date back to the mid 1980's, where the definition of what an incubator is has evolved substantially till this day and age.

The etymology of the word goes back to the Greek *incubatio*, a ritual performed by a person on the brink of a new experience to seek divine guidance to embark upon on a journey, or overcome a disease-depending on the specific God sought. (Aernoudt, 2004)

Modern day legend has it, that in the 1950's Batavia, New York, the Mancuso family converted an abandoned building complex that belonged to Massey-Ferguson, a manufacturer of agricultural equipment, into a hub for empowering new business and entrepreneurial ventures. The hub is now known as Batavia Industrial Center, and it offered shared office services and business advice as well as assistance in raising capital. (Batavia Development Corporation, 2017) (Abdul Khalid, 2012)

In 1975, British Steel had been declining, and to help revitalise the impoverished areas, created British Steel Industry, a subsidiary aimed at creating jobs (Aernoudt, 2004). At a later date, 1984, the European Business Innovation Network was incepted, which in turn created 150 Business Innovation Centres meant to incubate small and innovative businesses across 20 countries. (Aernoudt, 2004)

In 1985 publication, Allen defines Small Business Incubators as their facilities “that aid the early-stage growth of companies by providing rental space, shared office services, and business consulting assistance.” (Allen & Rahman, 1985). At the time, the Small Business Administration, an office for private sector initiatives, could count around 60 incubators across the US, the number rose to 150 on counting by (Kuratko & LaFollette, 1987), and later in 1990, Allen count 400 in the USA. (D. Allen & R. McCluskey, 1990). The numbers rose to 900 in the year 2000. (Peters, Rice, & Sundararajan, 2004)

Moving on to 1996, Mian defined the university business incubator as a strategy “employed for the development of new research/technology based firms” by “providing a nurturing environment” for those firms (Mian, 1996). In 2004, Hackett defined incubators as enterprises “that facilitate the early-stage development of firms by providing office space, shared services and business assistance. Peters describes an incubator as an “innovative organisational form that is a vehicle for enterprise development.” (Peters, Rice, & Sundararajan, 2004). The word is used to “denote institutions with completely different objectives.” (Aernoudt, 2004)

The American National Business Incubation Association describes it as a process of “dynamic business enterprise development.” (Aernoudt, 2004)



In 2007, Aerts describes incubators as an environment “especially designed to hatch enterprises” (Aerts, et al., 2007). (Aaboen, 2009) however still viewed them as organisations used by policy makers as tools to empower entrepreneurial activities, and by universities as tools to “commercialise research results”. Or as mentioned by (Zedtwitz & Grimaldi, 2006), incubators help with “commercialisation of technology.”

The latest definition was provided by Sentana as services “placed at the disposal of original, generally newly-created projects”. (Sentana, González, Gascó, & Llopis, 2017)

## Business Incubator Classifications

As with the definition of what incubators are, the classification of business incubators is not set concrete, but rather has evolved over time into an array based on the national differences and understandings as per the reviewed literature. For easier reference, the author has summarised them into four major classifications: By Sponsorship, By Core Services/Purpose, By Intervention Extent, By Generation.

### By Sponsorship

(Kuratko & LaFollette, 1987) have classified incubators into 4 classes based on the sponsoring and governing entity of the incubator:

- \* Publicly Sponsored: That is when governments intervene using tax-payers’ money to help fund the creation of new business and consequently job opportunities.
- \* Non-Profit Sponsored: That is when private persons/organisations or NGO’s/NPO’s take charity-like initiatives aimed at area development.
- \* Privately Sponsored: That is when private persons/organisations take it upon themselves to generate profit by encouraging the incubation of business ideas and entrepreneurial ventures.
- \* University Related: Those are managed by university faculty/staff and take advantage of academic research and student initiatives to promote further understanding of theories, and to develop new products and technologies.

### By Intervention Extent

(Clarysse, et al., 2005) classifies incubators by the degree of intervention that they have with incubates.

- \* Low-Selective: This model is one that depends on maximising the number of entrepreneurial ventures being spun-out of the system, usually not growing beyond a critical number of employees.
- \* Supportive: This model is one where the main aim is to generate as many successful and profitable businesses with high growth potential.
- \* Incubators: This model tends to provide research opportunities while still helping them get spun out into successful profitable businesses.



### \* **By Generation**

(Aerts, et al., 2007) gave some insights on the development of the concept of incubation over time, and splits them into chronological generations:

- \* First Generation: 1980's and early 1990's, where the focus of incubator services was "job creation and real estate appreciation".
- \* Second Generation: In the 1990's the focus shifted towards "consultancy services, training sessions, network access and venture capital".
- \* Third Generation: Late 1990's and early 2000's saw a focus on technology firms and the high-tech sectors.

### **By Core Services/Purpose**

Several studies have classified the purposes of incubators and their core service provisions. It was seen to be more convenient to summarise the different classes into the illustrative **Error! Reference source not found.**

Further differentiation of incubators can be by: (Zedtwitz & Grimaldi, 2006)

- \* Segment: e.g. University Incubators target faculty & student entrepreneurs.
- \* Location: e.g. Localised area effect
- \* Industry: e.g. Recycling or Furniture Manufacture

The range of services offered by incubators differ from one type of incubator to the other, and they can be the defining factor in the typology. And even though many definitions have been attributed to incubators, the range of services is as thus: (Zedtwitz & Grimaldi, 2006)

- \* Infrastructure: Offices, Meeting Rooms, Laboratories, Office Equipment, etc.
- \* Office Services: Secretariat, Cleaning, IT Support, Security, etc.
- \* Process Advice: Management, Marketing, Legal, Planning, etc.
- \* Networking: Vendors, Suppliers, Investors, Subsidiaries, etc.
- \* Direct Capital



Table 2.1: Incubators Classified by Core Service/Purpose

Model/Class	Description	Reference Paper
<b>Business Innovation Centre</b> (Regional) (Non-Profit) (Economic Development)	They are centres that are funded by the government and aim at bridging the entrepreneurial gap, as well as creating jobs in underprivileged regions. In Europe, these are the most prevalent form of business incubator, and are funded by the EU.	(Grimaldi & Grandi, 2005) (Zedtwitz & Grimaldi, 2006) (Aernoudt, 2004) (Peters, Rice, & Sundararajan, 2004)
<b>Private Business Incubator</b> (For-Profit)	These are created, funded, and managed by private individuals and/or organisations, their aim is to generate profits by encouraging small businesses to spring out.	(Grimaldi & Grandi, 2005) (Zedtwitz & Grimaldi, 2006) (Peters, Rice, & Sundararajan, 2004)
<b>University Business Incubator</b> (Basic Research) (Technology Incubators)	These are created by or affiliated to universities, or major research institutes, aiming to provide grounds for research-based entrepreneurial ventures to help migrate academic research to the industry. In the USA, around 50% of technology incubators have university affiliations. They provide: access to labs, academic support, academic & professional network, and reputability by affiliation. They lack, however, the seed money, and managerial competencies.	(Grimaldi & Grandi, 2005) (Zedtwitz & Grimaldi, 2006) (Aernoudt, 2004) (Peters, Rice, & Sundararajan, 2004)
<b>Social Business Incubator</b>	Their main aim is to create employment opportunities in underprivileged regions, and for individuals with low employment capacities. This way, low skilled workers are provided an opportunity for a stable income and long-term employment.	(Aernoudt, 2004)
<b>Virtual Business Incubator</b>	They are usually for-profit, funded and run by private individuals/organisations, and most of their services are given online. Sometimes at their inception, incubators prefer to start off virtually, to lower their expenses, before expanding to provide more physical services. In Carinthia, Austria, a virtual incubator was set up to offer online advice in several fields. Construction expenses have been slashed to a minimum, and the money was used as seed money for the businesses.	(Zedtwitz & Grimaldi, 2006) (Aernoudt, 2004)

(Grimaldi & Grandi, 2005) suggest a two-model system shown in

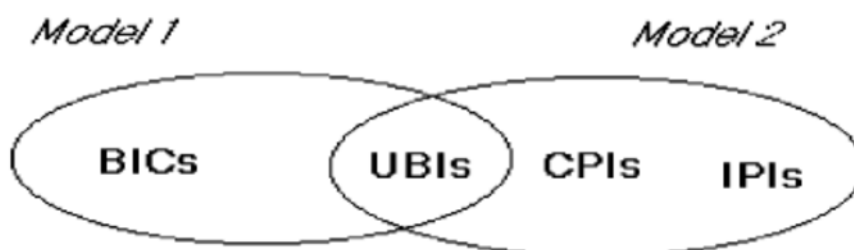


Figure 2.7: The Two Incubation Models (Grimaldi & Grandi, 2005)

#### Model 1:

- BIC: Business Innovation Centres

They are chiefly non-profit, funded by the state and aim chiefly at providing infrastructure and office services.

#### Model 2:

- CPI: Corporate Private Incubators
- IPI: Individual Private Incubators

This model encompasses incubators created and funded for the purpose of generating profit, their services are more oriented to providing capital, process advice, and networking.

#### Models (1+2)

- UBI: University Business Incubators

This is a compromise of the two models; by providing essential research infrastructure (model 1), as well as good networking and academic advice on the latest technologies (model 2) while still being not-for-profit (model 1).

Further characterising variables have been provided by (Grimaldi & Grandi, 2005):

- |                         |                      |
|-------------------------|----------------------|
| * Institutional Mission | * Intervention Phase |
| * Industry              | * Incubation Period  |
| * Location              | * Revenue Sources    |
| * Market                | * Service Offerings  |
| * Idea Originator       | * Management Teams   |



## Egyptian Ecosystem Theory of Change (Saeed, El-Aasser, & Wasfy, 2015)

Table 2.2: Egyptian Ecosystem Theory of Change (Saeed, El-Aasser, & Wasfy, 2015)

Stage	Focus	Attributes of High-Growth Start-ups							Delivering Organisations
		Product Development	Team Composition	Customers	Funding	Legal Status	Corporate Governance	Business Plan	
<b>1. Idea</b>	Write Product Description Find Co-Founders Find Coaches & Advisors Define Market Segment Win Prizes & Soft Money	Written Description	Founders	Identify	None	None	None	Concept	<b>Skills &amp; Networking:</b> Google Ebda2; Injaz; University Clubs
<b>2. Seed</b>	Create a Lab Prototype Initial Technical Team Create Business Model Seek Seed Capital Customer Market Research Register Company	Prototype	+ Technical Staff	Organised Feedback	Friends & Family; Accelerator Fund; Award Money	Registered Company	Long-Term Advisors; Potential Board Members	Business Model & Financial Forecasting	<b>Accelerators &amp; Labs:</b> Flat6Labs; Innoventures; Boost; V-Lab; Qafeer; FabLab; Ice-Cairo
<b>3. Take-off</b>	Launch Product Line Form Board of Directors Detailed Business Plan Build Sales Team Find Paying Customer Early Venture Capital	First Production Runs	+ Marketing Staff	Initial Users; Letters of Intent	Enough Capital for 6 month Operations	Ready to Accept Simple Investments	A Board Meeting Regularly	Business Plan; Financial Modelling; Pitch Deck	<b>Angel Investors:</b> Cairo Angels; Individual Angel Investors; Endeavor
<b>4. Growth</b>	New Product Lines Board Governance Build Operations Team Write an Expansion Plan Expand to New Markets Growth Venture Capital	Product Enhancement	+ Operations & Business Development	Paying Customers to Break-even	Capital from Institutional Investors	Ready to Accept Sophisticated Investments	Written Board Charter; Corporate Governance Guidelines	Expansion Plan	<b>Venture Capitalists:</b> Endeavor; Sawari Ventures; Idevelopers



## Chapter 3: The Three-Stage Model

### 3.1 Research Methodology

#### Sustainable Development Context

The core problem under research and discussion is unemployment in Egypt, specifically that of youth. The proposed sustainable solution is to encourage the creation of well established businesses that in turn guarantee job creation and subsequently a steady income for those employed.

To further improve the positive impact of those businesses, the suggested model would fit entrepreneurial ideas for solid waste recycling, particularly plastics, which covers a very wide range of different end products.

Achieving a sustainable development model is done by working on both business and engineering perspectives.

#### Entrepreneurship Works

1. Review of literature on business creation/incubation models.
2. Review of literature on business start-ups in Egypt.
3. Formulation of a framework for a business working in plastics recycling.
4. Following the proposed framework to create a product.
5. Writing up a business plan for a company the created product as its main selling item.

#### Engineering Works

6. Understanding how the material works and how it is fabricated in lab.
7. Proposing possible uses and end products along with their required specifications.
8. Assessing the products of highest value and least complex requirements.
9. Testing the mechanical properties of the material to get the key properties: Young's Modulus, Density, as well as the product-relevant specs, using ASTM or ISO whenever possible.
  - a. Three-Point Bending
  - b. Density
  - c. Tension
  - d. Pin-on-Disc Wear
  - e. Abrasion
  - f. Charpy Impact
  - g. Water Uptake
10. Assessing the success of the material in fulfilling the required specs, and evaluating its expected performance.
11. Setting a short-term product development plan.





Figure 3.1: Main Tasks for Decorative Panels



## 3.2 Stage 1: Start-up Matrix

### Business Model Framework

When trying to assess the effectiveness of processes meant for the support, development, and incubation of start-ups, it became very apparent that every business must go through a typical process starting from the mere idea or concept until the business is well established and generating a safe and steady profit margin, as well as an expanding product line and subsequently, workforce. However, variables such as: geographic location, political priorities, industry, and the general evolution of the concept of entrepreneurship over time seem to greatly influence the whole process.

It can also be deduced from reviewing US and European models the main services being offered:

1. Infrastructure: Offices, Meeting Rooms, Laboratories, Office Equipment, etc.
2. Office Services: Secretariat, Cleaning, IT Support, Security, etc.
3. Process Advice: Management, Marketing, Legal, Planning, etc.
4. Networking: Vendors, Suppliers, Investors, Subsidiaries, etc.
5. Direct Capital

As stated earlier in the GEM report, Egypt primarily lacks the entrepreneurial education at all stages, as well as some important entrepreneurial core skills that enable the success of business ventures; which is why many organisations in Egypt have managed to identify those shortcomings and attempted to work on them, namely: Injaz, Google Ebda2, & clubs in many universities among others.

Other major shortcomings in the Egyptian entrepreneurial scene are the research institutes and office spaces that allow entrepreneurs to develop their concepts and designs into tangible products and efficiently working teams, hence the efforts performed by workspaces and universities in and out of Cairo to provide a chance for the nurturing of ideas.

Therefore, and with regards to creating a workable model or template for a young Egyptian entrepreneur to follow, it has to be taken into consideration that these services are the ones lacking the most:

1. Core Skills Trainings & Process Advice
2. Infrastructure: Offices, Meeting Rooms, Laboratories, Office Equipment, etc.
3. Direct Funding

And while core skills trainings and infrastructure, as well as entrepreneurial competitions are starting to become common news in Egypt, a well-researched best-path model is yet to exist. Referring to the “Egyptian Entrepreneurship Ecosystem Theory of Change” suggested by (Saeed, El-Aasser, & Wasfy, 2015), adding some modifications to the concept to fit the priorities of the plastics recycling industry, the Start-Up Matrix on Figure 3.2 is proposed as an effort to entrepreneur Process Advice.



## Matrix Model

	1. Concept	2. Preliminary Design	3. Business Launch	4. Business Growth
A. Product Development	<ul style="list-style-type: none"> <li>i. Material Description</li> <li>ii. Potential Products &amp; Specs</li> </ul>	<ul style="list-style-type: none"> <li>i. Testing &amp; Choosing Prototypes</li> <li>ii. Specs Sheet</li> </ul>	<ul style="list-style-type: none"> <li>i. Enhancements</li> <li>ii. Final Specs</li> <li>iii. SOP's</li> </ul>	<ul style="list-style-type: none"> <li>i. New Lines</li> </ul>
B. Team Governance	<ul style="list-style-type: none"> <li>i. Originator</li> <li>ii. Lab Assistant</li> <li>iii. Product Designer</li> </ul>	<ul style="list-style-type: none"> <li>i. Business/Financial Consultant</li> </ul>	<ul style="list-style-type: none"> <li>i. Established Board &amp; Rules</li> </ul>	<ul style="list-style-type: none"> <li>i. Expanding Board</li> <li>ii. Board Charter</li> </ul>
C. Customers	<ul style="list-style-type: none"> <li>i. Target Market</li> </ul>	<ul style="list-style-type: none"> <li>i. Feedback Survey</li> </ul>	<ul style="list-style-type: none"> <li>i. Sales (Income)</li> </ul>	<ul style="list-style-type: none"> <li>i. New Markets</li> </ul>
D. Funding	--	<ul style="list-style-type: none"> <li>i. Friends &amp; Family</li> <li>ii. Accelerator Fund</li> </ul>	<ul style="list-style-type: none"> <li>i. 6 Months Capital Award</li> </ul>	<ul style="list-style-type: none"> <li>i. Profits</li> <li>ii. Investments</li> </ul>
E. Legal Status	--	--	<ul style="list-style-type: none"> <li>i. Registered Company</li> </ul>	--
F. Business Plan	--	<ul style="list-style-type: none"> <li>i. Business Canvas</li> <li>ii. Financial Forecast</li> <li>iii. Investors Presentation</li> </ul>	<ul style="list-style-type: none"> <li>i. Business Plan</li> </ul>	<ul style="list-style-type: none"> <li>i. Expansion Plan</li> </ul>

Figure 3.2: Start-up Guiding Matrix



## 3.3 Stage 2: Alpha Product

### 1. Conceptualisation

#### A. Product Development








##### 1.A.i Material Description

The proposed material is one that is fabricated by moulding a mixture of styrofoam and another material to produce functional panels. The product idea at this stage is still under investigation because the main aim is to find potential functions for the given material, which required understanding how the material itself works and the way it is typically fabricated.

##### Understanding Plastics

Plastic is the common commercial naming of polymer-based materials. Its properties depend on its composition of monomers and how they are linked, where a chain of monomers forms the polymer. Table 3.1 shows the different categories of polymers, which naturally influences the characteristics of the material and consequently its common uses.

Table 3.1: Categories of Plastics and Common Uses (Action Environmental Group, 2016)

Symbol	Type of Plastic	Common Uses	
	<b>PETE or PET</b> Polyethylene Terephthalate	* Bottles * Food Trays * Mouthwash Bottles	* Jelly Jars * Pickle Jars * Vegetable Oil Bottles
	<b>HDPE</b> High Density Polyethylene	* Milk Jugs * Juice Bottles * Motor Oil Bottles	* Butter Tubs * Detergent Bottles * Grocery Bags
	<b>PVC or V</b> Polyvinyl Chloride	* Clear Food Packaging * Pipes * Flooring	* Fencing * Window Frames * Shower Curtains
	<b>LDPE</b> Low Density Polyethylene	* Dry Cleaning Bags * Frozen Food Bags * Squeezable Bottles	* Lab Equipment * Frozen Food Bags * 6 Pack Rings
	<b>PP</b> Polypropylene	* Ketchup Bottles * Bottle Caps * Straws	* Dishware * Packing Tape * Medicine Bottles
	<b>PS</b> Polystyrene	* Disposable Plates * Disposable Cutlery * Egg Cartons	* Aspirin Bottles * Packaging Peanuts * Disposable Iceboxes
	<b>O</b> Other Plastics	* Water Jugs * Headlight Lenses * Safety Glasses	* Gas Containers * Bullet Proof Materials * Citrus Juice Bottles



Having been invented in the early 1900s, its synthesised types have been invented and commercialised so much that in 2014 the production has reached nearly 280 million tonnes annually. (Shen & Worrel, 2014)

While plastics are cheap, durable materials that do not corrode or significantly degrade over time making it a good choice for a wide variety of products, the problem is that those products are eventually discarded as waste, and pile up in waste dumpsites or along shorelines because they are non-biodegradable, and do not decompose over time. This means that for discarded plastics to not keep piling up, they either need to be incinerated, producing tonnes of harmful carcinogens in the process, or they can be re-used and recycled.

### Mechanical Recycling of Plastics

Mechanical Recycling of plastics is the main recycling method used in the European Union, where it simply involves the following steps: (Shen & Worrel, 2014)

1. The collected material is sorted
  - a. Induction Sorting: Conveyor belt with sensors underneath and controlled fast air jet
  - b. Eddy Current Separator: Electromagnetic field separates non-ferrous metals
  - c. Drum Separator: Rotating drum with perforated holes to separate different sizes
  - d. Sink-Float Separation: After placing in a liquid, some materials sink, and others float
  - e. X-Ray: Distinguish between materials based on density
  - f. Near Infrared Sensor: Plastics reflect light detectable by NIR sensors, then air jetted
2. The sorted material is shredded:
  - a. Rotating blades to shred;
  - b. then grid for grading;
  - c. then a collection bin.
3. Shredded material is washed and dried
  - a. Cold/Hot Water up to 60 C
  - b. Materials are dried till they have under 0.1% of weight in moisture content
4. Then, it is melted to be pelletised or to be formed into products directly.
  - a. Agglomeration: film cut and heated by friction then cooled to produce crumbs
  - b. Extrusion: blended and extruded from hopper to a rotating screw then melted and degassed to produce pellets
  - c. Injection Moulding: melting the pressing with high pressure into a split mould & cooled
  - d. Blow Moulding: screw forces polymer through die, then air expands tube to mould
  - e. Film Blowing: air blown into thin tube of polymer to expand into thin film
  - f. Fibre Extrusion: extruded polymer is sent to spinneret, drawn, dried and cut to staple



Figure 3.3: Advertisement on the recycling of Expanded Polystyrene (EPS). (Greenmax Admin, 2017)

Styrofoam (Polystyrene)

Styrofoam is a material found in abundance among the typical municipal solid waste. The following items (stock photos) all fall under the 'category 6' plastics:



Figure 3.4: The many uses and forms of styrofoam in the market. Left to right starting at the top: Disposable cutlery and cups; Protective cushions in electronic boxes; Disposable iceboxes; Pellet shaped; Block shaped; Section in block shape; Green styrofoam; Beige styrofoam; Rainbow-coloured swimming board.

**Styrofoam Recycling:**

The typical recycling process of styrofoam can be found in the advertisement in Figure 3.3. This should be very similar to the process intended to produce the alpha product.

The required pre-fabrication recycling process of styrofoam for the intended product is as follows:



Then, the moulding of the product into desired products under adequate pressure & heat using the hydraulic press machine described in 2.A.ii Equipment.



### Sustainable Development Lab Trials

The proposed idea was to try to formulate a functional product from the given materials at the lab. There were previous trials of fabricating various tiles made-up of the different kinds of plastics which are heat-pressed with various fillers. The main aim of the trials was to see the extent of things that can be fabricated using: provided materials, the 10 X 10 cm mould, and the hydraulic press machine.



Figure 3.5: Clean Shredded Styrofoam Powder

Following is a list of some of the fabricated tiles by category:

#### **Employing Transparent Acrylic & Styrofoam with a Sandwiched Item**

Acrylic was available as a 1 X 2 m sheet, which was cut into 10 X 10 cm panels which are then placed in the mould and heat-pressed with an arbitrary item placed in between two sheets.

Styrofoam was in powder form (Figure 3.5) and is placed in the mould and pressed to produce the tiles being enquired, however to sandwich any item, the sheets must be each formed first and then placed in the mould with the item. This is because the styrofoam melts completely during pressing and distorts the shape of the item.



Figure 3.6: Samples of two Styrofoam-based Panels Pressed with Plants in between.



