

Development of container based community factories

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Abstract

The main obstacle to electrification in Africa is not constructing power stations and building overhead power lines. It is working out how to help the region's households acquire sustainable energy with limited and irregular cash flows, little collateral and no access to credit. They cannot afford to pay for the huge investment needed to bring electricity to them. Even if the electricity was brought to them, most can barely afford to pay for usage. This problem can only be addressed by providing tools that bring wealth to the communities. After water, food and shelter comes the need of lighting to extend the productive hours of the day. The Department of Mechanical Engineering at the University of Johannesburg, in collaboration with Ecovest, a South African upcoming small scale enterprise, developed an innovative solar home lighting solution that can be manufactured off the grid in a community based container factory. Solar lighting is significant for many without electricity and the developed solution allows the Sun to pay to eradicate expensive unsustainable on-grid energy. The container based solution empowers the community to create jobs and generate wealth while producing affordable durable products due to reduced distribution and marketing costs. In existing and emerging markets, the gross product cost includes the costs of distribution which is well developed in existing markets but poorly developed in the emerging African market. Additionally, existing markets innovate incrementally (features of products) whilst emerging markets innovate radically (sustainable technology). Moving users from hazardous and expensive open flame solutions like candles to solar home systems, provides a more sustainable standard of living for off grid living.

Keywords: Community factories, Container factories, Home lighting system, Open community manufacturing, Solar Energy

Introduction and motivation

The current global economic conditions are worsening poverty levels, especially in developing countries. This is more pronounced in Sub-Saharan Africa. The economic conditions of most of these countries is directly linked to low levels of manufacturing. Most of the goods and services consumed are imported. This is despite the large resource base most African countries sit on. The main exported commodities of African nations include unprocessed gold and diamonds, oil, cocoa, timber and palm oil (Economy Watch 2010). The main imported commodities include finished machinery and equipment, scientific equipment and food. Imports from the USA have been reported to increase more than 100 % between 2009 and 2013 (International Trade Administration, US Department of Commerce 2014). Some of the imported products can be manufactured or partly manufactured locally. This provides significant hope and possibility to create employment and mitigate poverty levels.

The lack of production capacity in most Sub-Saharan countries is a major concern as GDP growth and poverty alleviation hinges on manufacturing as an engine for economic growth and development. The modern society depends on manufacturing capability and capacity. The state of society depends on the state of manufacturing as it promotes economic activities in all the other sectors. Having a strong manufacturing base is a prerequisite to eradicating poverty. The economic boom that has been observed in the

countries Brazil, Russia, India, China and South Africa (BRICS), is testimony that this comes at the back of widespread manufacturing growth in both consumer products (toys and clothing from China) and machinery such as the automotive sector. Therefore, there is need to implement programs to stimulate and broaden manufacturing with special focus on the local manufacture of products.

One program that has potential to achieve this is the concept of open community manufacturing (OCM) (Oosthuizen, et al. 2014). OCM is proposed as an innovative sustainable system that can be used to transfer knowledge and skills to the bottom of the pyramid (BoP) (Prahalad and Hart 2002) section of the population, those who are disconnected from the means of production and economic activity. It is based on the principles of value co-creation, open design and internet based networking. Harnessing the power of open source software and hardware, it proposes provision of open source design to allow communities to have access to knowledge and skills that promote ubiquitous manufacturing. Solutions for problems identified through community participation are developed by volunteer specialists such as mechanical and industrial design engineers. Blue prints of such solutions are made available for free access to communities and entrepreneurs through electronic and social media. The open design approach can be extended beyond products to actual manufacturing equipment (Vallance, Kiani and Nayfeh 2001). In the absence of intellectual property (IP) protection, open design of manufacturing equipment can empower communities to participate in product manufacturing in a way that broadens their economic activities and hence help grow the formal economy.

The model for the complex interactions that are required to make this successful have been articulated by Rebensdorf et al (Rebensdorf, et al. 2015). There is need to connect the community to designers, manufacturers, venture capital and the formal market. The target community exists largely in an informal economic space which remains largely isolated from the formal economy. Formal funding in such space is dominated by donors. However, the success rate of such a model is limited. The donor approach does not provide conditions for recipient commitment to solutions developed outside the community. The other sources of funding include government support, social corporate investment (CSI) and social corporate responsibility (CSR). Government support is limited and CSI/CSR has been largely committed to social good activities such as providing food to orphanages, old people's homes etc. This approach has largely lacked sustainability. A few years after such donations, nothing much exists to show evidence of such interventions. This is the major drawback of such an approach. However, if viable solutions with potential for significant impact on the community are available, a business model can be developed to channel such funding sustainably into community empowerment through OCM. This inevitably requires synergistic collaboration between CSI/CSR and financial services sector to provide a mechanism for revolving funding models to be developed in a way that nurtures entrepreneurial initiatives while promoting community commitment.