Figure 3.7: Sample with Acrylic Sheets with Wooden Straws in between



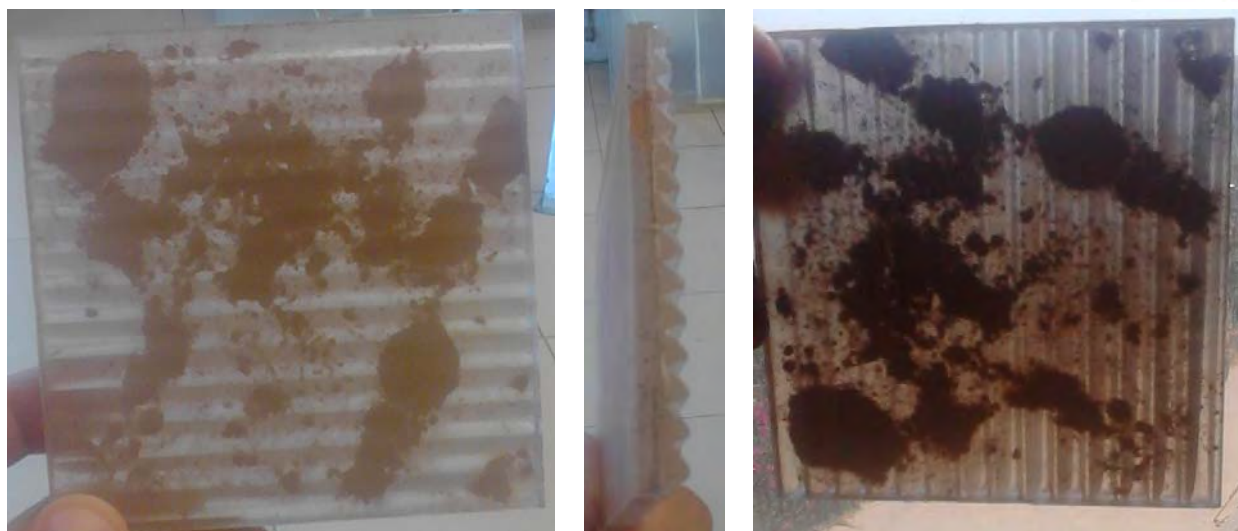


Figure 3.8: Sample of Two Acrylic Sheets Pressed with Redbrick Powder in between. One Side Smooth & the Other Zig-Zag Formed.

### Employing Glass Crystals

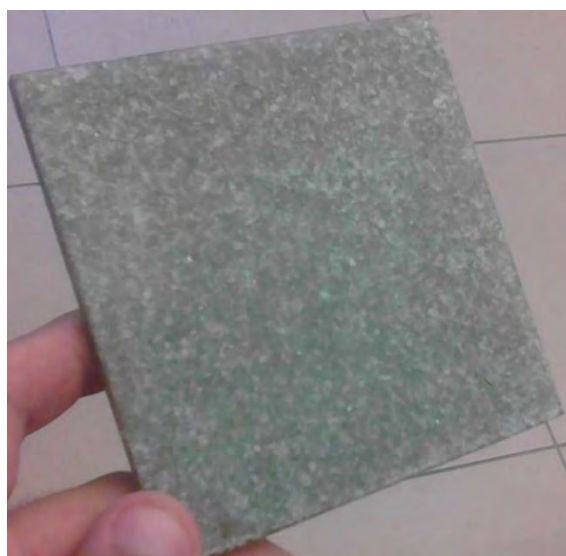


Figure 3.9: Sample of Clean Styrofoam with Green Glass Crystals

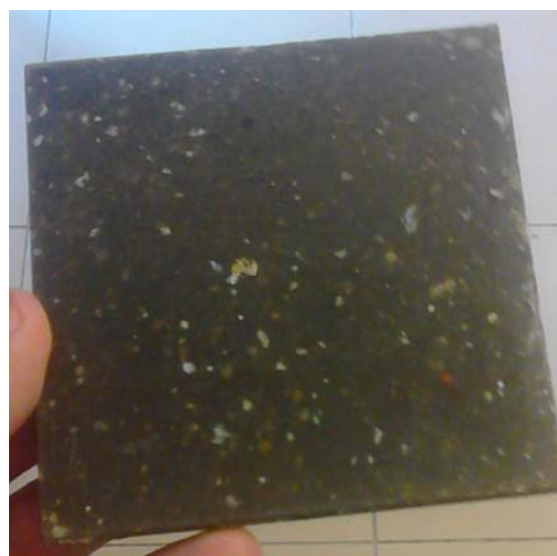


Figure 3.10: Sample of Dirty Styrofoam with Green Glass Crystals

### Employing Colours



Figure 3.11: Plastic Colours Used to Make the Coloured Samples.

Table 3.2: Colour Palette

<b>Orange</b> =	Yellow : Red	1.5:1
<b>Purple</b> =	Red : Blue	2.5:1
<b>Green</b> =	Yellow : Blue	1.5:1

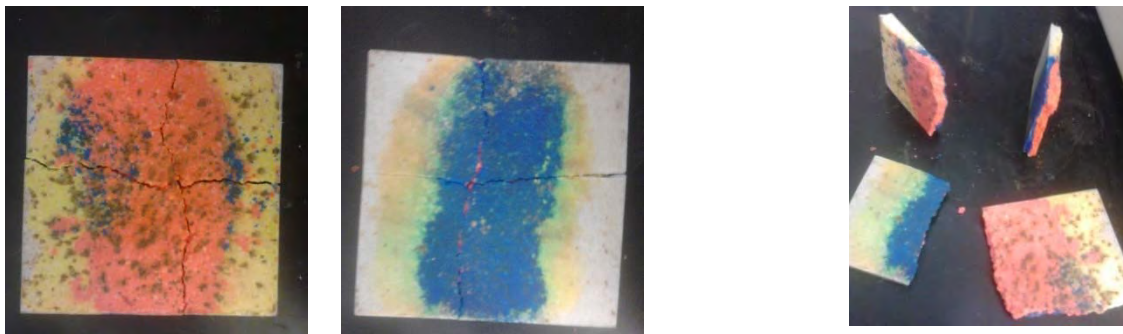


Figure 3.12: Coloured Sample of Clean Styrofoam. Distortion of Colouring Shown.

Clean Styrofoam				
Red (g)	Yellow (g)	Blue (g)	Colourless	Total
15	10	5	20	50

**Employing Rice Straw & Colours**

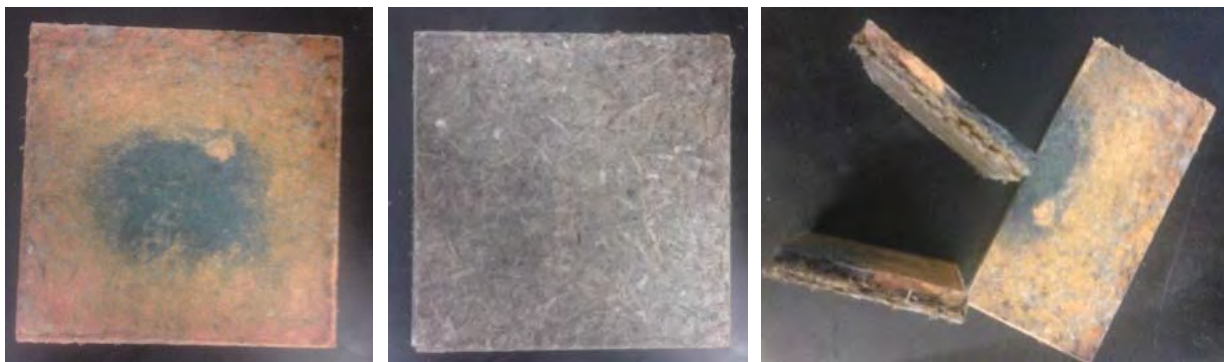


Figure 3.13: Coloured Sample of Dirty Styrofoam with Rice Straw Base.

Dirty Styrofoam				
Orange	Purple	Colourless	Rice Hay	Total
35	5	10	10	60

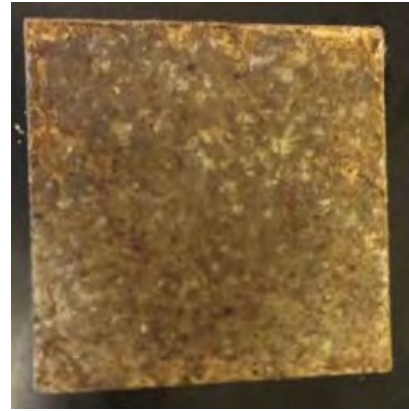


Figure 3.14: Coloured Sample of Clean Styrofoam with Rice Straw Base.

Acrylic 4 mm	Clean Styrofoam			Dirty Styrofoam	Rice Hay	Total
	Orange	Green	Purple			
	5	5	5	17.5	7.5	40



### Fabrication Process

The fabrication of a tile required 3 hours and 30 minutes according to the lab assistant, and being able to make more than 2 samples a day was proving to be a challenge. The pressing conditions were as follows:

- \* Maximum temperature of heating pads: 105 C
- \* Maximum temperature of mould: 100 C
- \* Constant pressure on mould: 50 kN
- \* Average time required: 3:30 hrs

As an improvement to the way things were, these new conditions were introduced, while maintaining 50 kN of constant pressure: (See Figure 3.15)

- \* Maximum temperature of heating pads:130 C
- \* Average time required 2:40

The final improvement done was to increase the maximum temperature as well as start cooling the assembly before it reaches the designated 100 C: (See Figure 3.16)

- \* Maximum temperature of heating pads:140 C
- \* Average time required 1:25

This meant the fabrication of twice as many panels just by altering the heating/cooling conditions, and gave an indication as to the most time-consuming activity: cooling.

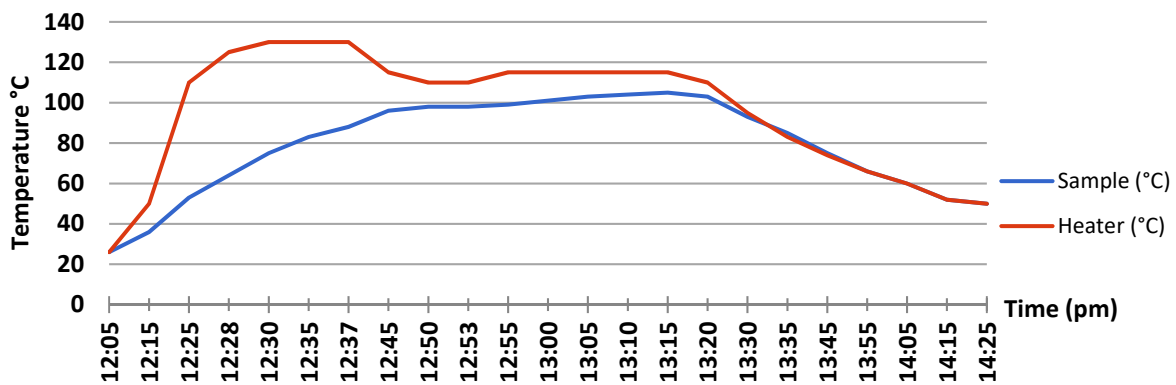


Figure 3.15: Early Attempts to Improve Fabrication Time (2 Hours and 40 Minutes)

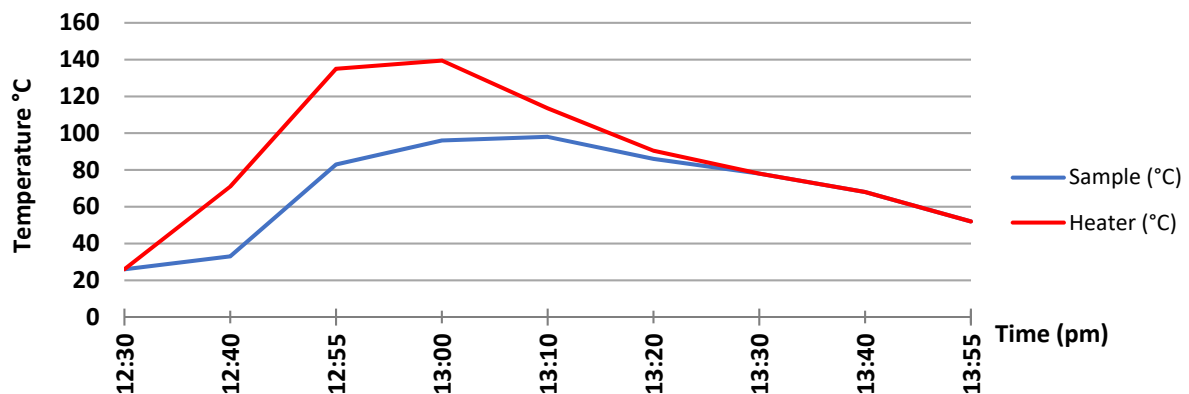


Figure 3.16: Typical Temperature VS Time Chart (1 Hour and 25 Minutes)



### 1.A.ii Potential Products & Specs

After extensive brainstorming with the product designer based on the shape and visible qualities of the samples produced a set of potential ideas was put forward, along with the matching set of specifications that will need to be met as per Table 3.3.

Table 3.3: Potential Products VS Critical Product Specs

		Strength	Fixability	Maximum Dimensions	Transparency	Pattern Control	Thermal Performance	Acoustic Performance
1	Folders		Critical / Impractical			Critical		
2	Acoustic Panels		Critical	Critical		Critical		Critical
3	Rulers					Critical		
4	Translucent Partitions	Critical	Critical	Critical	Critical	Critical		Critical
5	Floor Tiles	Critical	Critical	Critical				
6	Table Tops	Critical	Critical	Critical			Critical	
7	Coasters					Critical	Critical	
8	Shelves	Critical	Critical	Critical		Critical		

To each of the product suggestions placed, a list of critical specifications was placed, and then grouped into the simple tabulated form shown in Table 3.3. The least demanding products were:

1. Rulers                      1 Critical Spec
2. Coasters                 2 Critical Specs
3. Floor Tiles               3 Critical Specs

However, of those potential products, floor tiles had the highest potential value as a product and was therefore selected to be the alpha product for further elaborate design and testing in the Design Development Stage.



## B. Team Formation

The conceptualisation and creation of a product is a process that requires a lot of input from people with different backgrounds. The different people of valuable input should be considered essential to the conceptualisation of a product idea, and are mentioned in Table 3.4.

Table 3.4: Team Background and Input

Title	Minimum Background	Input
<b>Entrepreneur</b>	Basic understanding of methodical thinking. University Degree.	<ul style="list-style-type: none"> <li>* Idea Originating</li> <li>* Playmaker</li> <li>* Presenting Idea</li> </ul>
<b>Academia</b>	Materials or production engineering, or keen understanding of the topic.	<ul style="list-style-type: none"> <li>* Technical Support</li> <li>* Theoretical Experience</li> </ul>
<b>Lab Assistant</b>	Capable of handling relevant lab equipment and following instructions clearly.	<ul style="list-style-type: none"> <li>* Fabricating Samples</li> <li>* Some Ideas</li> </ul>
<b>Product Designer</b>	BSc. Applied Arts, Engineering or Architecture with some relevant professional experience.	<ul style="list-style-type: none"> <li>* Idea Consolidation</li> <li>* Market Advice</li> <li>* Product Development</li> </ul>

## C. Customers

For the selected alpha product, flooring, the target market is mainly residential flooring. Potential customers include but are not limited to:

- \* Young couples furnishing their homes
- \* Low-to-middle income people refurbishing their homes
- \* Lower scale office owners
- \* Lower scale shop owners
- \* All-range of incomes for their terraces





## 2. Design Development

### Product Development

#### 2.A.i Product Description

The flooring pattern consists of a single repetitive unit with a shape that allows it to be in co-dependent contact with all surrounding tiles. The interlocking mechanism would allow for very easy installation, and later repair or removal with minimum damage of tiles.

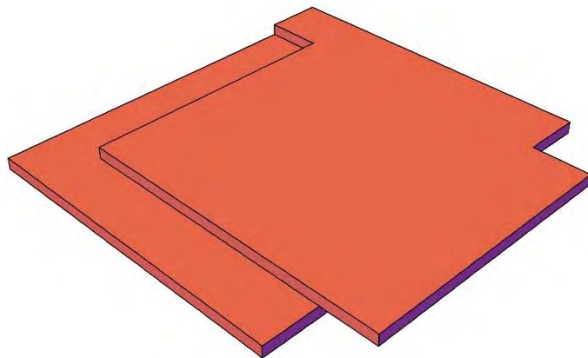


Figure 3.17: Tile Top View

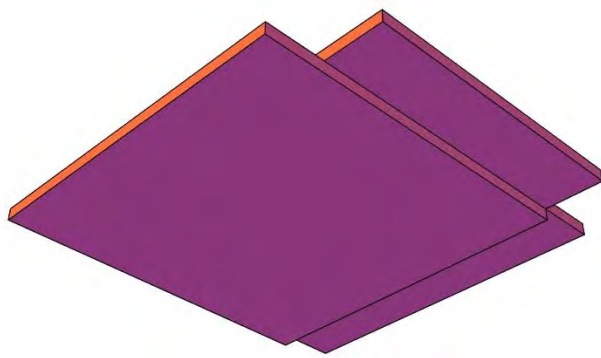


Figure 3.18: Tile Bottom View

The tile composition is of a mixture of redbrick and styrofoam that are thermally compressed to be moulded in the desired shape. ASTM D3878 defines such a material as polymer matrix composite:

**Composite material:** a substance consisting of two or more materials, insoluble in one another, which are combined to form a useful engineering material possessing certain properties not possessed by the constituents. A composite material is inherently inhomogeneous on a microscopic scale but can often be assumed to be homogeneous on a macroscopic scale for certain engineering applications. The constituents of a composite retain their identities: they do not dissolve or otherwise merge completely into each other, although they act in concert.”

**Matrix:** “the continuous constituent of a composite material, which surrounds or engulfs embedded filler or reinforcement.”

**Filler:** “in composite materials, a primarily inert solid constituent added to the matrix to modify the composite properties or to lower cost.”

The tile testing methods complied with ASTM D7264 [Flexural Properties of Polymer Matrix Composite Materials], ASTM D3039 [Tensile Properties of Polymer Matrix], ASTM G99 & ISO 18535:2016 [Wear Testing with a Pin-on-Disk Apparatus], EN ISO 179-1/2n [Charpy Impact Properties (Specimen Type 2 Normal Direction)]. Refer to Chapter 4: Results and Discussions.

Standardising the production process will require advice from a specialised consultant; the tile needs to be pressed and not released till it has cooled down, which may require a special cooling mechanism (while maintaining pressure). Currently, the tile mixture is placed in a square 10 cm mould, and heated to 100 °C while being pressed to 50 KN, then left to cool while maintaining pressure.

Material Innovation

Thermal compression moulding is not a new fabrication technique; however, it can be argued that the use of styrofoam, which is not a plastic that is usually recycled (see 1.A.i Material Description) in the context of an everyday product is innovative. Mechanical properties of the newly fabricated material will be required to assess its viability to be used for flooring tiles, as well as compared to existing flooring tiles in the market to assess the overall feasibility and marketability of such a product.

Pattern Innovation

The concept of the interlocking mechanism is that every single tile unit is supported from all sides by its adjacent tiles, and at the same time that is achieved using a single repetitive unit to lower the cost of compression moulding and make installation a lot easier.

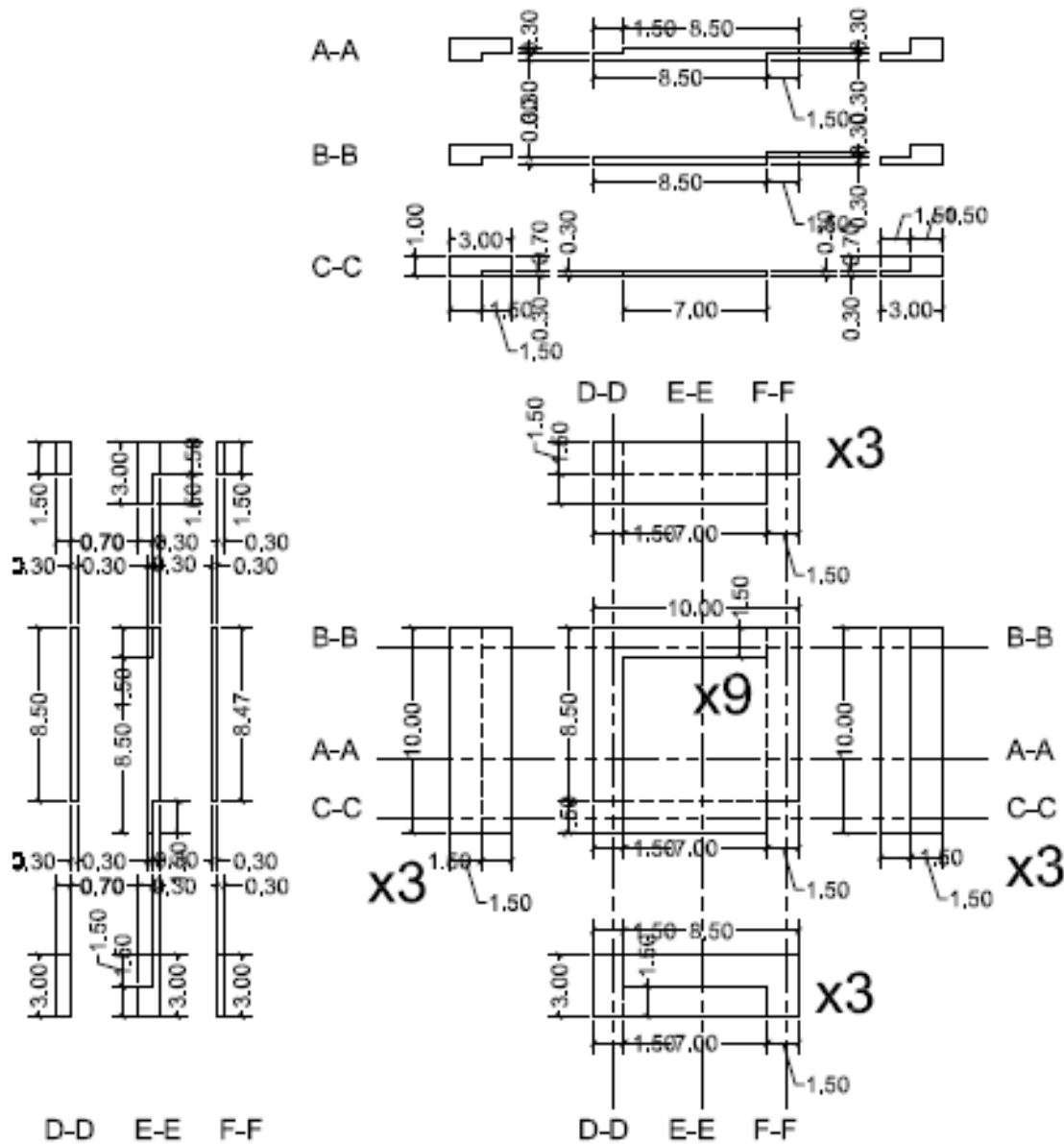


Figure 3.19: Pattern Innovation





Tests Required for flooring tiles:

It was found that the most prominent international bodies that overlook the standardising and testing of flooring tiles are ANSI (American National Standards Institute), ASTM (American Standard Testing Methods), and ISO. Even though the material under investigation is new, but it can be loosely related to the existing tests for guidance, especially those of 'polymer matrix composites'.