The biggest challenge in OCM is to identify products that can be manufactured successfully and sustainably in the community. Furthermore, there is need for manufacturing tools to be developed that are easily accessible to the community. This work presents the development of OCM products and manufacturing tools to empower communities to participate in the manufacturing space in an effective and sustainable way.

Methodology

The approach that was applied to address this problem has three main stages i.e. Product Identification, Product Development, Factory Development. The product that is developed has to be relevant to the target community. This requires community participation. Once the product has been identified, there is need to harness technical

expertise to develop the product. This is where the OCM concepts such as Open Source Hardware become effective. Manufacturing tools and processes can then be developed to enable product manufacture in the community. These steps are detailed next.

Product identification

The first challenge was addressed by identifying the key community needs in informal settlements of Gauteng, the economic hub of South Africa. A 2007 survey reported that Gauteng has 453 000 households living in shacks in 625 informal settlements spread around the province (The Housing Development Agency, 2012). This represents 14% of households in the province. This does not include the segment that lives in backyard dwellings. The major challenges identified through community consultation (through target groups) and expert observation can be identified as; 1.) Food, 2.) Water and sanitation, 3.) Energy and 4.) Clothing.

The energy component was found to be significant. Most households depend on paraffin for cooking and heating and candles for lighting. Given the large number of annual shack fires that are reported annually (Fire Protection Association of South Africa 2016), some of which take human lives, a decision was jointly taken to develop solutions that may address the energy needs with special focus on lighting and cooking. The identified lighting challenges are not unique to Gauteng but have been reported throughout Africa (Lighting Africa 2010). The International Energy Agency (IEA) estimates that only 290 million out of a population of 915 million people in sub-Saharan Africa have access to electricity (International Energy Agency (IEA) 2014). This is despite the fact that the region is rich in energy resources, especially freely available solar energy, but is poor in energy infrastructure delivery and energy supply.

Product design requirements

A product was required to address the lighting challenges in informal settlements. The key requirements identified for the product were:

1. Low cost (not more than R500 for a payback period of three to six months)
2. Solar powered
3. Provide lighting for a single shack
4. 2.1 Watt bulb
5. 240 luminens
6. Providing lighting for at least 8 hours on a single charge (2400 mAh)
7. Easy to partly manufacture and assemble in a community based factory

Product development

Product design entails functional analysis (FA) and product embodiments taking into account the concepts of design for manufacture (DfM), design for assembly (DfA) and design for the environment (DfE) (Dieter and Schmidt 2009). The FA framework developed for this home lighting system is shown in Figure 1. Several concepts were then developed to meet this functional need. The major design constraint was to arrive at a solution that can be manufactured in a container based community factory.

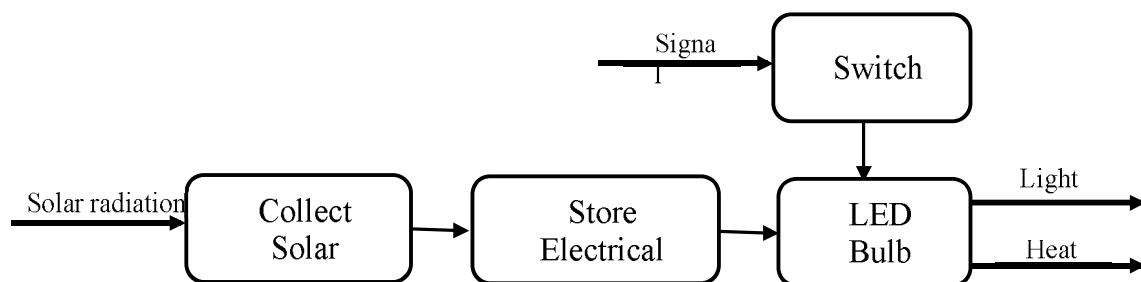


Figure 1: Home lighting system functional analysis

Key embodiment components included the solar PV panel, battery storage pack, LED light and switching and control system. Components that can be obtained off the shelf include the solar PV panel, storage batteries, LED light and control system. The product housing and mounting system can be manufactured using simple tools. A Pretoria based company was tasked with development of the LED control system while the PV panel was procured off the shelf. The housing of the battery storage and control system housing and the LED housing and mounting were developed for manufacture in a community factory. This required most of the components to be made with straight lines and holes. The sample parts are shown in Figure 2. A deliberate decision was taken to make most of the housings out of 3CR12 stainless steel for durability and low cost manufacture. The full embodiment of the product is shown in Figure 3.