<b>Flooring Standard Specifications</b>		Required
ANSI A137.1	Standard Specifications for Ceramic Tile	Finished
ISO 13006:2012	Ceramic tiles Definitions classification characteristics and marking	Referred to
ASTM F2982	Standard Specifications for Polyester Composition Floor Tile	Irrelevant
ASTM F141	Standard Terminology Relating to Resilient Floor Coverings	
ASTM D4762	Standard Guide for Testing Polymer Matrix Composite Materials	
<b>ASTM Polymer Matrix Composite Materials</b>		
ASTM D3039	Tensile Properties of Polymer Matrix Composite Materials	Finished
ASTM D6484	Open-Hole Compressive Strength of Polymer Matrix Composite Laminates	Irrelevant
ASTM D3479	Tension-Tension Fatigue of Polymer Matrix Composite Materials	Irrelevant
ASTM D7264	Flexural Properties of Polymer Matrix Composite Materials	Finished
ASTM D5961	Bearing Response of Polymer Matrix Composite Laminates	Irrelevant
ASTM D5229	Moisture Absorption Properties & Equilibrium Conditioning of Polymer Matrix Composite Materials	Irrelevant
<b>ISO Ceramic Flooring</b>		
ISO 1006	Building construction Modular Coordination Basic module	Irrelevant
ISO 10545-1	Part 1: Sampling and basis for acceptance	Irrelevant
ISO 10545-2	Part 2: Determination of dimensions and surface quality	Irrelevant
ISO 10545-3	Part 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density	Irrelevant
ISO 10545-4	Part 4: Determination of modulus of rupture and breaking strength	Irrelevant
ISO 10545-5	Part 5: Determination of impact resistance by measurement of coefficient of restitution	Irrelevant
ISO 10545-6	Part 6: Determination of resistance to deep abrasion for unglazed tiles	Irrelevant
ISO 10545-7	Part 7: Determination of resistance to surface abrasion for glazed tiles	Irrelevant
ISO 10545-8	Part 8: Determination of linear thermal expansion	Irrelevant
ISO 10545-9	Part 9: Determination of resistance to thermal shock	Irrelevant
ISO 10545-10	Part 10: Determination of moisture expansion	Irrelevant
ISO 10545-11	Part 11: Determination of crazing resistance for glazed tiles	Irrelevant
ISO 10545-12	Part 12: Determination of frost resistance	Irrelevant
ISO 10545-13	Part 13: Determination of chemical resistance	Irrelevant
ISO 10545-14	Part 14: Determination of resistance to stains	Irrelevant
ISO 10545-15	Part 15: Determination of lead and cadmium given off by glazed tiles	Irrelevant
ISO 10545-16	Part 16: Determination of small colour differences	Irrelevant
<b>Standard Testing Methods Used</b>		
ASTM D7264	Flexural Properties of Polymer Matrix Composite Materials	Finished
ASTM D3039	Tensile Properties of Polymer Matrix Composite Materials	Finished
ASTM G99	Wear Testing with a Pin-on-Disk Apparatus	Finished
EN ISO 179-1/2n	Charpy Impact Properties (Specimen Type 2 Normal Direction)	Finished

## 2.A.ii Equipment

### Hydraulic Press Machine Assembly

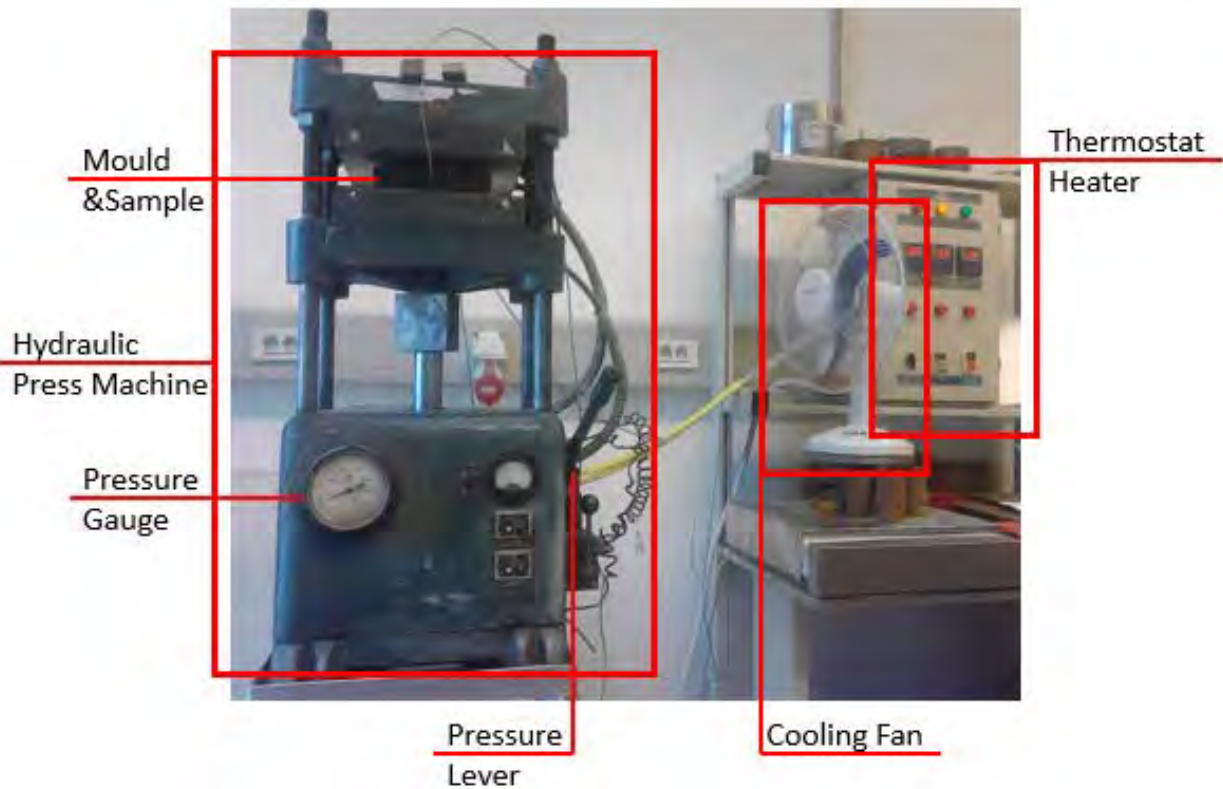


Figure 3.20: Hydraulic Press Machine Assembly with Description

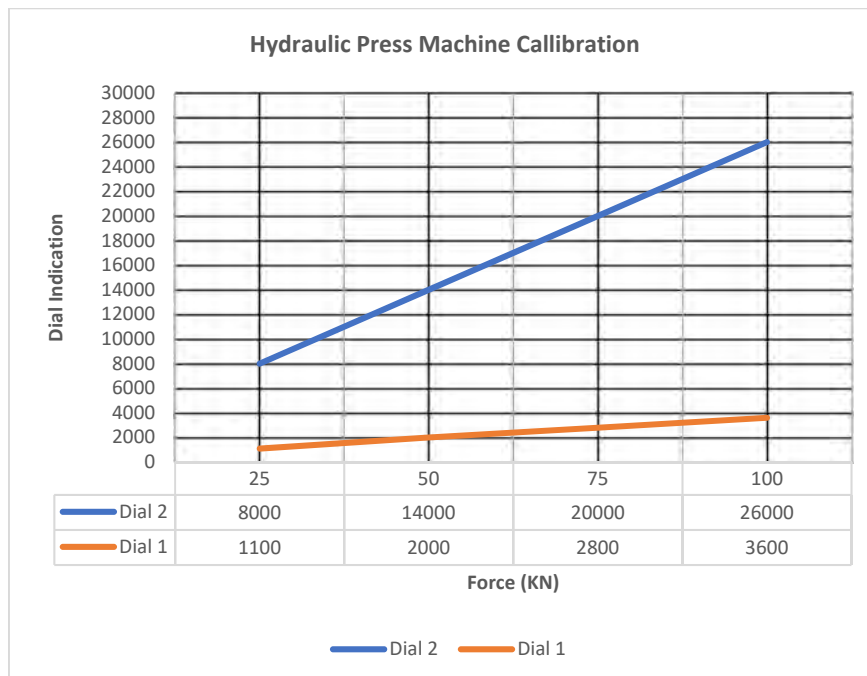
### Wabash Hydraulic Press

**Model:** 30-12-2T

**Serial No.:** 5441

**Bench press,** 30-ton

Made in Indiana, USA



### Machining: A Common Steel-Blade Saw



Figure 3.21: The Steel Blade Saw used in Machining the Samples

### Three-Point Bending



Figure 3.22: Lloyd LRX Plus Universal Testing Machine

### **Lloyd LRX Plus Universal Testing Machine**

(Lloyd Instruments, 2017)

The loading and support nose type is rolling, with a radius of 5 mm.

#### **Machine Specs as per supplier:**

**Force Range:** 2.5kN

**Crosshead Speed:** 0.1 to 1020 mm/min

**Speed Accuracy:** < 0.2%

**Load Resolution:** < 0.005% of load cell used

**Extension Resolution:** < 5 microns

**Data Sampling Rate:** 40Hz

**Extensometer Inputs:** +10V DC analogue input (optional) Digital - RS232

**Data Outputs:** Digital - RS232 Analogue - 10V DC

**Measuring System:** Exceeds the requirements of BS EN ISO7500:1999. Class 0.5, ASTM E4, DIN 51221.

**Analysis Software:** NEXYGEN™ Data Analysis

**Supply Voltage:** 115/230Vac ± 10% 50 - 60Hz

**Weight:** 54 kg

**Operating Temp:** 5° to 35°C



## Tension



### **Jinan Kason WDW-300 Tension-Compression**

30 tonne Computer Controlled Electronic Universal Tension Compression Test Equipment (Jinan Kason, 2017)

#### **Machine Specs as per supplier:**

**Model NO.:** WDW-300

**HS Code:** 9024101000

**Max Capacity:** 300 kN

**Load Way:** Electronic Load

**Display:** Computer Display

**Weight:** 100-500 kg

**Specification:** 350 kg

**Loading Method:** Static Load

**Control:** Computer Control

**Power Source:** AC 220 V

**Origin:** Jinan, Shandong, China

Figure 3.23: Jinan Kason WDW-300 Tension-Compression Machine

## Pin-on-Disc



A self-constructed pin-on-disc wear testing device at the Poly-lab, faculty of Engineering Ain Shams University. Samples were pressed at a normal load of 35N against a rotating grey cast iron counter disc (roughness Ra 0.89 $\mu$ m, 94HRB) at a sliding velocity of 8.4m/s for 60 minutes.



Figure 3.24: Locally Constructed Pin-on-Disc Machine

## Density



Figure 3.25: Adam Equipment PW254 sensitive scale

### **Adam Equipment PW254 Sensitive Scale**

Equipped with density measuring kit with kerosene (density  $7.91 \text{ g/cm}^3$ ) as the floating medium. (Balances.com, 2017)

**Applications:** Weighing, Net / total, Check weighing, Percentage weighing, Weight accumulation, Averaging, Parts counting, Animal / dynamic weighing, Density determination, below balance weighing.

### **Machine Specs as per supplier:**

**Maximum Capacity:** 250 g

**Readability:** 0.0001 g

**Units of Measure:** gram, carat, milligram, grain, newton, dram, ounce, troy ounce, pennyweight, momme, tael, tola, tical and 1 custom unit

**Interface:** Bi-directional RS-232 (Standard)

Display Backlit LCD with dual digits (24 mm high) and capacity tracker

**Operating Temperature:** + 10°C to 40°C

**Calibration:** With internal or external mass.

**Draft Shield Dimensions:** (Supplied standard)

20.1 cm x 15.7 cm x 21.6 cm

**Pan Size:** Ø 8.9 cm

**Overall Dimensions:** (w x d x h)

25.6 cm x 52.3 cm x 27.4 cm

**Net Weight:** 12 kg

## Charpy Impact



BEIJING JINSHENGXIN

XJJU-5.5/50J Izod & Charpy Impact Tester

(Jinhaihu JHH, 2017)

### Machine Specs as per supplier:

**Model:** XJJU-5.5

**Impact Energy:**

0.5J, 1J, 2J, 4J, 5J (Charpy);

1J, 2.75J, 5.5J (Izod)

**Impact Speed:**

2.9m/s(Charpy);

3.5m/s(Izod)

**Display:**

Digital display, result calculated automatically

**Standards:**

ISO179, ISO180, GB/T1043,

JB/Y8761, GB/T1843, ASTM D256



Figure 3.26: XJJU-5.5/50J Izod & Charpy Impact Tester





Abrasion



**Elgin Tool Works**

**Abrasion**

**Model No.: 1-12**

**Serial No.: 12177**

**Speed: 60 rpm**

**Made in Chicago, USA**

Figure 3.27: Elgin Tool Works Abrasion Machine

Water Absorption



Figure 3.28: Humidity Chamber, for Water Absorption Test



## B. Team Formation

The design development stage requires maturing the alpha product into a commercially marketable product. This implies the need for different input from team members as per Table 3.5.

Table 3.5: Team Background and Input

Title	Minimum Background	Input
<b>Entrepreneur</b>	Basic understanding of methodical thinking. University Degree.	* Playmaker * Presenting Idea
<b>Academia</b>	Materials or production engineering, or keen understanding of the topic.	* Technical Support * Theoretical Experience
<b>Lab Assistant</b>	Capable of handling relevant lab equipment and following instructions clearly.	* Fabricating Samples * Performing Tests
<b>Product Designer</b>	BSc. Applied Arts, Engineering or Architecture with some relevant professional experience.	* Market Advice * Product Development
<b>Business Developer</b>	Business background, capable of formulating basic financial & marketing planning.	* Marketing Strategy * Financial Projections

## C. Customers

### 2.C.i Feedback Survey

To understand how the customers would react to the product intended to become a production line, and to get an idea whether it will be acceptable as a substitute for flooring of the same category, an online survey was performed with a response rate of 50 respondents of random backgrounds:

#### Personal Identification

1. Age?
  - a. Under 25
  - b. 25 to 30
  - c. 30 to 40
  - d. Above 40
2. Gender?
  - a. Female
  - b. Male
3. Monthly Income Range?
  - a. Under 5000 LE
  - b. 5000 to 10,000 LE
  - c. 10,000 to 25,000 LE
  - d. Above 25,000 LE

#### Flooring Preference

4. Please Match your Choice of Flooring for every Room:
  - a. Bathroom
    - i. Ceramic
    - ii. Porcelain
    - iii. Marble
    - iv. Other
  - b. Kitchen
    - i. Ceramic
    - ii. Porcelain
    - iii. Marble
    - iv. Other
  - c. Terrace
    - i. Ceramic
    - ii. Porcelain
    - iii. Marble
    - iv. Other

#### Tile Rating & Use

5. See this depicted tile and tick the rooms you would use the tile at your home/office/shop:

Bathroom  Kitchen  Terrace  Office  Shop  Other



## F. Business Plan

### 2.F.i Business Model/Canvas

A business model is one that describes the rationale of how organisations create, deliver & capture value. The business model canvas (Osterwalder & Pigneur, 2010) is a good example of how to illustrate and simplify the research and assessment processes of a proposed business, where information is gathered to fulfil the following logic:

- \* Customer Segments
- \* Value Propositions
- \* Channels
- \* Customer Relationships
- \* Revenue Streams
- \* Key Resources
- \* Key Activities
- \* Key Partnerships
- \* Cost Structure

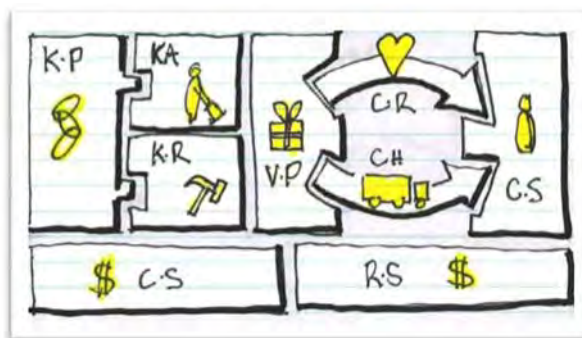


Figure 3.29: Business Model Canvas. (Osterwalder & Pigneur, 2010)



### Business Model Canvas

<b>Key Partners</b> <ul style="list-style-type: none"> <li>* Suppliers</li> <li>* Distributors</li> <li>* Entrepreneurs</li> <li>* Government</li> </ul>	<b>Key Activities</b> <ul style="list-style-type: none"> <li>* Incoming Raw Materials</li> <li>* Processing Styrofoam &amp; Redbrick</li> <li>* Storing Redbrick &amp; Styrofoam</li> <li>* Pressing, Heating &amp; Cooling</li> <li>* Packaging &amp; Storing</li> <li>* Outgoing Tiles</li> </ul>	<b>Value Proposition</b> <ul style="list-style-type: none"> <li>* Faux-Granite Tile Sales</li> <li>* Tile Installation</li> <li>* Tile Maintenance</li> </ul>	<b>Customer Relationships</b> <ul style="list-style-type: none"> <li>* Business Developer Makes Deals</li> <li>* Research &amp; Development Engineer Works on Feedback</li> </ul>	<b>Customer Segments</b> <ul style="list-style-type: none"> <li>* Young couples furnishing their homes</li> <li>* Low-to-middle income people refurbishing their homes</li> <li>* Lower scale office owners</li> <li>* Lower scale shop owners</li> <li>* All-range of incomes for their terraces</li> </ul>
<b>Cost Structure</b> <ul style="list-style-type: none"> <li>* Equipment and/or Premises</li> <li>* Raw Materials</li> <li>* Wages</li> <li>* Operation Expenses</li> </ul>	<b>Key Resources</b> <ul style="list-style-type: none"> <li>* Raw Material: Redbrick, Styrofoam</li> <li>* Equipment</li> <li>* Staff</li> </ul>		<b>Channels</b> <ul style="list-style-type: none"> <li>* Tile Retailers in Urban and Peri-Urban Areas in Greater Cairo</li> </ul>	



## 3. Business Development

### F. Business Plan

#### 3.F.i Industry Analysis

As with most products fabricated from innovative product recycling ideas, there is no industry for recycled flooring tiles, so it will be count among the variety of flooring options manufactured in Egypt. Table 3.6 provides a list of all factories, all owned by a handful of major investors with millions and perhaps billions of capital-investment pounds, which is referred to as a *concentrated*-type of industry.

Table 3.6: Egyptian Tile Factories Listing and Design Capacities (Osama & Soliman, 2016)

Factory	Design Capacity (Million m <sup>2</sup> /yr.)	Factory	Design Capacity (Million m <sup>2</sup> /yr.)
1. Pharaohs	6.0	20. Ceramica Cleopatra 2	4.0
2. Royal	16.5	21. Ceramica El-Amir	4.9
3. Gloria	12.0	22. Ceramica Laboteh	17.5
4. Granito	45.0	23. Porcelain Majestic	3.0
5. Masr Ceramics M.I.C.C	14.0	24. El Ragaa for clay products (Ceramica Venus Egypt, Omega, and Pyramids)	14.0
6. Ceramica Cleopatra Group	16.0	25. Porcelain and Ceramic El- Amir	7.5
7. Eldorado - Cleopatra	12.5	26. The Arabic company for ceramics - Aracemco	20.0
8.Fancy - Cleopatra	8.0	27. Sheeni	2.8
9. Galaria 1,2	23.0	28. El-Ezz company for ceramics and porcelain – Gemma 1	11.0
10. El-Ezz Company for Ceramics - Gemma	3.2	29. Ceramica Prima (EJMY)	8.1
11. Alfa	10.0	30. El-Ezz company for ceramics and porcelain – Gemma 2	6.0
112.1112. New Alfa	0.3	31. Ceramica Misr	15.0
13. Venus	6.5	32. El-Ahlia company for ceramics	2.7
14. Lecico Egypt	24.0	33. Venezia Group	11.0
15. El-Alamia Company (Ceramica rock)	10.0	34. Ceramica Art	9.0
16. The Egyptian Italian Company	4.0	35. Ceramica Mayorka	3.6
17. Karas manufacturing of ceramics &porcelain (ceramic orient)	4.0	36. El-Amal Company	4.4
18. Ceramica Glamour	6.0	37. Pharaohs company	3.0
19. Ceramica Cleopatra 1	2.9	38. Pharaohs Style	3.0

**Total Annual Production ≈ 374.4 Million m<sup>2</sup>**



This section of the business plan discusses some questions:

- \* Is the Industry Accessible?
- \* Is the Industry Lucrative?
- \* Are there Advantageous Gaps?
- \* What are the Threats to Beware?

### The Five Forces Model

According to Professor Michael Porter of Harvard University, identifying the five forces helps in better understanding the industry, and formulating the business plan. (Barringer & Ireland, 2012)

#### **Threat of Substitution**

The ceramic and porcelain tiles industry in Egypt is very competitive, where Egypt has been in the 10<sup>th</sup> top manufacturing countries consistently from 2006 through 2010 (ACIMAC, 2010), and has currently nearly doubled its production. The presence of such a strong substitute means that competitive pricing and sales services must be provided, as well as promoting the edge 'only green, environmentally-friendly flooring tile'.

#### **Barriers of Entry**

These are barriers that would face any new player attempting to get a share of the existing market share. They come in many forms and can sometimes be overcome:

- \* Economies of Scale:

Existing competitors have it easier because they operate multi-million pounds worth of capital investment in factory mass-production equipment. Their huge and non-stop sales mean that non-stop operations are going on, and that gives them the advantage of employing economies of scale.

- \* Cost Advantages Independent of Size

Existing competitors have had the advantage of purchasing their equipment through better deals, possibly even import them from disassembled European factories, at a time when the Egyptian Pound was three times its current value. However, being a starting business may give good funding opportunities from government-backed bank loans and business angels.

- \* Capital Requirements

Starting up in the intended setup doesn't require a huge capital, considering the relatively simple technology and basic equipment required, as well as the cheap availability of raw materials.

- \* Access to Distribution Channels

Expected distribution is through small retail shops in rural or peri-urban areas that provide low-income areas with cheap flooring options. Access will be mainly by incentivising the shops financially, as well as providing a salesperson to aid in promoting the tile.

- \* Product Differentiation:

This is basically the major forte of the flooring tile, because it is made of recycled materials that are cheaper, more durable, and manufactured by young hard-working Egyptians.



## Competitiveness

The level of competitiveness of the industry is an indicator of how much the business has to account for if it is expected to survive:

- \* Number of Competitors

The Egyptian scene of the tiling industry is ripe with competitive factories that provide all sorts of substitute tiles. They have large-scale factories that mass-produce, and they export much of their production.

- \* Degree of Difference between Products

Available products in the market cover a vast array that starts with the cheapest cement tiles, to the most expensive granite tiles. Table 3.7 illustrates the diverse products used as flooring options. Some are very similar, and some are significantly different, but none is quite like the proposed polymer-based redbrick tiles.

Table 3.7: Approximate Price Range of Existing Products (Tiles & Tools, 2017)

	Lower Range (LE/m <sup>2</sup> )	Higher Range (LE/m <sup>2</sup> )
<b>Ceramic</b>	55	310
<b>Porcelain</b>	165	380
<b>Marble</b>	165	2480
<b>Granite</b>	510	2345
<b>Vinyl</b>	170	170
<b>Cement</b>	35	60
<b>HDF</b>	243	440
<b>Parquet</b>	735	1100

- \* Level of Fixed Costs

The fixed costs for the start-up production line are relatively low, most is tied up in the hydraulic press machine, and the monthly premise rent. It is difficult to compare the factory's fixed costs to those of ceramic manufacture due to the completely different fabrication process.

## Bargaining Power of Suppliers

- \* Supplier Concentration

Suppliers are mainly garbage collectors for the styrofoam, and demolition contractors for the redbrick; both are not concentrated and if one presents problems they can be substituted for another for nearly no switching costs.

- \* Attractiveness of Substitutes

There are few substitutes for the suppliers, especially demolition contractors, to make money out of the demolition debris, so supplying the factory is nearly always the better option than dumping the debris somewhere.

- \* Threat of Forward Integration:

There is little risk of the suppliers entering the industry themselves.



## Bargaining Power of Buyers

### \* Buyer Group Concentration

Sales are expected to occur through many retail shops in low-income areas, which makes no threat of buyer concentration. However, in the future, upon entering the wholesale distributors, this may present a pressure point.

### \* Threat of Backward Integration

There is hardly a risk of backward integration because most distributors are not in the manufacture industry but merely retailers who will have to be testing whole new waters to start manufacturing.

## Industry Trends

As with many industries, the ancient Egyptians managed to be the forefathers of the ceramic tiles industry, where they have been decorating their homes with beautiful blue-clad ceramic tiles since the fourth millennium BC (EINouhy, 2013), and later decorated Djoser's Step-Pyramid with colourful tiling in 2600 BC. Later traces of ceramic tiles were found among the Babylonians and the Assyrians too, and the industry has been a live one through Roman, Saracen and European renaissance until the invention of the tunnel kiln in the early twentieth century, which revolutionised and automated the tile manufacturing industry. (Butterworth, 2015)

In modern times, the Egyptian tile production industry retained its ancient strength; in 1996 production was 20 million m<sup>2</sup> of tiles, which jumped to 83 million m<sup>2</sup> in 2004, 120 million m<sup>2</sup> in 2006, 220 million m<sup>2</sup> in 2010 and more than 375 million m<sup>2</sup> in 2016, illustrating curve shown in Figure 3.30.

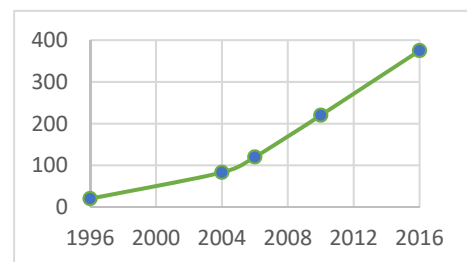


Figure 3.30: Egyptian Production of Ceramic Tiles over Years (million m<sup>2</sup>)

(El-Fadaly, Bakr, & Abo Breka, 2010), (ACIMAC, 2010), (Osama & Soliman, 2016)

Two Egyptian company groups are of the world's 20 biggest players in the ceramics and sanitaryware industry; Lecico being the proud tenth, and Ceramica Cleopatra the twentieth. (MECS, 2017)

### **2016 Results of Select Tile Manufacturers:** (Lecico, 2016) (CERA, 2017) (Gemma, 2016)

Sales and sales revenues of all three manufacturers went up between the fiscal years of 2015 and 2016, indicating a growing demand in the local market regardless of the overall slowing economic progress due to the floatation of the Egyptian Pound and the reduced consumer purchase ability. Lecico tile revenues went up the most (51 %), however, profits fell by 23%. However, Remas sales revenue went up 17%, & gained a considerable 21% profit, as well as Gemma, whose sales revenue rose by just 7%, while maintaining a profit of 25 %

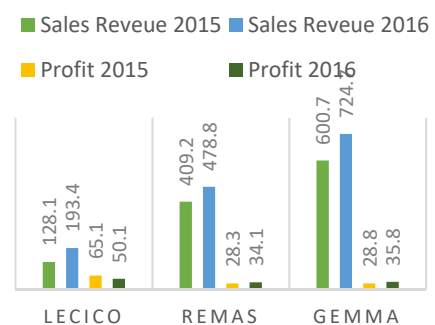


Figure 3.31: 2015 VS 2016 Performance of Egyptian Top Tile Manufacturers (Million Egyptian Pounds)



### Industry Type & Opportunities

The flooring tiles industry in Egypt has been well established over many years, so much that the Egyptian industry has been named the tenth biggest producer worldwide, and the seventh biggest consumer worldwide, as well as the fourteenth biggest exporter worldwide in the “World Production and Consumption of Ceramic Tiles 2010” report. (ACIMAC, 2010) The production and exports have just grown ever since, nearly doubling by the year 2016 (Osama & Soliman, 2016).

Identifying the industry as a mature, global one, it is generically suggested that the business has a good chance following process innovation and above-standard after-sale services (Barringer & Ireland, 2012), and having an eye for exports-in the near future-for more environmentally-conscious markets.

### Competitor Analysis

**Indirect Competitors:** Table 3.6 shows a list of indirect competitors who produce flooring tiles made of ceramics and porcelain options which the offered redbrick tiles are trying to substitute.

**Future Competitors:** The idea of producing tiles by pressing cannot be patented, so copying the idea and making new product lines by competitors (existing or new-coming) can be expected in the following year or two.



### 3.F.ii Company Description

#### Mission Statement

Recycling the Discarded to Make Everyday Products.

#### Products Portfolio

It should be clear that one of the long-term objectives of the company is to create a database of expertise on the best use scenario for most of the commonplace solid wastes, along with feasibility analyses on how best to turn them into business opportunities.

#### **Faux-Granite Tile** (Product Alpha)

A flooring option that is made up of a single repetitive unit with a shape that allows it to be in co-dependent contact with all surrounding tiles. The interlocking mechanism would allow for very easy installation, and later repair or removal with minimum damage of tiles.

The tile is of a mixture of recycled redbrick and styrofoam that have been tested in accordance with the American Standards for flooring tiles.



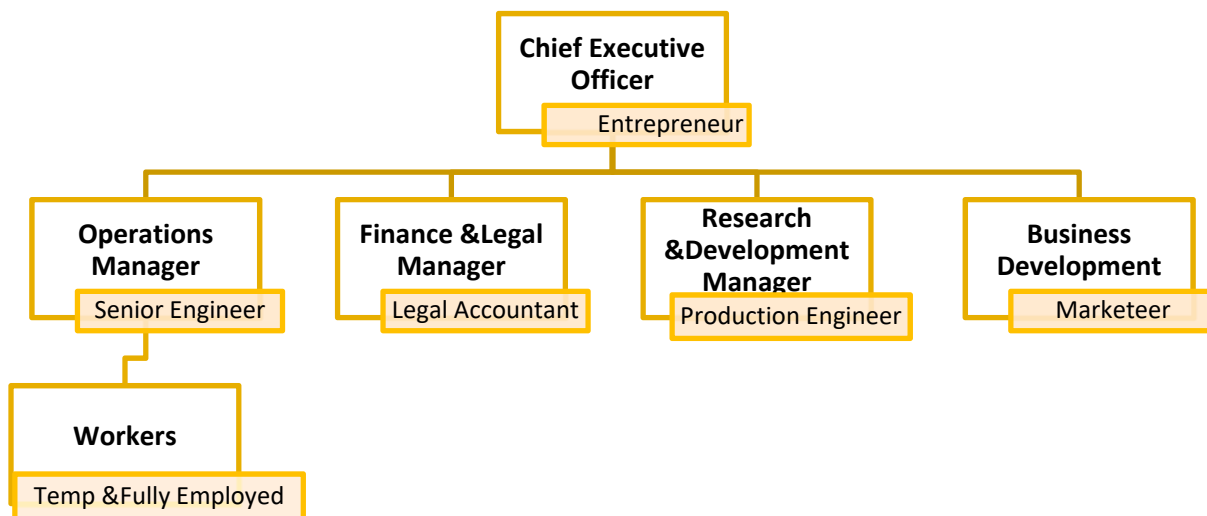
Figure 3.32: Faux-Granite Tile

#### Legal Status

Privately owned, with a possibility of partnership with someone who would add a high-value asset (warehouse or press machine).

In five years' time, the situation may be re-assessed to turn it into a private limited company LTD, with shares distributed among family and friends.

#### Organisation Chart







### Skills Profile

<b>Title</b>	<b>Minimum Background</b>	<b>Job Description</b>
<b>Chief Executive Officer</b>	<u>The Entrepreneur</u> University Degree. Basic understanding of methodical thinking.	<ul style="list-style-type: none"> <li>* Setting Company Strategies</li> <li>* Company Frontman</li> <li>* Overlooking all Operations</li> <li>* Managing Human Resources</li> </ul>
<b>Operations Manager</b>	<u>Senior Engineer</u> +5 years' experience in project management, preferably in factories.	<ul style="list-style-type: none"> <li>* Managing Supply Chain</li> <li>* Managing Factory Operations</li> <li>* Managing Workers</li> <li>* Managing Facility</li> <li>* Controlling Quality</li> </ul>
<b>Finance &amp; Legal Manager</b>	<u>Legal Accountant</u> BSc. Law with +5 years' experience in financial management.	<ul style="list-style-type: none"> <li>* Managing Finances</li> <li>* Managing Legal Matters</li> <li>* Handling Permits &amp; Licences</li> </ul>
<b>Research &amp; Development Manager</b>	<u>Production Engineer</u> BSc. Materials or Production Engineering or Architecture with some relevant professional experience.	<ul style="list-style-type: none"> <li>* Managing &amp; Auditing Quality</li> <li>* Managing New Product Ideas</li> <li>* Testing Products</li> <li>* Technical Support</li> <li>* Conducting Market research</li> </ul>
<b>Business Development</b>	<u>Marketer</u> Business background, capable of formulating basic financial & marketing planning.	<ul style="list-style-type: none"> <li>* Setting Marketing Strategy</li> <li>* Handling Sales</li> <li>* Handling Promotions</li> <li>* Handling Product Delivery</li> <li>* Handling Customer Feedback</li> </ul>
<b>Workers</b>	<u>Temp &amp; Fully Employed</u> Capable of handling relevant machinery & equipment and following instructions clearly.	<ul style="list-style-type: none"> <li>* Operating Machines (Full)</li> <li>* Heavy-lifting (Full)</li> <li>* Driving Fork-lifter (Full)</li> <li>* Truck Delivery (Temp)</li> </ul>



### **3.F.iii Operations Plan**

This section of the business plan discusses the major activities taking place that lead to the transformation of the business plan and product idea to turn into actual sales and profits. It elaborates on those activities, how they're done, and the perceived timescale of their action.

#### Activities



*Figure 3.33: Core Business Activities*

The core activities of the business can be seen in Figure 3.33, where they start by landing deals with distributors, followed by the estimation of required production and consequently the ordering the required raw materials. Following, the logistics of procuring the raw materials and delivering them to the factory (see Figure 3.35), where they go through the production process explained in the Production Process Supply Chain section. Finally, the delivery of the tiles and obtaining customer feedback for any suggested improvements in the service provided or product delivered.

#### Production Process Supply Chain

The core activities undertaken to manufacture the product can be clearly seen in Figure 3.34. The production process can be studied in conjunction with the factory layout shown in Figure 3.35, where every stage of the process must be accounted and well planned to achieve thorough understanding of the required efforts that would ensure success.

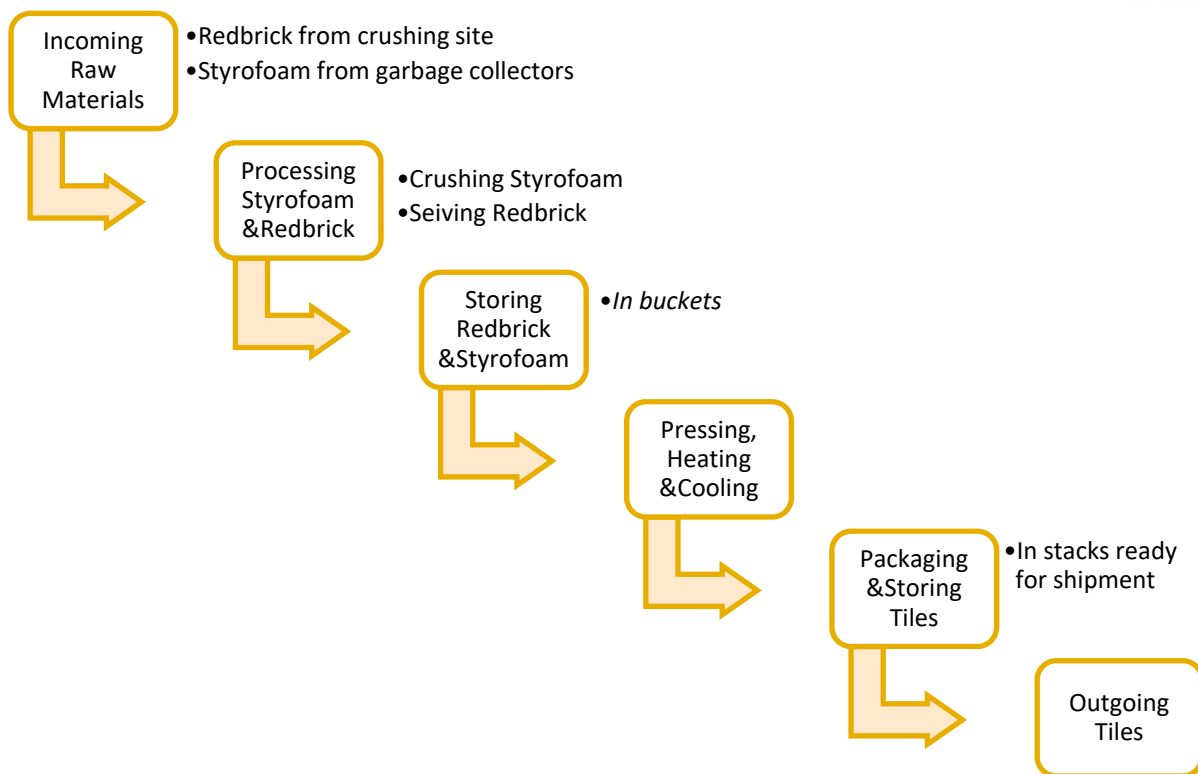


Figure 3.34: Production Process Supply Chain



Monthly Schedule

Activities	One Month Schedule																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Deals with Distributors																																
Orders to Suppliers																																
Transportation Logistics																																
Incoming Raw Materials																																
Processing Styrofoam & Redbrick																																
Storing Redbrick & Styrofoam																																
Pressing, Heating & Cooling						<i>25 days of production per month, two 12-hour shifts (2 hr breaks), 45 minutes per press, 2 m<sup>2</sup> per press: 53.3 m<sup>2</sup> per day * 25 days = <b>1333.3 m<sup>2</sup> per month</b> (two hydraulic press machine, 4 tiles per press each)</i>																										
Packaging & Storing Tiles																																
Outgoing Tiles																																
Handling Customer Feedback																																



Factory Layout

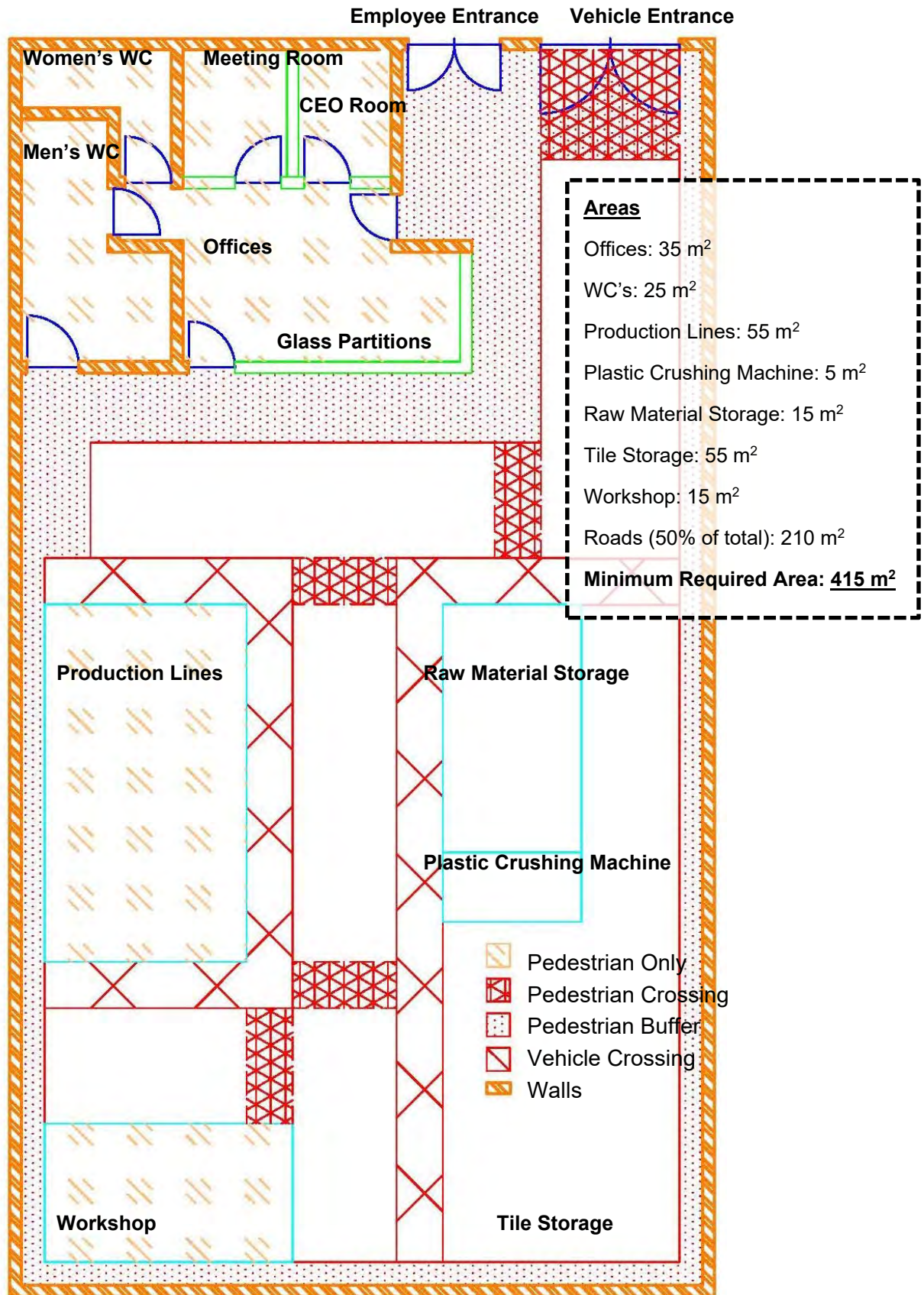


Figure 3.35: Factory Layout



### **3.F.iv Design &Development Plan**

The continuous improvement of the business operations is a key factor in its success, and it can be achieved by paying attention to two major categories: product and business development.

#### **Product Development**

The research and development manager is in charge of the continuous improvement of the product portfolio, as well as the founding of new product ideas through the successful operation of the 'incubator' located in the workshop area (see Figure 3.35 for the factory layout).

Among ideas to improve the existing tile is the use of a different polymer instead of polystyrene; or possibly finding new cooling methods that would lessen the production time and allow the production of more tiles per hour.

The intake of new product ideas must be taken seriously, since the business can only thrive if it constantly takes advantage of every feasible idea conceived by the incubator teams. The incubator operates as a research and development department, except that those working on the development are young entrepreneurs wishing to test their recycling ideas using the given facilities.

#### **Quality Assurance &Quality Control**

The Research and Development Manager sets a plan for quality assurance that includes product, production and packaging quality standards, as well as the method and frequency of auditing. The Operations Manager oversees quality control while ensuring that the whole production process follows the agreed quality standards.

Another part of quality assurance is through the visual inspection and random sampling of incoming raw materials. Redbrick received from crushing sites is to be sieved, and individual styrofoam pieces visually inspected prior to weighing, or admittance to the raw material storage area. Materials that do not comply with the product requirements are to be returned at the expense of the supplier.

#### **Business Development**

Finding new markets for the production tile mean that expansion will be required and expected to meet a-hopefully-increasing demand, which means that instead of a single hydraulic press machine, investment in a production line or two would be recommended, and no chance for such advance should be left unused.

The business developer is expected to lead the efforts to find new customers, distributors, suppliers and potential incubates. Expanding the horizon for the growing business, where even if it can't at its starting phase take on more orders due to limited production lines, it can still help build a database and a network of contacts in all directions that would enable better operations by possibly employing newly learned ideas, or taking advantage of opportunities that present themselves through the extended network.



### **3.F.v Marketing & Sales Plan**

This section of the business plan discusses the marketing strategy intended to be employed to achieve target sales. It begins with setting a target market and target sales, then setting the 4 major elements of the marketing mix: product, price, place, and promotion.

#### Marketing Targets

##### **Target Market**

Due to the nature of the product, target customers who would want to use the faux-granite flooring tile, the business' alpha product, would include, but are not limited to:

- \* Young couples furnishing their homes
- \* Low-to-middle income people refurbishing their homes
- \* Lower scale office owners
- \* Lower scale shop owners
- \* All-range of incomes for their terraces

##### **Target Sales**

The maximum production capacity is intended in the first six months to be around 8000 m<sup>2</sup>, assuming an average of 20 working hours daily. And while taking on more orders would not be good for business, it is possible to raise the price if a market has been consolidated. This means that if no change in the production lines is achieved in the first year, annual sales are expected to be no more than 16,000 m<sup>2</sup>.

##### **Target Reputation**

The mission of the business is to turn discarded items into everyday products. This means being known as a hub for product recycling design expertise. It's the intention to use the workshop/incubator provided as an edge to promote the idea that supporting this business is an indirect support to young entrepreneurs, as well as the environment. The business is at core part of the green economy initiative and is expected to show and pilot the efforts to maintain a successful business while utilising green production and supporting the community.

#### Product

The alpha product being offered is the 'faux-granite tile', which includes the tile itself, well presented in a protective wrapping package and quick-installed upon the request of customers. A warranty will be provided on the technical performance of the tile, with the Research and Development Manager overseeing any returns or technical issues with the installation or performance of the tile.





### Price

According to Table 3.7 on page 48, showing the available substitute products in the market and their price ranges, it is recommended to place the product price somewhere along the lower ceramics price range. The actual price, of course, being no less than 15% more than the actual cost of production, calculated in the 3.F.vi Business Economics section; no less than 130 LE/m<sup>2</sup>, but no more than 170 LE/m<sup>2</sup>, according to deals made with distributors or clients. It must be noted that in the early months of operation, the price will acutely affect the breakeven point and business liquidity, so the selling price suggested is 150 LE/m<sup>2</sup>.

### Place

Potential customers usually purchase flooring tiles by going to their local tiles retailers/wholesalers who showcase their range of products. The suggested strategy is to target distributors in lower-class urban and peri-urban areas around the Greater Cairo Metropolitan Area (GCMA) who would normally be seeking cheap tiles that are low maintenance and easily installed. Other options such as an online purchasing system or opening a small shop for product display may be open for discussion at later stages.

### Promotion

Communicating the presence of the product to potential customers will be done through the following media:

- \* Product Display at the Distributors' Shops
- \* Banners around the Distributors' Shops
- \* Online Advertisement through Social Media
- \* Word of Mouth
- \* Being hosted in TV Programmes as a Young Entrepreneurial Venture





### 3.F.vi Business Economics

#### Revenue Drivers

Revenue drivers are the range of products and services offered by the business in return for clients' rewards. At the beginning of the business operations, the main revenue driver is the product being sold, but at a later stage another revenue driver is expected to emerge, being possible government funds for the incubator.

#### Cost Structure

Table 3.8: Business Cost Structure

	Item	Unit Price (EGP)	Units	Total Price	Type
1. Raw Materials	Styrofoam (tonne)	6,000	2.1	12,800	Current Assets
	Redbrick (tonne)	400	2.1	853	Current Assets
2. Equipment	Hydraulic Press Machine	50,000	2.0	100,000	Fixed Assets
	Mould	5,000	2.0	10,000	Fixed Assets
	Water Jet	10,000	2.0	20,000	Fixed Assets
	Storage Tables	1,000	10.0	10,000	Fixed Assets
	Forklift	5000	1.0	5000	Fixed Assets
	Depreciation	2000	1.0	2000	Current Liabilities
	Maintenance	1000	1.0	1000	Current Liabilities
3. Office	Furnishing	50,000	1.0	50,000	Fixed Assets
	Printer	5,000	1.0	5,000	Fixed Assets
	Laptops	15,000	5.0	75,000	Fixed Assets
	AC	9,000	4.0	36,000	Fixed Assets
4. Wages	Senior Engineers	15,000	2.0	30,000	Current Liabilities
	Junior Engineers	10,000	2.0	20,000	Current Liabilities
	CEO	17,500	1.0	17,500	Current Liabilities
	Workers	2,500	8.0	20,000	Current Liabilities
5. Legal	Permits	5,000	1.0	5,000	Current Liabilities
6. Bills	Electricity	5,000	1.0	5,000	Current Liabilities
	Water	1,000	1.0	1,000	Current Liabilities
	Warehouse Rent	15,000	1.0	15,000	Current Liabilities
	Transportation Rent	5,000	4.0	20,000	Current Liabilities
<b>Total</b>				<b>464,140</b>	



Table 3.9: Summary of Major Cost Categories

Cost Category	Total (EGP)
1. Raw Materials (per month)	13,653
2. Equipment (minus depreciation)	145,000
3. Office	166,000
4. Wages (per month)	87,500
5. Legal	5,000
6. Bills (per month)	41,000
<b>Fixed Costs</b>	<b>311,000</b>
<b>Equity</b>	<b>188,153</b>
<b>Current Assets</b>	<b>13,653</b>
<b>Current Liabilities</b>	<b>136,500</b>
<b>Production Cost (of 1 m<sup>2</sup>)</b>	<b>112.62</b>

#### Nomenclature

**Current Assets:** “include cash, accounts receivable, inventory, prepaid expenses and other assets that can be converted to cash within one year” (Oxford Dictionary)

**Current Liabilities:** “include short-term debt, interest, accounts payable and any other outstanding liabilities that are due within a year's time.” (Oxford Dictionary)

**Fixed Assets:** “Assets which are purchased for long-term use and are not likely to be converted quickly into cash, such as land, buildings, and equipment.” (Oxford Dictionary)

**Equity:** It's the total worth of the business calculated by subtracting the liabilities from the total assets.

$$\text{Equity} = \text{Fixed Assets} + \text{Current Assets} - \text{Current Liabilities}$$

**Cost of Product:** Total Costs that went in the fabrication of a single product unit

$$\text{Cost of Product} = \frac{\text{Current Assets} + \text{Current Liabilities}}{\text{Number of Units}}$$

#### Break-Even

$$\text{Breakeven Sales} = \frac{\text{Total Fixed Costs}}{\text{Unit Sales Price} - \text{Unit Production Cost}}$$

$$\text{Breakeven Time} = \frac{\text{Breakeven Sales}}{\text{Projected Sales per Month}}$$