Figure 2: Laser blanked and drilled components designed for community factory manufacture

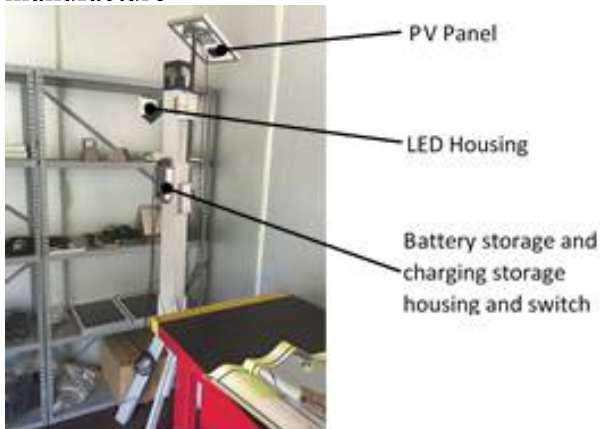


Figure 3: Home lighting system embodiment

Factory development

The identified product was designed for community manufacture. A decision was made to develop an off-grid factory given the large percentage of people in sub-Saharan Africa living off the grid. However, factory design and development is a complex process requiring special attention to sustainability issues (Terkaj, et al. 2014), (Chen, et al. 2012). For distributed OCM to succeed, the factory must meet certain criteria including:

1. Off-grid capability
2. Mobile
3. Sustainable
4. Affordable
5. Easy to use
6. None polluting

Fox discusses most of these concepts in great detail (Fox 2015). It is critical to note also the importance of the type of product that has to be manufactured in the factory. In this work, a manually operated 10 ton press was designed as the tool for the main factory operations. This allows off grid manufacturing that is none polluting. The press also offers manufacturing flexibility as more products can be produced from the same press with a simple change of tooling. The press would be applied mainly to bending and punching operations. This therefore, requires that the components to be processed in the factory are supplied in a form suitable for the required processes. An entrepreneur and business incubation facility in Mpumalanga (Mpumalanga Stainless Steel Initiative (MSSI)) provided the pre-processing operations required to implement this part of the value chain. The full steps required for product realisation are presented in Figure 4.

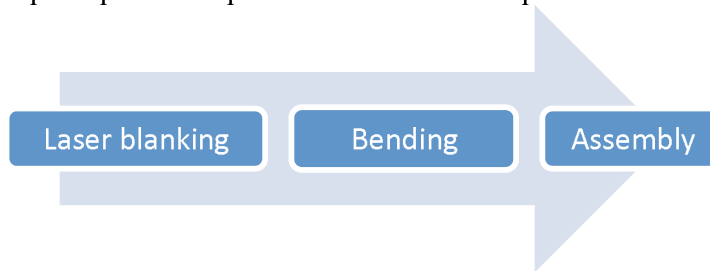


Figure 4: Product realization chain

A total of four tool sets were developed for the LED and battery storage housings. The components would be assembled using standard rivets and machine screws. The developed 10 ton bending press is shown in Figure 5. The figure also shows the layout of the interior of the workshop including working benches and storage shelves. This is also depicted in Figure 3.



Figure 5: Off grid manually operated 10 ton bending press

The factory was housed in a composite panel structure. The light weight structure ensures full mobility. It can be easily towed to any location for use and is not dependent on access to grid power. The factory can also be made from a shipping container at the risk of reduced mobility. The simple tooling applied also meant low training is required for skill transfer reducing turnaround time from procurement to full production. Furthermore, a supply chain was established for easy access to raw materials.



Figure 6: Trailer mounted community factory

Products produced in the factory had 30 % community value add. The raw materials were supplied at a price of R250 pack and could be sold at R450 with a minimum profit of R150. Therefore, the model has real potential of creating employment. In addition, other products can also be produced in the same factory. Trial runs were made to make cooking stoves and curios in the same factory and potential for this was demonstrated. The developed factory opens up new opportunities for distributed manufacturing while encouraging the Bottom of the Pyramid (BoP) segment of the population to participate in economic development, reducing poverty and saving lives.

Conclusions

This paper has presented the development of a product that can make a contribution to the support of open community manufacturing. The product was identified from the needs of local households living in informal settlements. A value adding chain for the product realisation was developed which included local incubation centre. A container based factory was developed which used a 10 ton manually operated press to add 30% value to the product by performing mainly bending and punching operations. In addition, all the components are assembled in the factory with reduced labour costs.

The proposed community manufacturing solution was successfully developed and tested. It has real potential to create jobs, add BoP sector into economic activity, reduce poverty and minimise loss of human life by providing safer, renewable and sustainable home lighting system to low income housing in informal settlements. The solution is easy to use, needs no grid power and can be moved from one place to the next. A supply chain was developed in the process to ensure sustainability.

The major challenge to widespread implementation is cost. Each factory can be procured from a local SME at a cost of R200 000 (two hundred thousand rands) with one month supply of raw materials. This is not affordable for low income households living in an informal settlement. However, this is a solution that can attract government funding and even corporate funding through CSR/CSI if the business model is well developed.

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