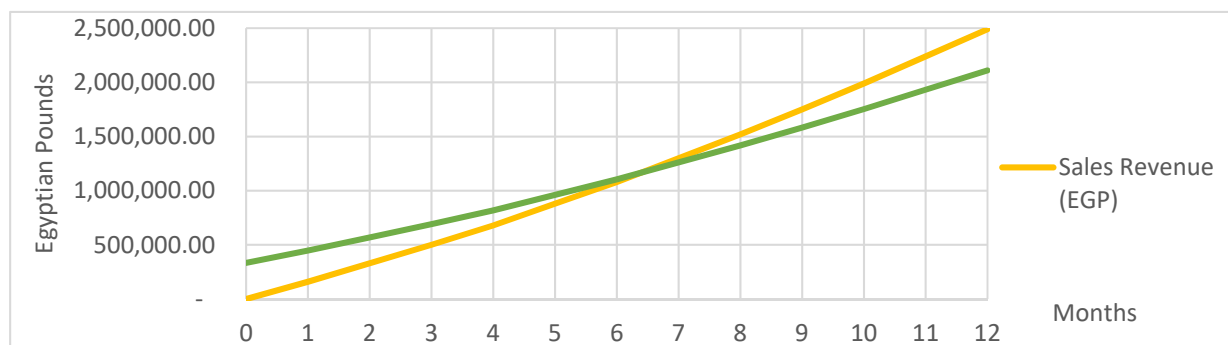


Figure 3.36: Breakeven Chart (Case 1)



### 3.F.vii Financial Projections

#### Proforma Income Statement

	2018	2019
<b>Net Sales</b>	<b>2,490,000</b>	<b>4,860,000</b>
<b>Cost of Goods Sold</b>	Styrofoam	199,680
	Redbrick	13,312
	Workers	312,000
<b>Gross Profit</b>	<b>2,086,160</b>	<b>4,335,008</b>
<b>Operation Expenses</b>	Depreciation	5,000
	Maintenance	7,800
	Electricity	78,000
	Water	15,600
	Warehouse Rent	234,000
	Transportation Rent	312,000
<b>Wages</b>	Senior Engineers	468,000
	Junior Engineers	312,000
	CEO	273,000
	Income before Tax	2,629,608
<b>Tax</b>	<b>174,636</b>	<b>591,662</b>
<b>Net Income</b>	<b>601,524</b>	<b>2,037,946</b>
<b>Retained by Owners</b>		
	150,381	509,487
<b>Retained by Business</b>		
	451,143	1,528,460

#### Proforma Balance Sheet

	31/12/2018	31/12/2019		31/12/2018	31/12/2019
<b>Current Assets</b>			<b>Current Liabilities</b>		
Cash	35,779	80,664	Equipment Suppliers	336,000	542,750
Styrofoam	153,600	199,680	Redbrick Supplier	10,240	13,312
Redbrick	10,240	13,312	Styrofoam Supplier	153,600	199,680
<b>Accounts Receivable</b>	<b>2,490,000</b>	<b>4,860,000</b>	<b>Wages Payable</b>		
			Senior Engineers	360,000	468,000
			Junior Engineers	240,000	312,000
			CEO	210,000	273,000
			Workers	240,000	312,000
<b>Fixed Assets</b>			<b>Bills Payable</b>		
Hydraulic Press Machine	100,000	230,000	Electricity	60,000	78,000
Mould	10,000	23,000	Water	12,000	15,600
Water Jet	20,000	46,000	Warehouse Rent	180,000	234,000
Storage Tables	35,000	51,250	Transportation Rent	240,000	312,000
Forklift	5,000	11,500	Maintenance	6,000	7,800
Furnishing	50,000	65,000	<b>Tax Payable</b>	<b>174,636</b>	<b>591,662</b>
Printer	5,000	5,000	<b>Equity</b>		
Laptops	75,000	75,000	Owner's Equity	350,000	350,000
AC	36,000	36,000	Retained Earnings	451,143	1,979,603
Depreciation	- 2,000	- 7,000			
<b>Totals (EGP)</b>	<b>3,023,619</b>	<b>5,689,406</b>	<b>Totals (EGP)</b>	<b>3,023,619</b>	<b>5,689,406</b>

\* It was assumed that all accounts receipt and payment were postponed till 1/1 the following year.



## Ratio Analysis

### **Profitability Ratios** (Barringer & Ireland, 2012)

They relate the income earned with the resources used in its generation:

$$\text{Return on Assets} = \frac{\text{Net Income}}{\text{Total Assets}}$$

$$\text{Return on Equity} = \frac{\text{Net Income}}{\text{Total Equity}}$$

$$\text{Profit Margin} = \frac{\text{Net Income}}{\text{Total Sales Revenue}}$$

### **Liquidity Ratios** (Barringer & Ireland, 2012)

They assess the ability of the company to cover short-term liabilities by liquidating assets:

$$\text{Current} = \frac{\text{Total Current Assets}}{\text{Total Current Liabilities}}$$

### **Activity Ratios**

They measure the efficiency of assets used into the generation of income:

$$\text{Turnover} = \frac{\text{Total Sales Revenue}}{\text{Total Assets (Current + Fixed)}}$$

Table 3.10: Forecasted Financial Ratios (2-year) – Case 1

	2018	2019	Difference
<b>Profitability Ratios</b>			
Return on Assets	20%	36%	+16%
Return on Equity	75%	87%	+12%
Net profit Margin	24%	42%	+18%
<b>Liquidity Ratios</b>			
Current	121%	153%	+32%
<b>Activity Ratios</b>			
Turnover	82%	85%	+3%

### Optimisation of Work Efforts

As it can be seen from the relations between cost values, the breakeven chart, the income statement, the balance sheet, and the financial ratios, an MS Excel spreadsheet was formulated to link all values and ensure the integrity of results. That sheet was used to produce the values in Table 3.11 that shows the different cases of daily production and sales price, and their effect on the breakeven time and financial ratios.

While cases 2 and 5 may exhibit the highest profitability, cases 1 and 6 are the most likely scenarios giving 20 % return and 7 months to breakeven if the tiles are sold at 150 EGP, and only 13 % return and 11 months to breakeven if the selling price was forced down to 130 EGP.



Table 3.11: Cases for Optimum Time, Shifts & Selling Price

Case No.	Time of Single Press	Shift length	Number of Daily Shifts	Selling Price	Cost of Product	Daily Production	Annual Revenue	Annual Costs	Breakeven Time	Return on Assets	Return on Equity
1*	45 mins	10+2	2	150	106.99	53.3 m <sup>2</sup>	2,490,000	2,110,034	7 months	20 %	75 %
2	30 mins	10+2	2	150	74.74	80 m <sup>2</sup>	3,735,000	2,195,026	3 months	35 %	85 %
3	30 mins	8	2	150	90.87	64 m <sup>2</sup>	2,988,000	2,144,030	5 months	27 %	82 %
4	30 mins	8	2	130	90.87	64 m <sup>2</sup>	2,589,600	2,144,030	6 months	20 %	71 %
5	30 mins	8	2	170	90.87	64 m <sup>2</sup>	3,386,400	2,144,030	4 months	32 %	84 %
6*	45 mins	10+2	2	130	106.99	53.3 m <sup>2</sup>	2,158,000	2,110,034	11 months	13 %	59 %
7	45 mins	10+2	2	170	106.99	53.3 m <sup>2</sup>	2,822,000	2,110,034	5 months	26 %	81 %
8	45 mins	8	2	150	131.18	42.7 m <sup>2</sup>	1,992,000	2,076,037	13 months	9 %	47 %

\*Most likely scenarios

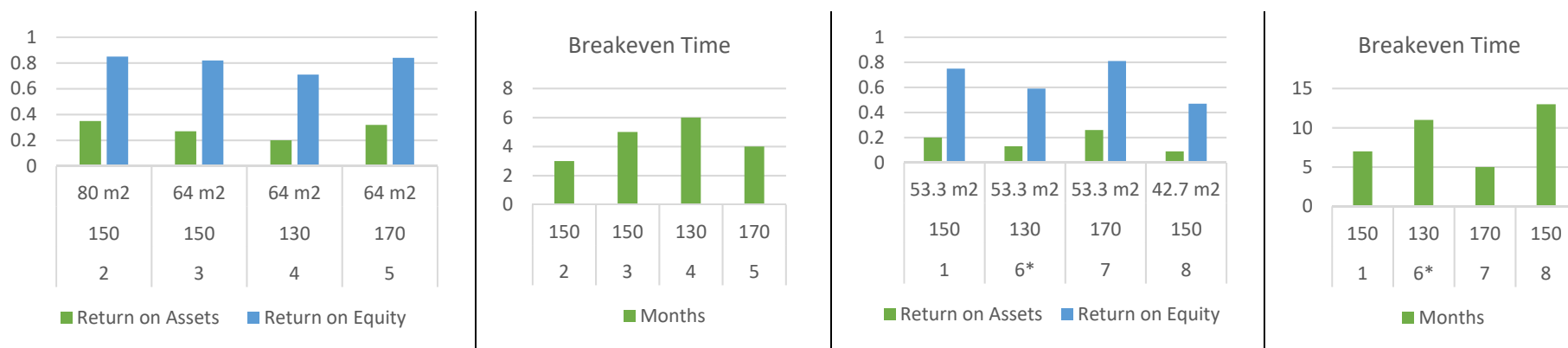


Figure 3.37: Graphical Comparison of Financial Performance Based on Press Time & Shifts

The graphs in Figure 3.37, and numbers shown in Table 3.11 indicate a clear effect of the daily production on the financial performance of the business as a whole. This highlights the importance of focusing on developing methods to increase the daily production through development of the production line's technology, or increasing work shifts.

### 3.F.viii Executive Summary

Sales Revenue 2015 Sales Revenue 2016 Profit 2015 Profit 2016

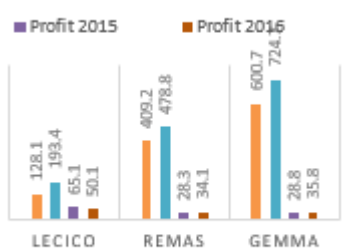
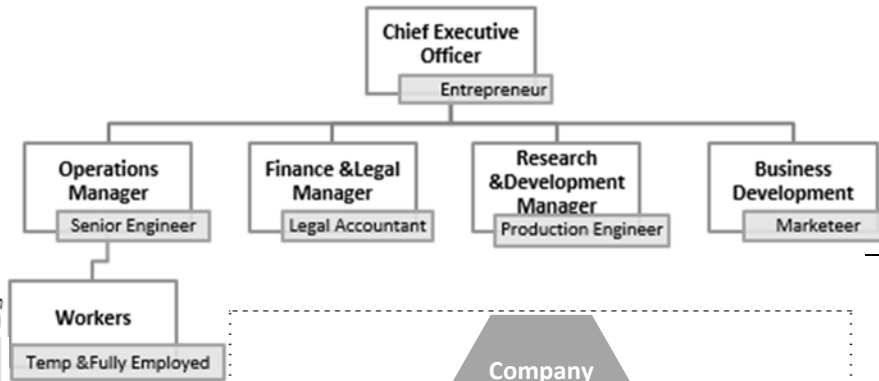
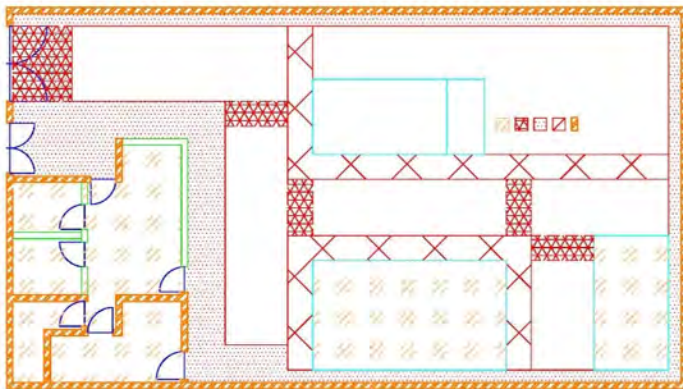


Figure 2: 2015 VS 2016 Performance of Egyptian Top Tile Manufacturers (Million Egyptian Pounds)



Figure 1: Egyptian Production of Ceramic Tiles over Years (million m<sup>2</sup>)



#### Product Development

- \* Product Research
- \* Incubation
- \* Quality Assurance
- \* Quality Control

#### Business Development

- \* Market Research
- \* Incubation
- \* Finding Deals

#### Product

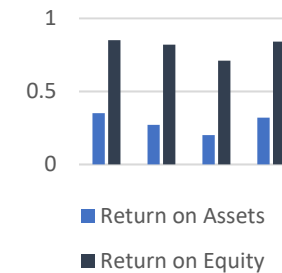
- \* Well Presented
- \* Nicely Packaged
- \* Quickly Installed
- \* Warranty

#### Price

	Lower (LE/m <sup>2</sup> )	Higher (LE/m <sup>2</sup> )
Cer.	55	310
Porc.	165	380
Mar.	165	2480
Gran.	510	2345
Prod.	130	170

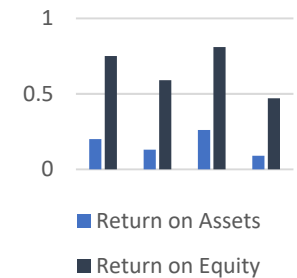
#### Place

- \* Local Tile Retailers
- \* C-Class Urban & Peri-Urban
- \* Future Shop

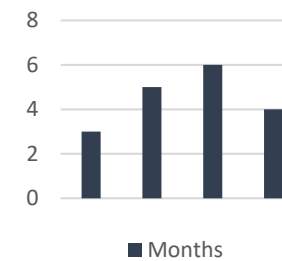


#### Promotion

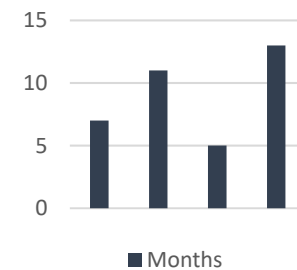
- \* Distributors' Shops
- \* Banners
- \* Online Promotion
- \* Word of Mouth
- \* TV Hosting



#### Breakeven Time



#### Breakeven Time





### 3.4 Stage 3: Incubator

Following the predicted success of the alpha product, the next stage of the three-stage process is the incubation of entrepreneurs with ideas for new product lines. This is a dual-purpose stage, and its success means more than adding to the product portfolio, and business expansion; its success means that the business has been able to achieve the win-win formula for both business owners and society.

#### Services Provided

Literature tells us that incubators provide services such as: Infrastructure, Office Services, Process Advice, Networking, Direct Capital (Zedtwitz & Grimaldi, 2006).

Table 3.12: Services Provided to Entrepreneurs by Incubator

Service	Description	Required Resources
<b>Infrastructure</b>	The incubator provides a place for entrepreneurs to work on their ideas; this means they need a well-equipped accessible workshop where they get to innovate and test their innovations.	Hydraulic Press, Lab Assistant, Workshop, Raw Materials, Access to Labs
<b>Office Services</b>	The incubator provides a place for entrepreneurs to work on their ideas; this means they need a safe and easy-access work area for their meetings, discussions and research.	Meeting Room, Printers, Internet
<b>Process Advice</b>	The engineers and staff operating the business have been through the same process as the entrepreneurs, and they surely have some good tips on how best to manage the product (as well as the business) development.	Engineers' Time
<b>Networking</b>	Networks provide access to countless possibilities, whether the entrepreneur is seeking a specific raw material, a lab test, or even an academic to talk to.	Engineers' Time, Listing of Vendors, Suppliers & Labs.
<b>Start-up Boost</b>	Once a product idea is proven to be feasible, a contract is drawn with the idea owners on how best to utilise the idea in a win-win manner. This will be subject to pre-agreed (standard) conditions signed at the beginning of the incubation period.	As per Contract Agreement







## Incubator Model

The proposed incubator model is one that is very similar to the previously referred to “Corporate Private Incubators”, where the incubator budget comes from a private company and its goal is to generate revenue for that company. The model in brief is of three steps: Pre-Incubation, Incubation, Post-Incubation.

- Pre-Incubation: A preliminary (standard with time frame) agreement is drafted by the lawyer and signed by all parties that states that products coming out from the incubator are patented to the entrepreneur who created it, however its production is bound to the factory.
- Incubation: As discussed in Table 3.12, services provided during the incubation itself do not include direct funding, but rather sharing the factory resources, specifically the workshop and printer. An incubation programme will be developed by the Research & Development Manager after some time managing and observing the incubates.
- Post-Incubation: A contract is drafted under the supervision of lawyers representing the company and the entrepreneur that honours the preliminary agreement, while being customised to the nature of the product to ensure a win-win for both the entrepreneur whose idea succeeded, and the incubator that helped the innovation.

According to both references: (Grimaldi & Grandi, 2005), and (Zedtwitz & Grimaldi, 2006), Table 3.13 shows the model’s defining characteristics.

Table 3.13: Incubator Model Defining Characteristics

Characteristic	Discussion
<b>Mission</b>	Generating profit by leveraging new ideas
<b>Industrial Sector</b>	Recycling, specifically compression moulding
<b>Location</b>	Greater Cairo Municipal Area
<b>Market</b>	Depending on type of product designed
<b>Origin of Ideas</b>	Contracted entrepreneurs

Characteristic	Discussion
<b>Intervention Phase</b>	Conceptualisation Stage or later.
<b>Incubation Period</b>	6 months to a year.
<b>Revenue Sources</b>	Company funds, business angels
<b>Competitive Focus</b>	Attracting innovative entrepreneurs
<b>Profitability Measure</b>	New product lines added, gaining funds.



## Chapter 4: Results and Discussions

### 4.1 Experimental Works

#### 4.1.1 Test Report for Three-Point Bending

ASTM D7264/D7264M – 15

Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials (reporting of items beyond the control of a given testing laboratory, such as might occur with material details or panel fabrication parameters, shall be the responsibility of the requestor)

#### General Test Information

- \* Test Date: 17/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Ismail Tammam, Aya Adel
- \* Test Procedure A, Three-Point Bending
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

#### Test Description

As per Figure 4.2, the sample is freely supported like a beam and deflected by a concentrated, and constantly moving downwards load acting at its midspan. The machine has sensors that measures midspan deflection due to the applied load, and software where the specimen dimensions and loading conditions are input to calculate the Stress-Strain curve, and consequently Young's Modulus, as well as producing the load-stress-strain points in tabulated form.

#### Expected Outcomes

- \* Maximum Load on Sample Section (P<sub>max</sub>, kN)
- \* Maximum Deflection on Sample at Maximum Load (δ<sub>max</sub>, mm)
- \* Maximum Bending Stress at Maximum Load (σ<sub>max</sub>, MPa)
- \* Maximum Bending Strain at Maximum Load (ε<sub>max</sub>)
- \* Material Stress-Strain Curve --
- \* Material Young's Modulus (E, MPa)
- \* Material Modulus of Resilience (μ<sub>r</sub>, MPa)

#### Equations Used

$$\sigma = \frac{3PL}{2bh^3}$$

$$\epsilon = \frac{6\delta h}{L^3}$$

$$E_f^{secant} = \frac{L^3 m}{4bh^3}$$

$$E_f^{chord} = \frac{\Delta\sigma}{\Delta\epsilon}$$

$$\mu_r = \frac{\sigma^2}{2E}$$

L: Sample Length = 128 mm

b: Sample Width = 13 mm

h: Sample Thickness = 4 mm

m: Secant Slope of Force-Deflection Curve

## Equipment Used

As shown in Figure 4.2, and to (2.A.ii Equipment), the test equipment is required to impose a tensile measurable load on the supported sample to cause a measurable extension and record the maximum breaking load, thence the stress-strain diagram can be drawn, and Young's Modulus concluded. No variations to this test method or anomalies were noticed during testing, and no equipment problems occurred during testing.

## Material Identification & Sampling

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	<i>5 Samples each</i>
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 250 X 250 mm and 10 X 10 mm moulds.	
	<ul style="list-style-type: none"> <li>* Length: 128 mm;</li> <li>* Width: 13 mm;</li> <li>* Thickness: 4 mm.</li> </ul>	

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 250 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

<b>AA</b>	<b>RB</b>	<b>B</b>	<b>X</b>
-----------	-----------	----------	----------

**AA:** Red Brick Content: 25, 50, 60 %    **B:** Bending Test Indication

**RB:** Red Brick Indication

**X:** Sample Number 1 to 5



Figure 4.1: Samples for Three-Point Bending Test

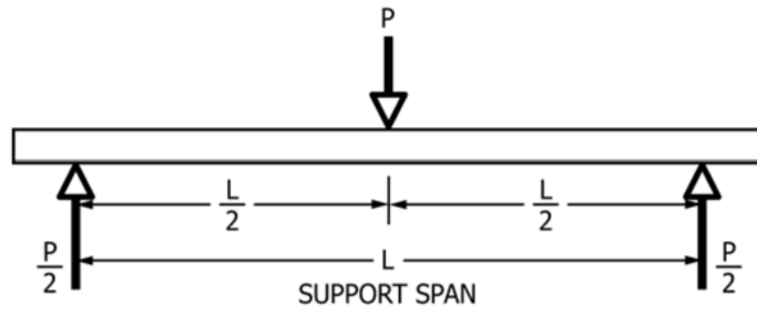


Figure 4.2: Procedure A (Three-Point Bending) Loading Diagram, ASTM D7264

### Testing Procedure

The Sample is placed as per the assembly shown in Figure 4.2, where the sample is positioned so that the support span  $L$  is 80 mm and the rest of the sample length (about 20%) is on either side of the supports. Load,  $P$ , is applied and reported in kN, and the moving arm extension is measured and reported in mm. The movement speed of the arm is 1 mm/sec.

### Test Data

For test data, please refer to Appendices, Tests'

### Test Results and Analysis

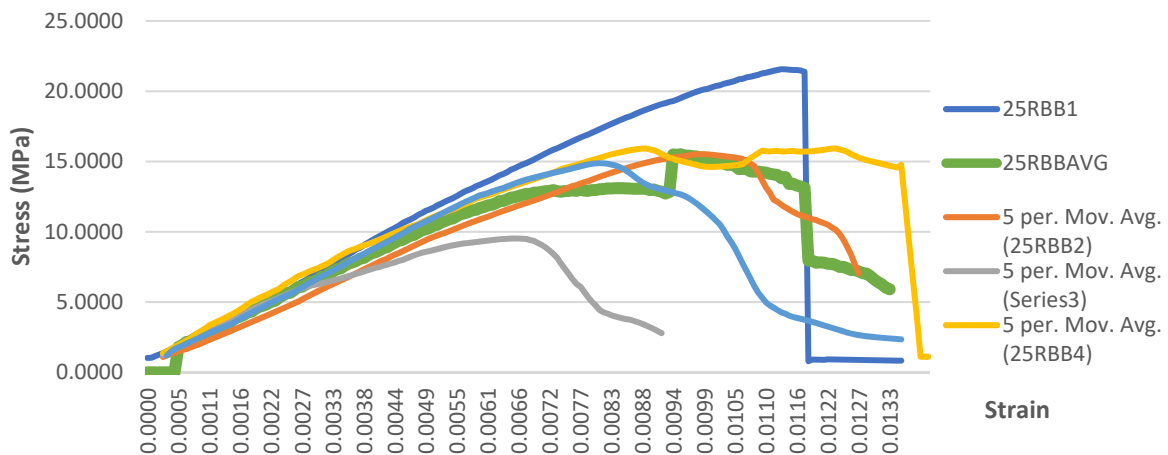


Figure 4.3: Stress-Strain Curve for Bending Performance of 25 % Redbrick Composition

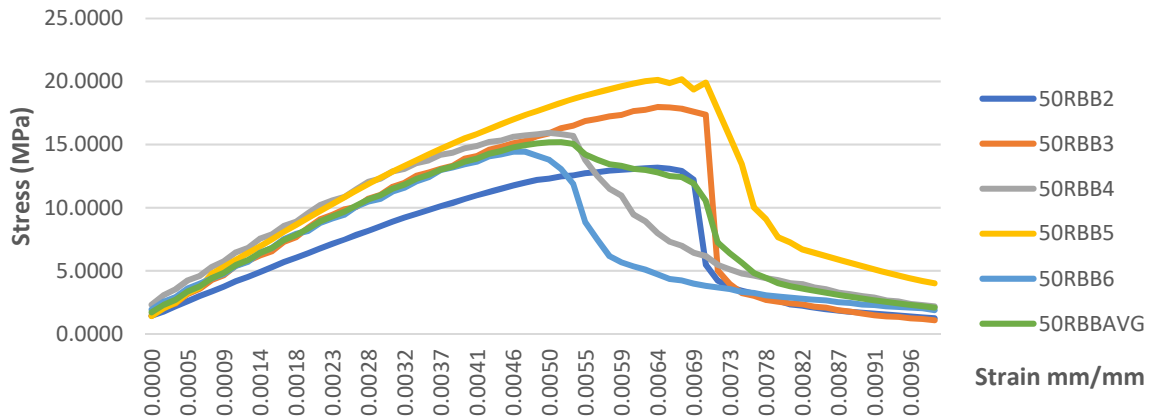


Figure 4.4: Stress-Strain Curve for Bending Performance of 50 % Redbrick Composition

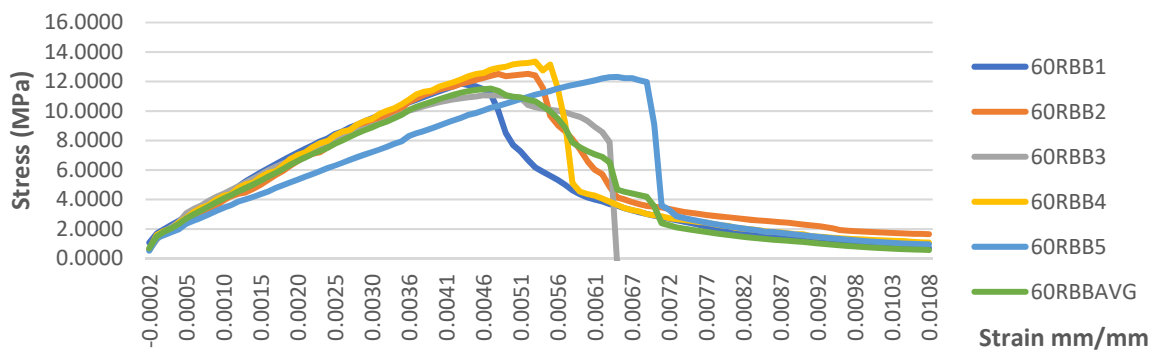


Figure 4.5: Stress-Strain Curve for Bending Performance of 60 % Redbrick Composition

Results indicate that the 25 % and 50 % redbrick composition tiles can withstand higher bending stress than the 60% counterparts, with no conclusive indicator as to which has a higher bending stress capacity. Knowing that the strength of the redbrick filler is higher than the polymeric binder, these results indicate that at higher redbrick content the reason for failure is the absence of enough polymer to bind the redbrick particles together, or possibly higher inhomogeneity of the composite.

Results also show that the resilience of the tile increases proportionally with the increase of the polymer content, which is typical behaviour indicating higher energy absorption by the polymer chains as opposed to the redbrick, which can also be seen in the higher strain exhibited by samples with higher polymer content.

As a compromise between all three types of samples, the 50 % redbrick sample seems to achieve optimum results when bending strength, deflection and resilience are all taken into consideration; the 60 % redbrick is notably weaker as well as of lower resilience, but the polymeric content being more expensive than redbrick, and the very insignificant difference in overall performance of the 25 % compared to the 50 % redbrick, means that the 50 % redbrick is the optimum choice of the three.



## 4.1.2 Test Report for Specifying Density

### General Test Information

- \* Test Date: 18/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Ismail Tammam, Menna Adel
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

### Test Description & Equipment Used

Density specification requires simply and accurately measuring the mass and the volume of the sample. Ideally, volume measurement is more accurate when done using displacement method by putting it in a fluid and measuring the displacement to calculate the volume.

The testing equipment takes readings for the mass, then the sample is removed and placed in the liquid (kerosene oil density 0.779 g/cm<sup>3</sup>) for the displacement, and calculates the density with high accuracy.

### Expected Outcomes

- \* Density (ρ, g/cm<sup>3</sup>)

### Equations Used

$$\rho = \frac{mass}{volume}$$

### Material Identification

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	3 Samples each
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 10 X 10 mm moulds.	
	* Length X Width: 3 mm X 3 mm	
	* Thickness: 10 mm.	



## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 100 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

AA	RB	D	X
----	----	---	---

**AA:** Red Brick Content: 25, 50, 60 %    **B:** Bending Test Indication

**RB:** Red Brick Indication

**X:** Sample Number 1 to 3



Figure 4.6: Samples for Specifying Density

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

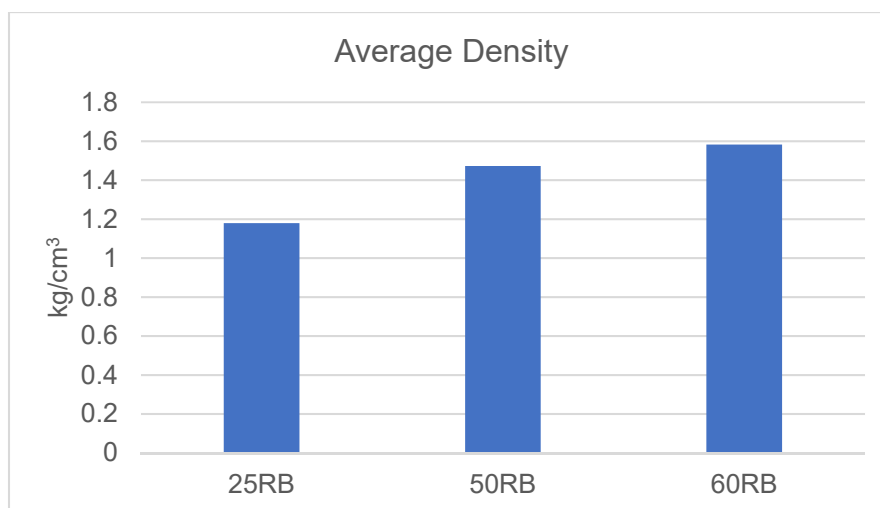


Figure 4.7: Average Densities of Different Compositions

Results show a consistent pattern of direct proportionality between density and redbrick content, because redbrick has a density higher than that of the styrofoam.

### 4.1.3 Test Report for Tension

ASTM D3039/D3039M – 14

Standard Test Method for Tensile Properties of Polymer Matrix

#### General Test Information

- \* Test Date: 18/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Ismail Tammam, Aya Adel, Menna Adel
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

#### Expected Outcomes

- \* Maximum Tensile Load on Sample Section ( $P_{max}$ , kN)
- \* Maximum Extension of Sample at Maximum Load ( $\delta_{max}$ , mm)
- \* Maximum Tensile Stress at Maximum Load ( $\sigma_{max}$ , MPa)
- \* Maximum Tensile Strain at Maximum Load ( $\epsilon_{max}$ )
- \* Material Stress-Strain Curve --
- \* Material Young's Modulus (E, MPa)
- \* Flexural Chord Modulus of Elasticity ( $E_{f^{chord}}$ , MPa)
- \* Flexural Secant Modulus of Elasticity ( $E_{f^{secant}}$ , MPa)

#### Test Description & Equipment Used

The tension test is when an elongated sample of the material is pulled in either direction at a constant rate to determine its stress-strain behaviour until it snaps. The tensile stress-strain diagram shows the yielding of the material and gives an indication on its different mechanical properties such as Young's Modulus, Poisson's ration, and also the location of failure may be indicative of the material behaviour.

The apparatus (refer to 2.A.ii Equipment) is a machine with an accompanying software that imposes a load of a known value and moves at a constant rate, then the software takes record of the extension and load, and knowing the section dimensions it calculates the stress-strain diagram, and consequently Young's Modulus.

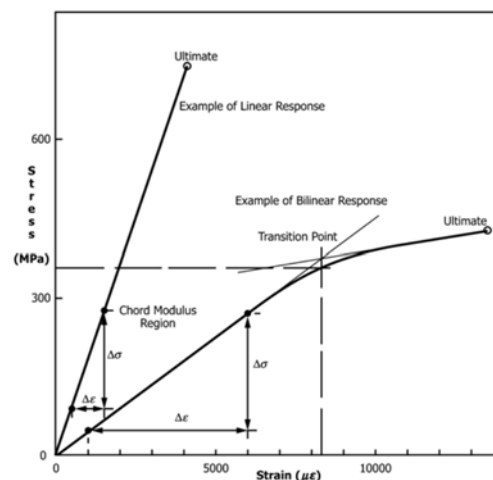


Figure 4.8: Typical Stress-Strain Curve ASTM D3039



## Equations Used

$$\sigma = \frac{P}{A}$$

$$\epsilon = \frac{\delta}{L}$$

$$E_f^{chord} = \frac{\Delta\sigma}{\Delta\epsilon}$$

A = Sample Cross-Sectional Area = 25\*2.5 = 62.5 mm<sup>2</sup>

L = Gage Length = 150 mm

## Material Identification

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	5 Samples each
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 250 X 250 mm moulds.	
	<ul style="list-style-type: none"> <li>* Length: 250 mm</li> <li>* Width: 25 mm</li> <li>* Thickness: 2.5 mm.</li> </ul>	

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 250 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

<b>AA</b>	<b>RB</b>	<b>T</b>	<b>X</b>
-----------	-----------	----------	----------

**AA:** Red Brick Content: 25, 50, 60 %  
**T:** Tension Test Indication

**RB:** Red Brick Indication  
**X:** Sample Number 1 to 5



Figure 4.9: Samples for Tension Test

## Test Procedure

Samples were placed as per their gage length at 50 mm from edges and grips were set accordingly, the machine software was set to a movement speed of 2 mm/sec, and sample dimensions input. Every sample that was tested had its mode of failure recorded and a stress-strain diagram was produced for every sample.

Failure is reported according to the ASTM D3039 Three-Part Failure Identification Code:

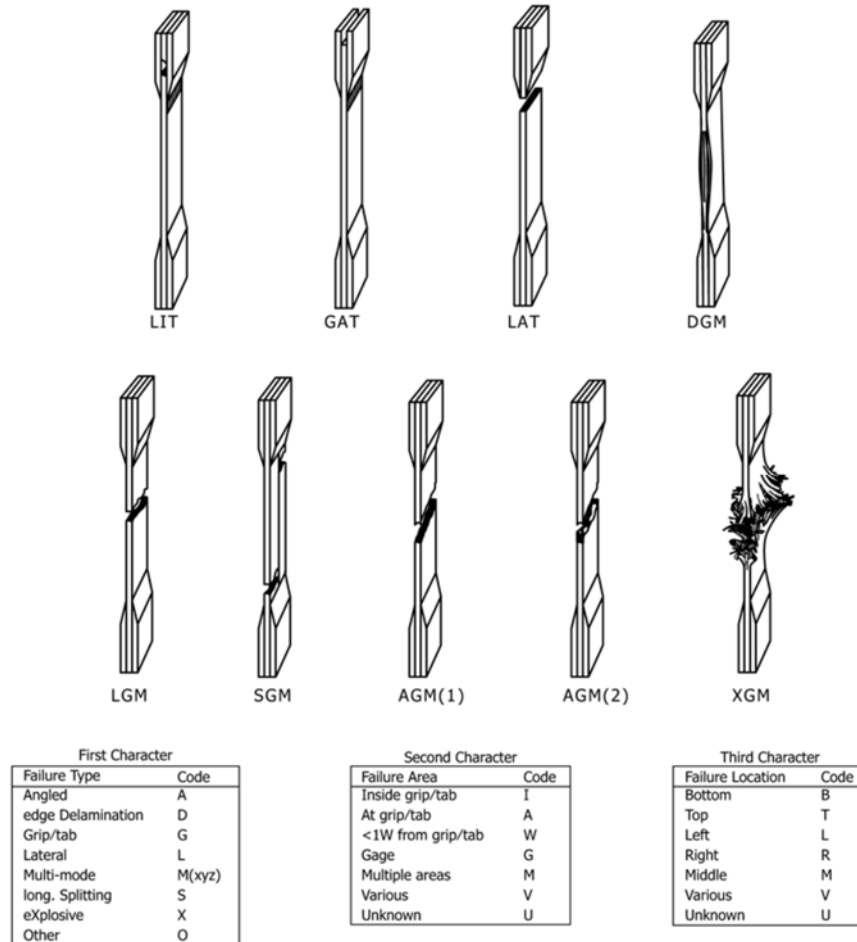


Figure 4.10: Tensile Test Failure Modes/Codes ASTM D3039

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

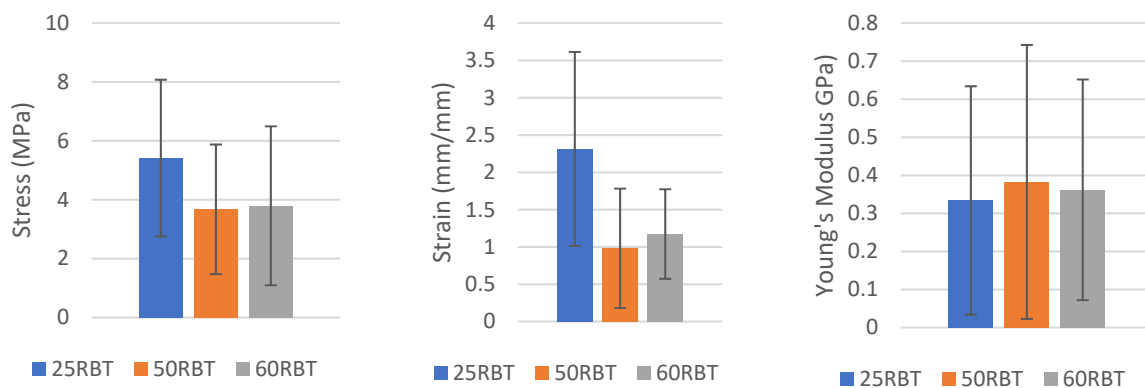


Figure 4.11: Results for Tension Test

It can be seen from the standard deviation that whether the property being measured is the tensile strength, strain, or even Young's Modulus, the test results are highly unreliable and have given no conclusive evidence as to the said mechanical properties. This could be due to the nature of this specific composite material.



## 4.1.4 Test Report for Pin-on-Disc Wear

### General Test Information

- \* Test Date: 19/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Ismail Tammam, Menna Adel
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

### Test Description

The specimen is mounted on a rotating disk and fixed by a pin-like element to allow the rotation of the disk at a known speed while keeping the sample stationary for the test duration. Readings of the sample mass are taken before and after the exposure to rotation, then the difference in volume is calculated to be able to determine the specific wear of the samples against cast iron.

### Expected Outcomes

- \* Specific Wear ( $W$ ,  $\text{mm}^3/\text{N.m}$ )

### Equations Used

$$W = \frac{\Delta V F}{L}$$

$$\Delta V = \frac{\Delta \text{mass}}{\rho}$$

$$L = \text{Rpm} * \text{circumference} * \text{time}$$

$$= 800 * \pi(179.5) * 10 \text{ mins}$$

$$= 451.1327 \text{ m}$$

$$F = \text{mass} * 9.81 \frac{\text{m}}{\text{s}^2} = 3 \text{ kg} * 9.81 = 29.48 \text{ N}$$

$\Delta V$ : Volume Difference

F: Imposed Load

L: Distance covered during rotation

$\rho$ : Sample Density

Rpm: Round per Minute

### Material Identification & Sampling

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	3 Samples each
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 100 X 100 mm moulds.	
	* Length X Width: 30 X 30 mm	
	* Thickness: 10 mm	
	* Centred Notch with 0.5 mm depth and 10 mm diameter.	
	See Figure 4.12 for the typical sample shape.	

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 100 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

AA	RB	W	X
----	----	---	---

**AA:** Red Brick Content: 25, 50, 60 %      **W:** Wear Test Indication

**RB:** Red Brick Indication                      **X:** Sample Number 1 to 3



Figure 4.12: Typical Wear Sample

## Testing Procedure

First, the smoothness of the surface of the sample and the rotating disc is ensured by wiping it thoroughly with an acetone drenched cotton piece. The sample is weighed, mass recorded, then the notched sample is mounted under the pin and the firmness of the contact is ensured to avoid any slippage. The speed controller is set at a frequency of 20 Hz which causes the disc to rotate at 800 Rpm, turned on, time is recorded, and timer set to 10 minutes. Then, the sample is weighed again and mass recorded to the nearest 4 digits.

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

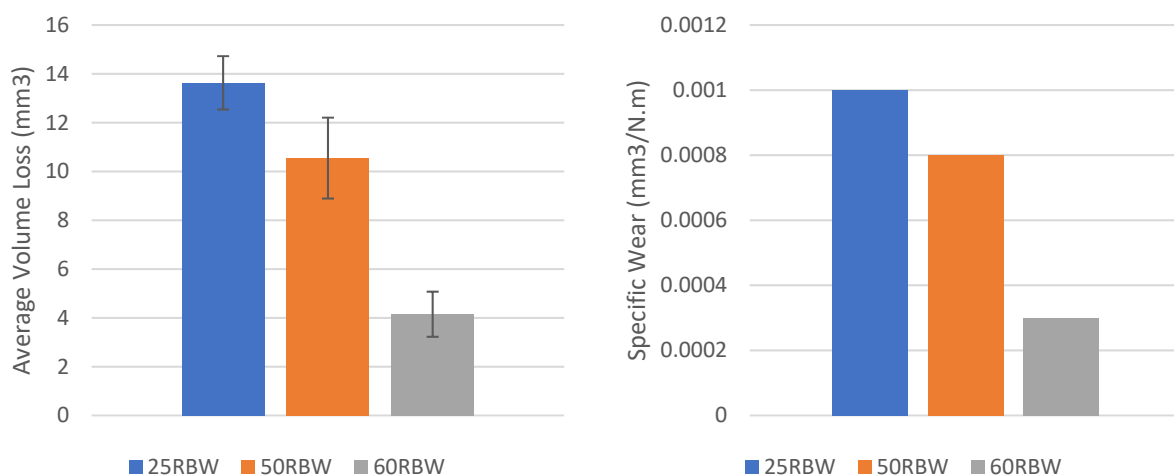


Figure 4.13: Pin-on-Disc Test Results



Results show a clear trend of adverse proportionality between the redbrick content and specific wear of the material against the cast iron disc; as redbrick % increases, the specific wear decreases, which means better performance for the 60 % redbrick content, followed by the 50 %, and 25 % being the lowest.

Referring to (Gomez-Tena, Gilabert, & Toledo, 2011) who assessed the resistance of porcelain tiles to wear using a similar setup, specific wear rate was in the range of 0.0145 to 0.0165 mm<sup>3</sup>/Nm, which is significantly higher than all three samples, indicating better wear resistance of the proposed material.





## 4.1.5 Test Report for Charpy Impact

EN ISO 179-1/2n

Determination of Charpy Impact Properties (Specimen Type 2, Normal Direction)

(reporting of items beyond the control of a given testing laboratory, such as might occur with material details or panel fabrication parameters, shall be the responsibility of the requestor)

### General Test Information

- \* Test Date: 17/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Aya Adel, Menna Adel
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

### Test Description & Equipment Used

The Charpy impact machine imposes an impact with a known velocity, according to a standard setup, and it outputs the hammer lost energy, as well as the angles of free fall and impact.

The machine has a moving pendulum with a hammer edge which is released from a high position to hit the sample which is placed in a lower position in the path of the pendulum, such that the hammer hits the mounted sample in its midspan.

### Expected Outcomes

- \* Charpy Impact Strength (a<sub>cU</sub>, kJ/m<sup>2</sup>)

### Equations Used

$$a_{cU} = \frac{E_c}{hb} * 10^3$$

$$E_c = E_h * [\sin\left(FIA - \frac{\pi}{2}\right) - \sin\left(AIA - \frac{\pi}{2}\right)]$$

E<sub>c</sub>: Corrected Absorbed Energy (J)

E<sub>h</sub>: Hammer Energy (J)

h: Sample Thickness = 8 mm

b: Sample Width = 10 mm

FIA: Free Fall Angle (rad)

AIA: Impact Fall Angle (rad)

## Material Identification & Sampling

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite		
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %		
	Redbrick: 50 %, Styrofoam: 50 %		5 Samples each
	Redbrick: 60 %, Styrofoam: 40 %		
<b>Source</b>	AUC Sustainable Development Labs		
<b>Sample Sizing</b>	Blocks produced from 250 X 250 mm.		
	* Length: 160 mm;		
	* Width: 10 mm;		
	* Thickness: 8 mm.		

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 250 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

AA	RB	I	X
----	----	---	---

**AA:** Red Brick Content: 25, 50, 60 %    **I:** Impact Test Indication

**RB:** Red Brick Indication

**X:** Sample Number 1 to 5



Figure 4.14: Samples for Charpy Impact

## Testing Procedure

The prepared sample was mounted on the Charpy impact machine, and the pendulum hammer was released. The software recorded the energy lost by the hammer and (presumably) gained by the sample to cause its breakage. To calculate the actual (corrected) energy of breakage, the free fall angle, and the impact angle also are recorded to be used to correct the value of the hammer energy. All values are recorded and later used to calculate and average the Charpy impact strength.

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

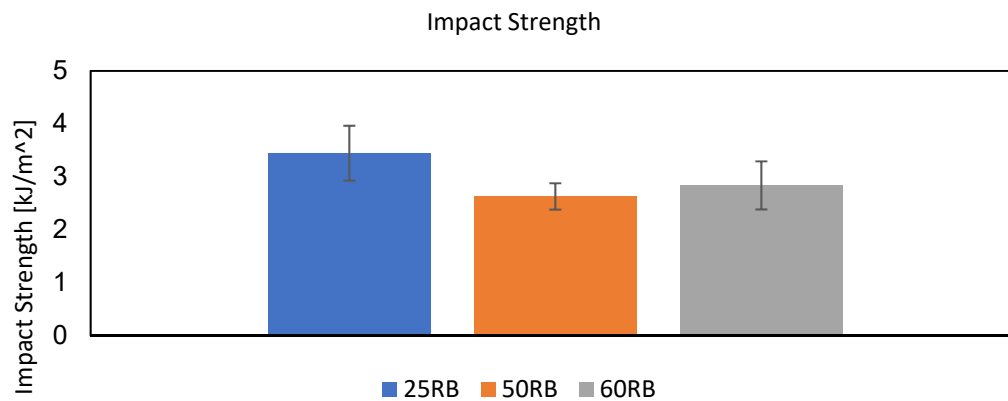


Figure 4.15: Charpy Impact Test Results

The test results show a clear lead in Charpy impact strength for the 25 % redbrick composition samples, which means it absorbs more energy during impact than its counterparts. However, inconclusive evidence regarding the 50 % and 60 % composition, but both show a lower Charpy impact strength. The higher content of polymer chains helps in energy absorption, and gives higher resilience (**Error! Reference source not found.**).

## 4.1.6 Test Report of Resistance to Abrasion

### General Test Information

- \* Test Date: 22/11/2017,
- \* Test Location: Ceramics Lab, American University in Cairo
- \* Test Operators: Ismail Tammam, Dina Fouad
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

### Test Description & Equipment Used

The test is performed by placing the sample, along with the weights as shown in Figure 4.16, on the rotating disk. The rotating disk is covered with a layer of abrasive material (1.5 spatulas) and some water to spread the abrasive material over the rotating disk.

The disk rotates at 60 rpm, and the test is timed at 1.5 minutes (100 rotations) using a 3 kg mass.

The test was performed on 3 samples of each redbrick constituent, then on a single control sample of a typical ceramic flooring tile.



Figure 4.16: Lab Assistant Placing Sample on Rotating Disk

### Expected Outcomes

- \* Mass Loss (%)

### Equations Used

$$\text{Mass Loss \%} = \frac{\text{Mass of Sample after} - \text{Initial Mass}}{\text{Initial Mass}} * 100 = \frac{M_{\text{before}} - M_{\text{after}}}{M_{\text{before}}} * 100$$

### Material Identification

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	3 Samples each
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 50 X 50 mm moulds.	
	* Length X Width: 50 mm X 50 mm	
	* Thickness: 20 mm.	

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 100 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

AA	RB	A	X
----	----	---	---

**AA:** Red Brick Content: 25, 50, 60 %    **A:** Abrasion Test Indication

**RB:** Red Brick Indication                      **X:** Sample Number 1 to 3



Figure 4.17: Samples for Abrasion Test

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

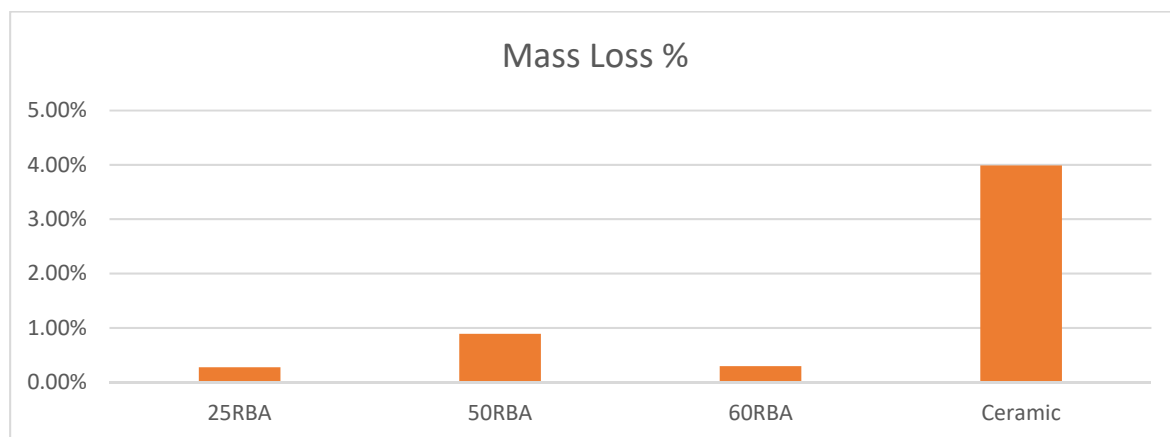


Figure 4.18: Resistance to Abrasion Test Results

The results shown in Figure 4.18 show an inconclusive comparison among the three redbrick compositions, however, compared to the ceramic tile, which has only been tested for 1 minute unlike the remaining samples, it shows significantly lower resistance to abrasion-loses most mass%.



## 4.1.7 Test Report on Water Uptake

### General Test Information

- \* Test Date: 22/10/2017,
- \* Test Location: Polymers Lab, Faculty of Engineering, Ain Shams University
- \* Test Operators: Aya Adel, Menna Adel
- \* Laboratory Temperature: 24 C
- \* Laboratory Relative humidity: 55%

### Test Description & Equipment Used

Before the moisture absorption testing, the composite specimens were dried in an oven at 60°C for 48h until constant weight was attained. The specimens were weighed before placing them in a humidity chamber at 25°C and 100% RH, then weighing daily until the weight became constant (variation less than 0.001 g). The moisture content was then calculated.

### Expected Outcomes

- \* Moisture Uptake (%)

### Equations Used

$$\text{Moisture Uptake} = \frac{\text{Mass of Sample at time } (t) - \text{Initial Mass}}{\text{Initial Mass}} * 100 = \frac{M_t - M_0}{M_0} * 100$$

### Material Identification

<b>Material Type</b>	Polymer matrix with high stiffness filler Composite	
<b>Material Composition</b>	Redbrick: 25 %, Styrofoam: 75 %	
	Redbrick: 50 %, Styrofoam: 50 %	3 Samples each
	Redbrick: 60 %, Styrofoam: 40 %	
<b>Source</b>	AUC Sustainable Development Labs	
<b>Sample Sizing</b>	Blocks produced from 100 X 100 mm moulds.	
	* Length X Width: 3 mm X 3 mm	
	* Thickness: 10 mm.	

## Sample Fabrication & Labelling

Granules of styrofoam and redbrick powder in the specified mix ratios are added to the 100\*100 mm<sup>2</sup> mould, which is then placed on the hydraulic press machine fitted with a heater and digital thermostat. (2.A.ii Equipment).

The produced units were then marked and cut using a steel blade saw (2.A.ii Equipment) into the required dimensions.

Upon cutting, samples are labelled according to the following scheme:

AA	RB	U	X
----	----	---	---

**AA:** Red Brick Content: 25, 50, 60 %    **U:** Water Uptake Test Indication

**RB:** Red Brick Indication

**X:** Sample Number 1 to 3



Figure 4.19: Samples for Water Uptake

## Test Data

For test data, please refer to Appendices, Tests'

## Test Results and Analysis

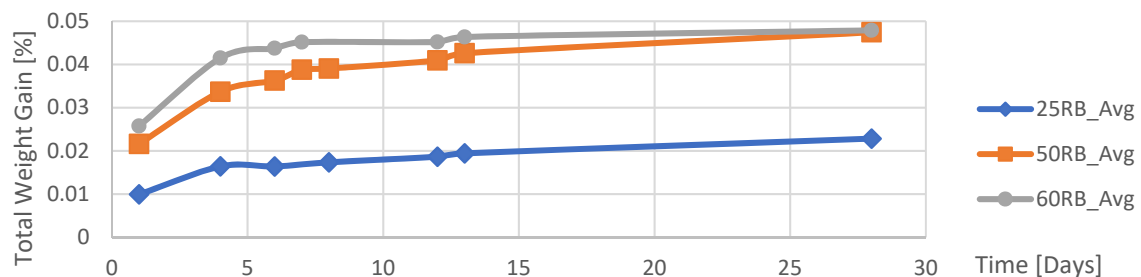


Figure 4.20: Graphical Results of Water Uptake Test

Test results show a clear pattern of direct proportionality between the maximum water uptake and the redbrick content. This makes sense because redbrick is known to have much higher water absorption than polymers; this is displayed in an almost halved water gain when comparing 50RB & 60RB to the 25 RB as per Figure 4.20.



## 4.1.8 SAP Model for Tile Loading

### Parameters

- Units: KN, m
- Loads:
  - Live Load: 5 KN/m<sup>2</sup>
- Shell Sections:
  - 3 mm
  - 6 mm
- Material:
  - ERB25 = 2332901 KN/m<sup>2</sup>
  - Weight per Unit Volume:  $\gamma_{25RB} = 11.562$  KN/m<sup>3</sup>
  - ERB50 = 4093624 KN/m<sup>2</sup>
  - Weight per Unit Volume:  $\gamma_{50RB} = 14.445$  KN/m<sup>3</sup>
  - ERB60 = 3144015 KN/m<sup>2</sup>
  - Weight per Unit Volume:  $\gamma_{60RB} = 15.524$  KN/m<sup>3</sup>

### Dimensions & Layout

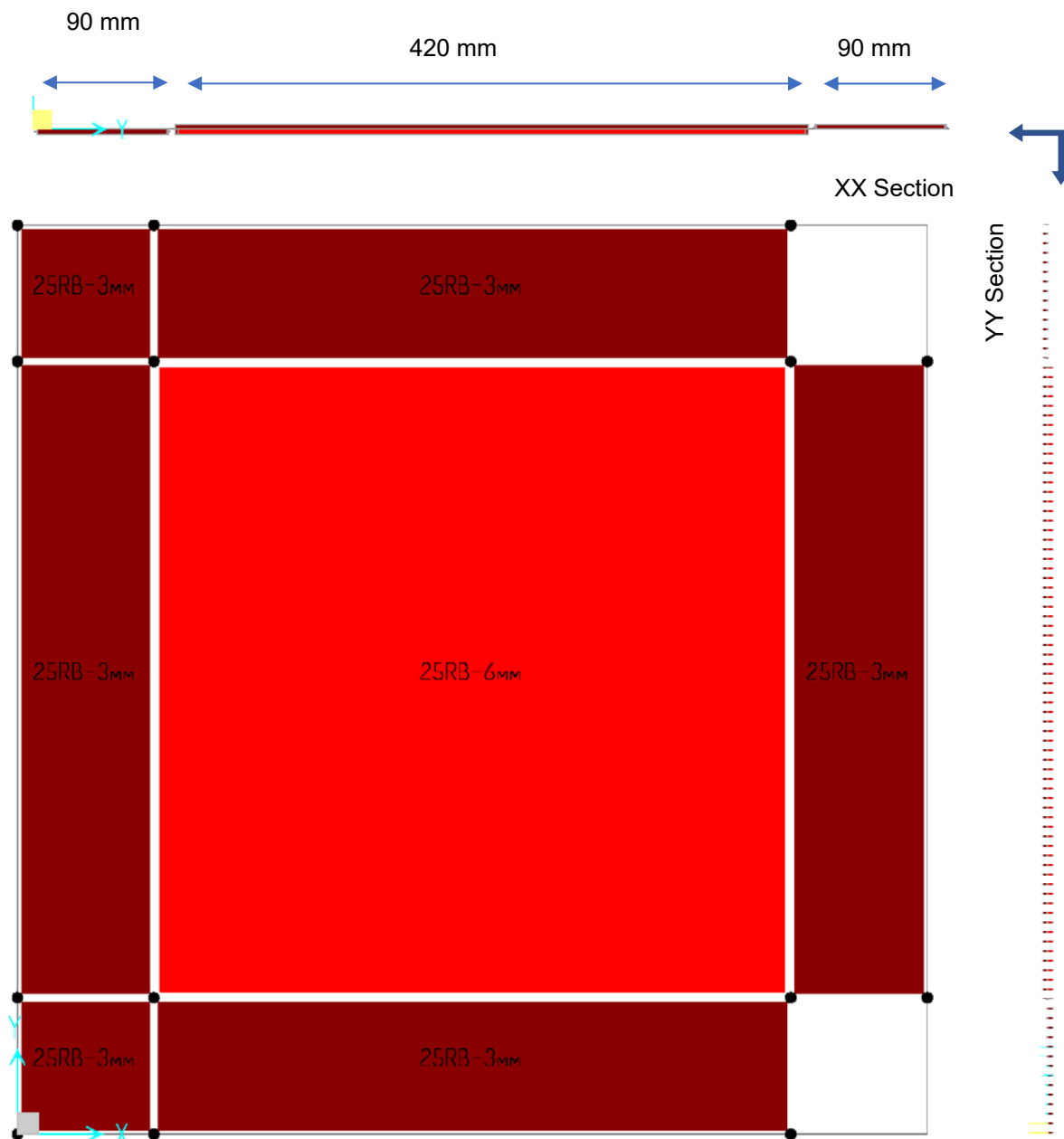


Figure 4.21: SAP Model Dimensioning & Layout (Plan & Sections)

## Equations Used

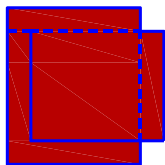
- $\gamma = \rho * a_g$  (Weight per Unit Volume, KN/m<sup>3</sup>)
- $k = \frac{E}{h}$  (Area Spring Stiffness, KN/m)
  - E: Young's Modulus, obtained from Three-Point Bending Test (MPa)
  - h: Thickness of tile in contact (mm)

## Restraints

- Area Springs for parts in contact with adjacent tiles
  - $k_{RB25} = 2332901/0.003 = 777,633,667$  KN/m
  - $k_{RB50} = 4093624/0.003 = 1,364,541,333$  KN/m
  - $k_{RB60} = 3144015/0.003 = 1,048,005,000$  KN/m
- Translation restraint for X & Y directions according to loading cases#

## Results

\*The red-shaded areas are the ones assume to bear all the tile loading.



### Normal Case

Ideally, the tile is correctly placed in a level manner with no voids or bumps; equal load distribution and load reaction, no significant stresses to report.

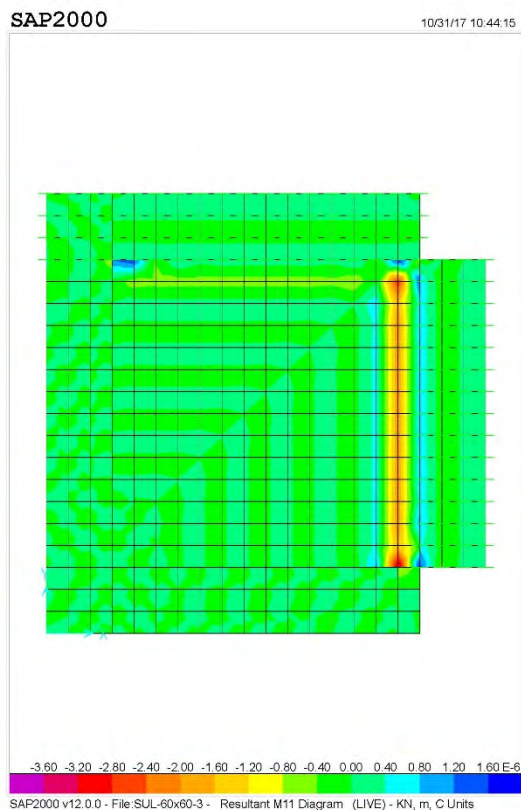


Figure 4.22: SAP 25RB, M11, Normal Case

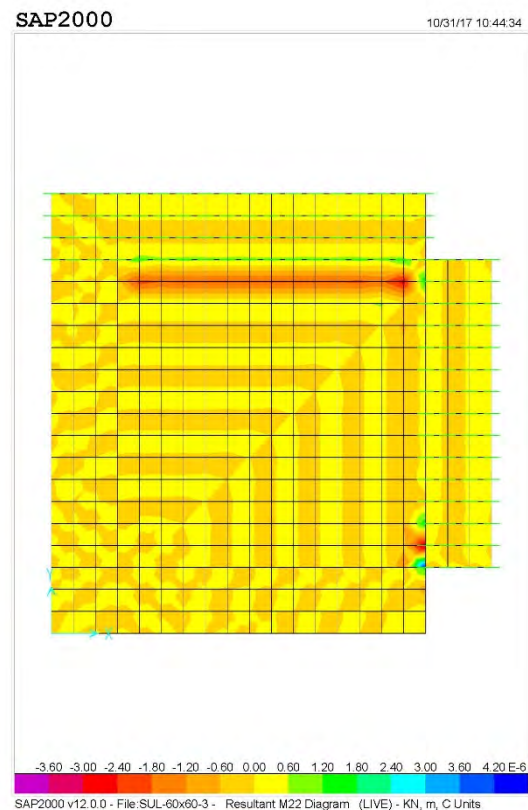
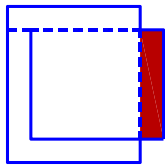


Figure 4.23: SAP 25RB, M22, Normal Case



### 25RB Critical Case 1 – Cantilever X

Assuming a void under the whole tile with only the shaded edge supported on the adjacent tile, generating maximum negative moment.

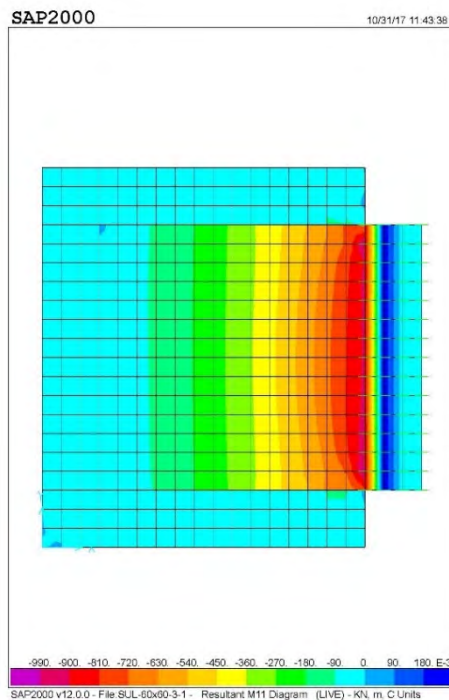


Figure 4.24: SAP 25RB, M11, Case 1

-1 KN/m'

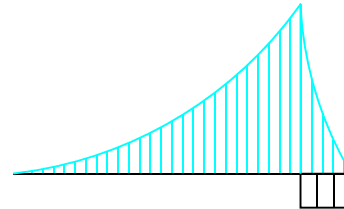
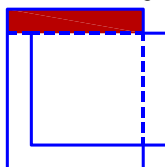


Figure 4.25: 25RB Case 1 Bending Moment Diagram

This bending moment diagram in Figure 4.25 shows the cantilever effect causing a maximum negative moment of 1 KN.m/m'. This moment is achieved at the limiting edge line between the supporting edge and the rest of the tile as per Figure 4.24.



### 25RB Critical Case 2 – Cantilever Y

Assuming a void under the whole tile with only the shaded edge supported on the adjacent tile, generating maximum negative moment.

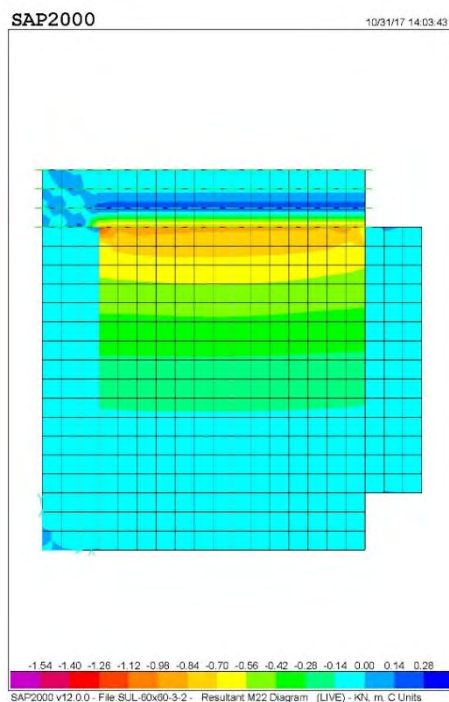


Figure 4.26: SAP 25RB, M22, Case 2

-0.9 KN.m/m'

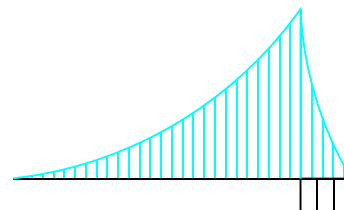
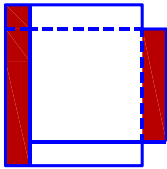


Figure 4.27: 25RB Case 2 Bending Moment Diagram

This bending moment diagram in Figure 4.27 shows the cantilever effect causing a maximum moment of 1 KN.m/m'. This moment is achieved at the limiting edge line between the supporting edge and the rest of the tile as per Figure 4.26.



### 25RB Critical Case 3 – Positive X

Assuming only the two shaded sides of the tile are supported with a void underneath its midsection, generating the maximum positive moment.

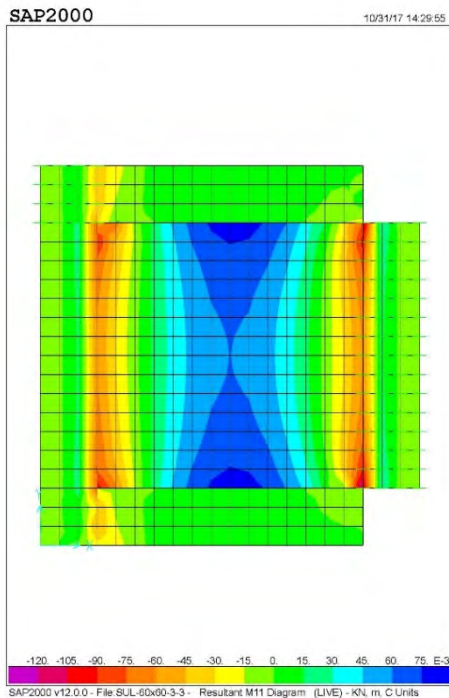


Figure 4.28: SAP 25RB, M11, Case 3

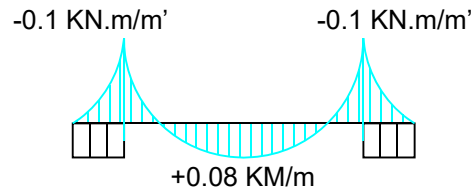
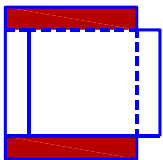


Figure 4.29: 25RB Case 3 Bending Moment Diagram

The bending moment diagram in Figure 4.29 shows a typical beam with cantilevers shape, due to the stiffness of the connecting wall between the 6 mm and 3 mm edge, which acts as a fixation rather than being a hinge. As per Figure 4.28, the area of highest negative moment is the connecting edges on both sides, and the maximum positive moment is achieved midspan. Highest negative moment achieved was  $-0.1 \text{ KN.m/m'}$ , and highest positive bending moment was just  $+0.08 \text{ KN.m/m'}$ .



### 25RB Critical Case 4 – Positive Y

Assuming only the two shaded sides of the tile are supported with a void underneath its midsection, generating the maximum positive moment.

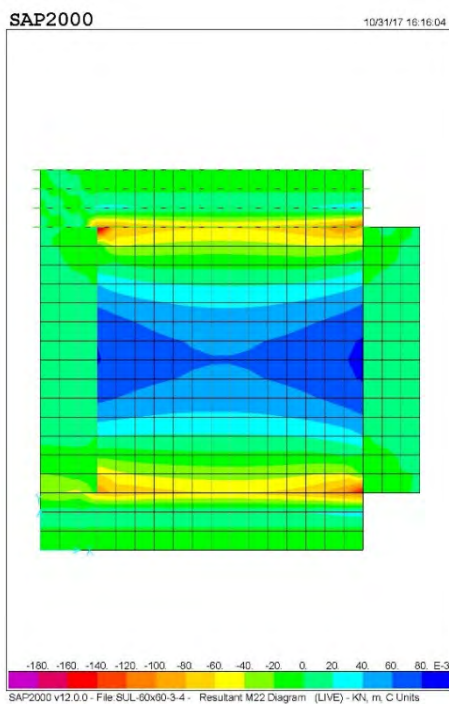


Figure 4.30: SAP 25RB, M22, Case 4

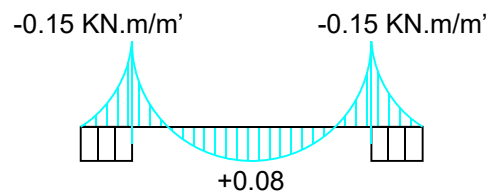
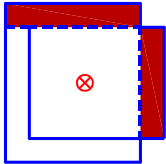


Figure 4.31: 25RB Case 4 Bending Moment Diagram

The bending moment diagram in Figure 4.31 shows a typical beam with cantilevers shape, due to the stiffness of the connecting wall between the 6 mm and 3 mm edge, which acts as a fixation rather than being a hinge. As per Figure 4.30, the area of highest negative moment is the connecting edges on both sides, and the maximum positive moment is achieved midspan. Highest negative moment achieved was  $-0.15 \text{ KN.m/m'}$ , and highest positive bending moment was just  $+0.08 \text{ KN.m/m'}$ .





### 25RB Critical Case 5 – Pebble Loading

This is an imagined worst-case scenario of a pebble stuck under the tile during installation, causing a concentration of stresses in the tile, and an expected void at the other end.

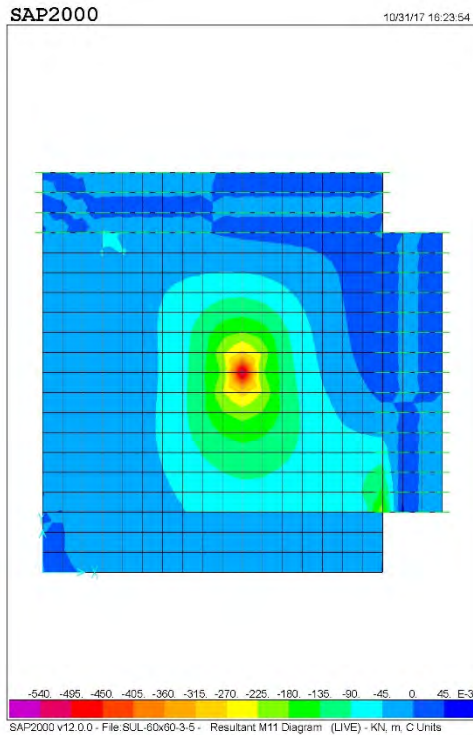


Figure 4.32: SAP 25RB, M11, Case 5

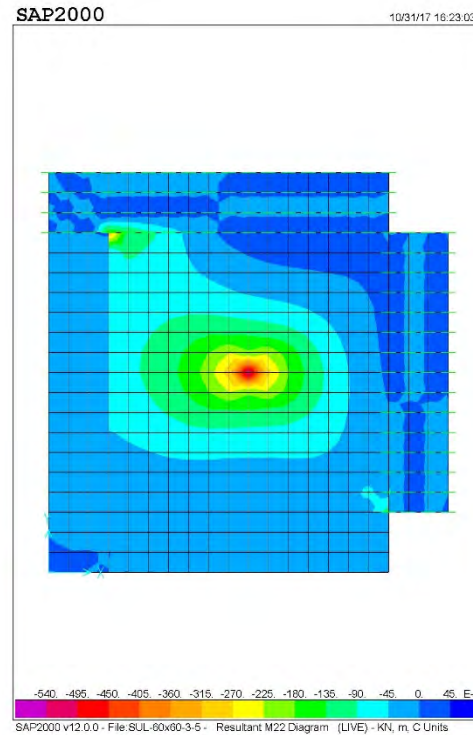


Figure 4.33: SAP 25RB, M22, Case 5  
-0.6 KN.m/m'

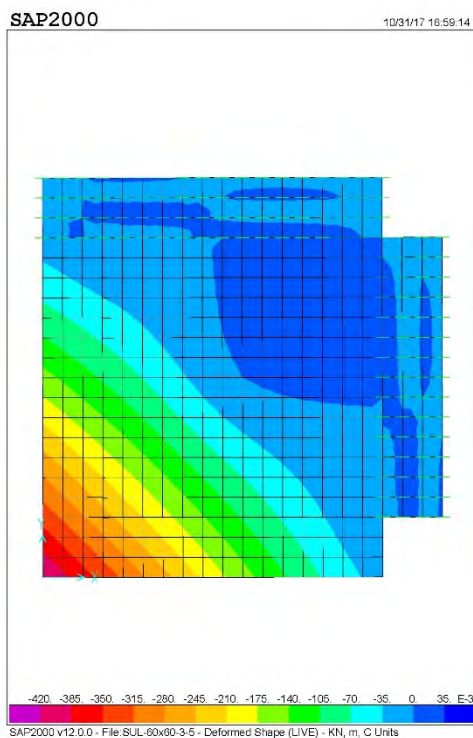


Figure 4.34: SAP 25RB, U3 Load Deflection, Case 5

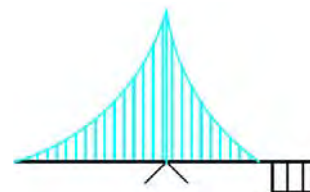


Figure 4.35: 25RB Case 5 Bending Moment Diagram

Figure 4.34 shows the manner by which the tile has awkwardly deflected due to the pin-like support of the assumed pebble. The bottom-left edge which is unsupported has theoretically deflected and risen by nearly 420 mm, which is realistically not possible due to the presence of the adjacent confining tiles.

This deflection generates a negative bending moment of just 0.6 KN.m/m', in the critical strip just above the assumed pebble as per Figure 4.35, Figure 4.32, and Figure 4.33.

Note that results for the 50RB and 60RB file were almost identical to the 25RB.



## 4.2 Business Works

Assessing the business performance can only be done after a year's operation takes place. However, forecasts are required to be able to set forth a view of whether the product line is feasible and would generate enough profit for future sustenance of the business. The author used 8 different scenarios to predict the possible future performance and then picked the most realistic to assess the breakeven time and the financial ratios based on both the income statement and the balance sheet.

Even in the worst-case scenarios, the breakeven period lasted no more than 13 months, and return on assets was 9 %. This indicates the high profitability potential as well as high resilience of the business even if no significant annual investment takes place to boost productivity. It is also shown through trial and error that the number of units produced per day is the most critical factor in determining the profitability of the business as a whole.

## 4.3 Sustainable Development Context

Tackling unemployment, the proposed process managed to establish a business that directly employed at least 13 Egyptians in its first forecasted year, indirectly employed suppliers, drivers, as well as giving further opportunity to several entrepreneurs to establish their own ventures that employ further people. The first year only saw turning 2.1 tonnes of redbrick and 2.1 tonnes of styrofoam from discarded trash to flooring tiles using minimum energy and causing minimum environmental effect, especially if compared to normal ceramic tiles.

The three-staged process is projected to improve the socio-economic conditions of people in direct or indirect employment, while also improving the environment by recycling and encouraging recycling product design.



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## Chapter 5: Conclusion and Recommendations

The core attempt of the thesis has been to formulate a model that would ensure a win-win solution to the main problems faced by Egyptian entrepreneurs, while still being profitable to the business that sponsor it. Furthermore, the study specifically discusses the product and business development, where not only does it provide a very feasible product 'the faux-granite tile', but it also provides a very useful and workable template for any similar product.

1. The core issue selected by the author was sustainable development by eradicating unemployment, which complies with SDG target 8.6: "By 2020, substantially reduce the proportion of youth not in employment, education or training".
2. Based on reading the status quo of the Egyptian economy and employment figures, and on the state of entrepreneurship in Egypt, it was found that many potential jobs can be created by simply helping Egyptians with the poor entrepreneurial education at all stages and the poor legal & commercial infrastructure.
3. It was also found that the best way to achieve that is by implementing an Egyptian version of the US and European business incubators which come in many forms based on their funding and targets. The existing Egyptian accelerators were reviewed to understand the status quo of the Egyptian start-up scene was achieved through (Saeed, El-Aasser, & Wasfy, 2015) Egyptian Entrepreneurship Theory of Change.
4. The literature helped formulate the thesis hypothesis, which is the Three-Stage Entrepreneurial Model that includes: Matrix Model, Alpha Product, and Incubation. The model assumes a single entrepreneur's idea as a start-up for more than just one business; first the entrepreneur formulates the matrix model, which is his plan for product and business development, then the alpha product development and its business planning and development, and finally once a successful product line is created incubation of other entrepreneurs while getting a long-term benefit for the incubation services.
5. The matrix model was drawn out, defining the specific tasks to work through to develop the product and business. This was based on the Theory of Change. The alpha product typically consists of 4 stages: Conceptualisation, Design Development, Business Development, and Business Launch. Due to time and resource constraints of the thesis, only the majority of the tasks from the first three stages were discussed in detail.
  - a. Conceptualisation constituted of early product development, where tests were performed to understand the material and to draw out conclusions on its possible uses.
  - b. Design Development saw the actual product testing, mentioning all required facilities and core tests along with a thorough analysis of every tests' results; Flexure, Tension, Density, Water Uptake, Pin-on-Disc Wear, Abrasion and Charpy.
  - c. Then came the Business Development phase, which included a business plan with sections discussing an analysis of the industry, a description of the company, a narrative of the operations and design & development plans, a marketing plan, and finally a realistic representation of the breakeven chart, financial pro-forma statements and expected financial ratios.
6. The services intended to be provided by the incubator, as well as the business model for the successful operation of the incubator are briefed out as a cornerstone for application as soon as the business generates a single pound of profit. (Expected in no more than a year of operation)

Though the thesis aims to reconcile what has been considered unreconcilable, the author's firm belief is that the future is in greening the economy by finding win-win pilot solutions to sustainably develop.



## Recommendations

During the making of this thesis, the author came across several subsidiary research-points whose inclusion in the scope would have cost much time and effort, as well as possible distraction from the main focus question and hypothesis under investigation. These points were mostly either product-related or business-related, as such:

### Product related:

- \* Working on developing alternative product uses.
- \* Trying use of different materials to form the tiles.
- \* Optimising a range of products and materials and studying their feasibility.
- \* Installing the tiles and using them in a high-traffic area to study its performance.

### Business related:

- \* Interviews with owners and operators of start-up accelerators in Egypt to fine-tune the proposed incubator model.
- \* Interviews with a general selection of entrepreneurs to better understand the start-up scene and success requirements.
- \* Seeking professional aid with the formulation of each section of the business plan:
- \* Business Developer for the industrial analysis
- \* Production Engineer for the design & development
- \* Financier for the pro-forma financial statements



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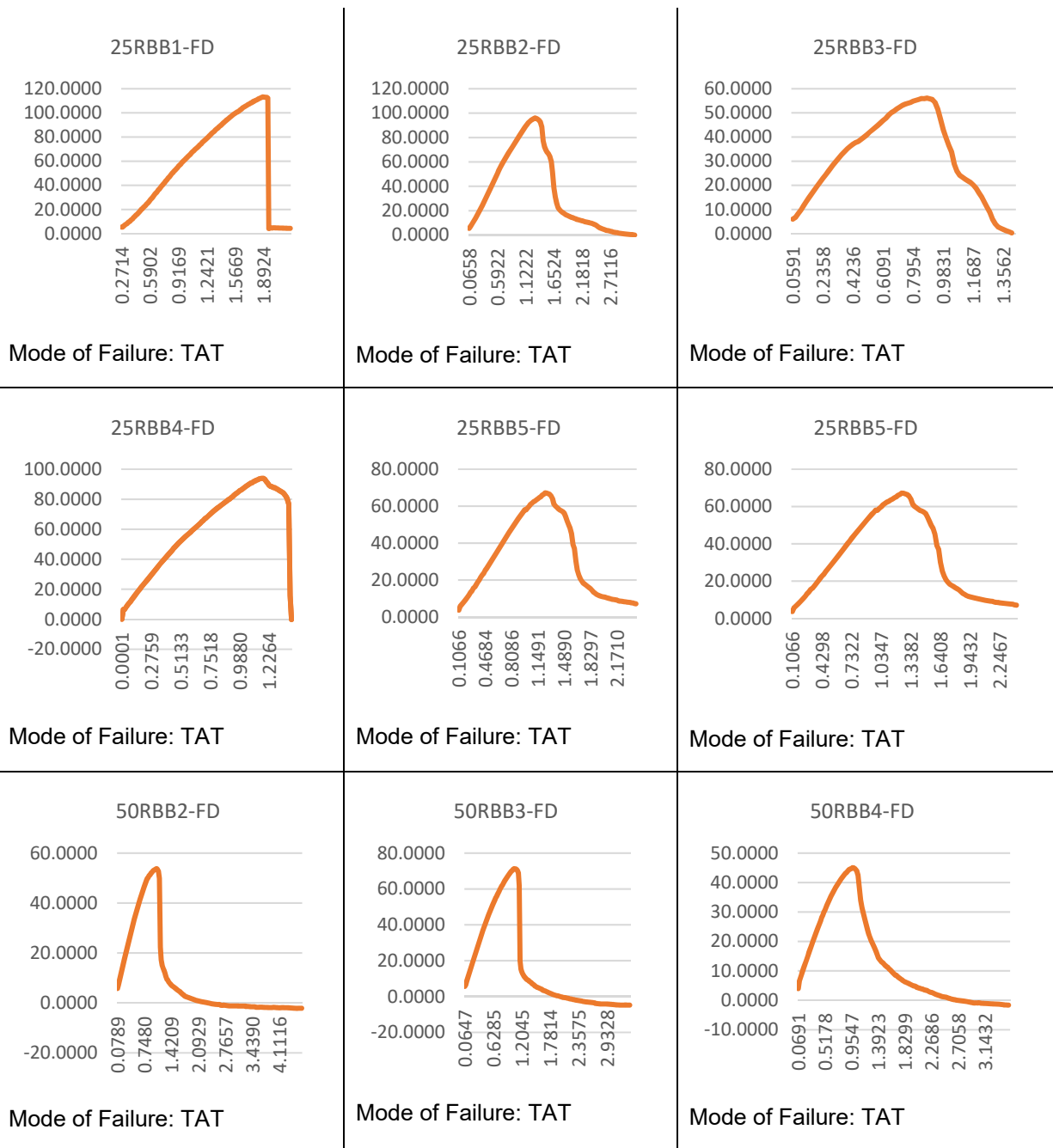
# Appendices

## Tests' Data

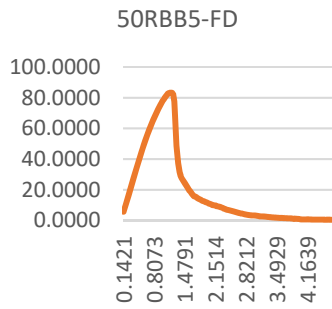
### Test Report for Three-Point Bending

#### Force-deflection curves:

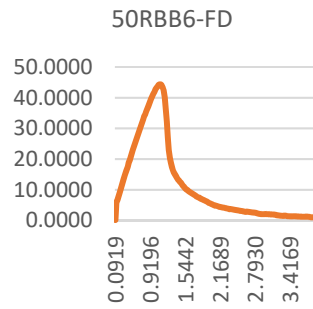
For each sample, the load-extension combination is recorded throughout the testing process until failure occurs. The following diagrams show the behaviour of each sample up to the point of its break.



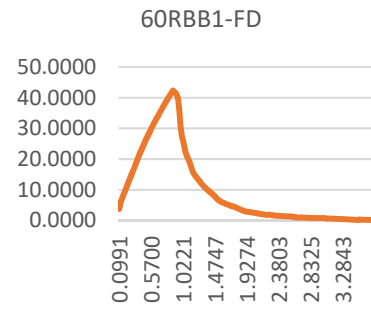




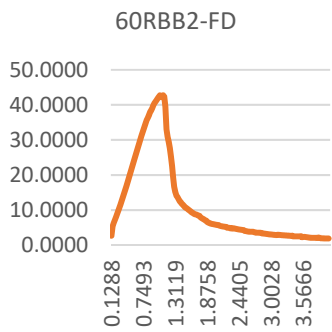
Mode of Failure: TAT



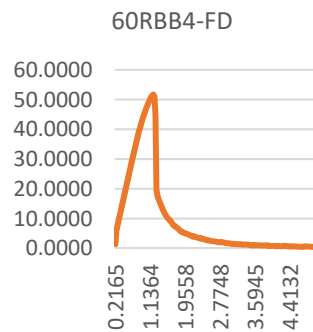
Mode of Failure: TAT



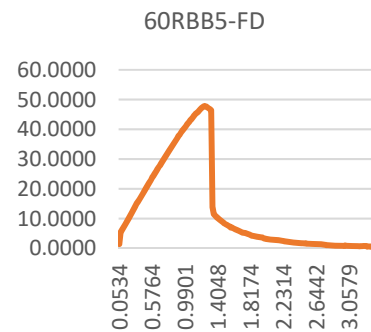
Mode of Failure: TAT



Mode of Failure: TAT



Mode of Failure: TAT



Mode of Failure: TAT

Failure is reported according to the ASTM D7264 Three-Part Failure Identification Code:

<u>First Character</u>		<u>Second Character</u>		<u>Third Character</u>	
Failure Mode	Code	Failure Mode	Code	Failure Mode	Code
Tension	T	At loading nose	A	Top	T
Compression	C	Between loading noses	B	Bottom	B
Buckling	B	At support nose	S	Left	L
Interlaminar Shear	S	Between load & support	L	Right	R
Multi-mode	M(xyz)	Unknown	U	Middle	M
Other	O			Various	V
				Unknown	U



## Maximum Loads, Stresses, Strains, and Young's Modulus

Table 0.1: Tabulated data of maximum loads, flexural stresses and strains, as well as Young's modulus.

	Maximum Load (kN)	Maximum Bending Stress at Maximum Load (MPa)	Maximum Bending Strain at Maximum Load	Young's Modulus of Bending (MPa)
60RBB1	0.0427	11.97	0.0044	3276.10
60RBB2	0.0428	12.53	0.0052	3071.42
60RBB3	0.0422	11.09	0.0046	3937.57
60RBB4	0.0517	13.35	0.0053	3131.23
60RBB5	0.0478	12.35	0.0064	2303.76
50RBB2	0.0539	13.19	0.0064	3108.98
50RBB3	0.0714	18.00	0.0064	4390.52
50RBB4	0.0451	15.94	0.0050	4601.96
50RBB5	0.0835	20.24	0.0066	4242.40
50RBB6	0.0445	14.49	0.0047	4124.26
25RBB1	0.1134	21.60	0.0114	2468.47
25RBB2	0.0962	15.58	0.0104	2000.91
25RBB3	0.0563	9.57	0.0064	2661.28
25RBB4	0.0938	15.96	0.0087	2340.91
25RBB5	0.0672	14.94	0.0078	2192.93

Table 0.2: Tabulated mean results for every sample composition, reporting Young's modulus, maximum bending stress and Modulus of Resilience

	Young's Modulus (MPa)	Standard Deviation (MPa)	Maximum Bending Stress (MPa)	Standard Deviation (MPa)	Maximum Bending Strain (%)	Standard Deviation (%)	Modulus of Resilience (MPa)
60RBB	3144.015	± 582.802	12.260	± 0.822	0.5 %	± 0.08 %	0.024
50RBB	4093.624	± 578.608	16.371	± 2.807	0.6 %	± 0.09 %	0.033
25RBB	2332.901	± 253.027	15.531	± 4.271	0.9 %	± 0.20 %	0.052

## Test Report for Specifying Density

Table 0.3: Tabulated Results of Densities of Different Compositions

	Sample 1	Sample 2	Sample 3	Average Density (g/cm <sup>3</sup> )	Standard Deviation
<b>25RB</b>	1.185	1.153	1.198	1.179	± 0.023
<b>50RB</b>	1.481	1.466	1.471	1.473	± 0.008
<b>60RB</b>	1.569	1.602	1.579	1.583	± 0.017

## Test Report for Tension

Table 0.4: Tabulated Results of Tension Test

	Maximum Load (kN)	Maximum Tensile Stress (MPa)	Maximum Tensile Strain	Young's Modulus (GPa)
25RBT1	1.26	8.02	3.538	0.26
25RBT2	1.17	7.13	2.682	0.46
25RBT3	0.85	5.7	1.568	0.79
25RBT4	0.82	5.12	3.344	0.1
25RBT5	0.2	1.12	0.436	0.06
50RBT1	0.65	4.33	1.034	0.9
50RBT2	0.24	1.57	0.356	0.06
50RBT3	1.04	6.47	2.1	0.3
50RBT4	0.37	2.34	0.436	0.27
50RBT5				
60RBT1	0.305	7.989	1.486	0.17
60RBT2	0.43	2.6	1.034	0.15
60RBT3	0.69	4.96	1.664	0.14
60RBT4	0.465	1.956	1.502	0.73
60RBT5	0.22	1.47	0.178	0.62

Table 0.5: Tabulated Mean Results of Tension Test

	Maximum Tensile Stress (MPa)	Standard Deviation	Maximum Tensile Strain	Standard Deviation	Young's Modulus (GPa)	Standard Deviation
25RBT	5.418	± 2.66	2.3136	± 1.3	0.334	± 0.3
50RBT	3.6775	± 2.2	0.9815	± 0.8	0.3825	± 0.36
60RBT	3.795	± 2.7	1.1728	± 0.6	0.362	± 0.29

## Test Report for Pin-on-Disc Wear

Table 0.6: Tabulated Results of Pin-on-Disc Test

	Mass (Kg)	Duration	Initial Mass (g)	Final Mass (g)	Mass Loss (g)	Volume Loss (mm <sup>3</sup> )	W=V/FL (mm <sup>3</sup> /N.m)
25RBW1	1.5	00:05	5.3245	5.3139	0.0106	--	--
25RBW1	1.5	00:20	5.3139	5.2753	0.0386	--	--
25RBW1	3.0	00:10	5.2753	5.2578	0.0175	14.8473	0.0011
25RBW2	3.0	00:10	6.3915	6.3765	0.0150	12.7262	0.0010
25RBW3	3.0	00:10	5.8387	5.8230	0.0157	13.3201	0.0010
50RBW1	3.0	00:10	10.2433	10.2258	0.0175	11.8832	0.0009
50RBW2	3.0	00:10	9.1886	9.1723	0.0163	11.0684	0.0008
50RBW3	3.0	00:10	10.2778	10.2650	0.0128	8.6917	0.0007
60RBW1	3.0	00:10	11.4033	11.3965	0.0068	4.2947	0.0003
60RBW2	3.0	00:10	10.6295	10.6245	0.0050	3.1579	0.0002
60RBW3	3.0	00:10	11.1182	11.1103	0.0079	4.9895	0.0004

Table 0.7: Tabulated Mean Results of Pin-on-Disc Test

	Average Mass Loss (g)	Average Volume Loss (mm <sup>3</sup> )	Standard Deviation	Specific Wear (mm <sup>3</sup> /Nm)
25RBW	0.0161	13.6312	± 1.094	0.0010
50RBW	0.0155	10.5478	± 1.658	0.0008
60RBW	0.0066	4.1474	± 0.925	0.0003

## Test Report for Charpy Impact

Table 0.8: Tabulated Data of Charpy Impact Test

Sample	Thickness [mm]	Width [mm]	Free Impact Angle (rad)	Impact Fall Angle (rad)	Absorbed Energy [J]	Impact Strength [kJ/m <sup>2</sup> ]
25RBI1	8.85	8.15	149.805	142.87	0.2682	3.7185
25RBI2	8.88	6.55	150.255	146.25	0.1471	2.5289
25RBI3	8.61	10.64	150.255	141.48	0.3434	3.7485
25RBI4	8.75	9.35	149.895	142.15	0.3020	3.6908
25RBI5	8.79	10.66	150.255	141.75	0.3317	3.5400
50RBI1	6.57	9.64	150.120	145.12	0.1869	2.9506
50RBI2	7.01	7.70	149.940	145.98	0.1466	2.7166
50RBI3	7.00	6.83	149.670	146.16	0.1301	2.7221
50RBI4	7.04	7.53	150.525	147.06	0.1253	2.3640
50RBI5	7.03	6.30	150.255	147.33	0.1058	2.3887
60RBI1	5.46	10.03	150.705	147.37	0.1198	2.1870
60RBI2	5.45	9.84	150.435	146.65	0.1379	2.5709
60RBI3	5.6	9.37	150.480	145.89	0.1689	3.2186
60RBI4	5.71	9.70	150.165	145.75	0.1635	2.9517
60RBI5	5.94	10.61	150.705	145.17	0.2050	3.2535

Table 0.9: Tabulated Results of Charpy Impact Test

	Absorbed Energy (J)	Impact Strength (kJ/m <sup>2</sup> )	Standard Deviation
25RBI	0.2784	3.4453	0.5185
50RBI	0.1389	2.6284	0.2488
60RBI	0.1590	2.8363	0.4543

## Test Report of Resistance to Abrasion

Table 0.10: Tabulated Results of Abrasion Test

	M <sub>before</sub> (g)	M <sub>after</sub> (g)	Duration (mins)	Mass Loss (g)	Mass Loss %
25RBA1	72.8	72.6	1.5	0.2	0.27%
25RBA2	72.2	72.0	1.5	0.2	0.28%
25RBA3	73.3	73.1	1.5	0.2	0.27%
50RBA1	78.5	77.8	1.5	0.7	0.89%
50RBA2	78.0	77.5	1.5	0.5	0.64%
50RBA3	79.0	78.1	1.5	0.9	1.14%
60RBA1	79.3	79.1	1.5	0.2	0.25%
60RBA2	77.8	77.5	1.5	0.3	0.39%
60RBA3	81.6	81.4	1.5	0.2	0.25%
Control	75.2	72.2	1.0	3.0	3.99%

## Test Report on Water Uptake

Table 0.11: Tabulated Data of Water Uptake Test

Sample	Before Oven	Time (days)									
		0	1	4	5	6	7	8	12	13	28
25RBU1	5.151	5.137	5.185	5.223	5.214	5.221	5.218	5.222	5.233	5.237	5.252
25RBU2	3.678	3.668	3.707	3.729	3.718	3.727	3.727	3.729	3.732	3.737	3.749
25RBU3	4.289	4.278	4.321	4.345	4.339	4.350	4.350	4.358	4.362	4.363	4.381
50RBU1	3.259	3.246	3.317	3.359	3.354	3.367	3.375	3.377	3.383	3.389	3.403
50RBU2	3.622	3.609	3.672	3.712	3.709	3.720	3.732	3.735	3.740	3.744	3.764
50RBU3	3.308	3.294	3.379	3.419	3.418	3.429	3.436	3.433	3.441	3.448	3.463
60RBU1	3.324	3.311	3.396	3.448	3.444	3.458	3.461	3.455	3.462	3.465	3.473
60RBU2	3.574	3.560	3.639	3.693	3.686	3.703	3.709	3.702	3.709	3.715	3.718
60RBU3	3.603	3.590	3.695	3.753	3.742	3.758	3.763	3.755	3.762	3.765	3.769

Table 0.12: Tabulated Results of Water Uptake Test

Sample		Time (days)									
		0	1	4	5	6	7	8	12	13	28
25RB	Weight [g]	4.361	4.404	4.432	4.424	4.432	4.431	4.437	4.442	4.446	4.460
	Gain [%]	0.000	0.010	0.006	0.002	0.002	0.000	0.001	0.001	0.001	0.003
	Total Gain [%]	0.000	0.010	0.016	0.014	0.016	0.016	0.017	0.019	0.019	0.023
50RB	Weight [g]	3.383	3.456	3.497	3.493	3.505	3.514	3.515	3.521	3.527	3.543
	Gain [%]	0.000	0.022	0.012	0.001	0.003	0.002	0.000	0.002	0.002	0.005
	Total Gain [%]	0.000	0.022	0.034	0.033	0.036	0.039	0.039	0.041	0.043	0.047
60RB	Weight [g]	3.487	3.576	3.631	3.624	3.639	3.644	3.637	3.644	3.648	3.654
	Gain [%]	0.000	0.026	0.015	0.002	0.004	0.001	0.002	0.002	0.001	0.001
	Total Gain [%]	0.000	0.026	0.041	0.039	0.044	0.045	0.043	0.045	0.046	0.048