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Evaluating the State of Product Design in Trinidad and Tobago

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Abstract: *This paper describes a study of product design and manufacturing companies in Trinidad and Tobago. Using the Trinidad and Tobago Manufacturers' Association (TTMA) database, three companies engaged in original mechanical or electrical product design and manufacturing agreed to participate in the study. Design process and product audits were used to evaluate the current design practice and quality of the designed products. The research findings demonstrate that local design process capabilities and product quality are lacking within Small and Medium Enterprises (SME's). This was due to companies not being able to afford full-time product design expertise and formal design skills not being appreciated by business owners. Recommendations were made to address this situation including design education workshops to sensitise business owners about product design techniques and audits, and national incentives to encourage and support the business of product design through product design partnerships.*

Keywords: *Product Design, Design Process Improvement, Design Audit, Design Management*

1. Introduction

In 2016, the Petroleum sector accounted for 32% of Trinidad and Tobago's (TT) Gross Domestic Product (GDP), whereas the Manufacturing sector only contributed to 7.8%, which has been decreasing from 8.6% since 2011 (Ministry of Finance, 2016). In the presence of the country's current financial crisis with decreasing fossil fuel revenues, the need for development in the manufacturing sector is not only imperative but has now become long overdue as several companies have already decreased production investments or have gone out of business entirely.

Scholarly publications targeting the local industry's product design practice are rare. One study concluded that the current use of Integrated Manufacturing Technologies (IMT) within manufacturing firms in Trinidad and Tobago is not at required levels to facilitate the design and development of new products (Chowdary, 2009). Another study found that Trinidad and Tobago and the wider Caribbean region lack product and process innovation capabilities that lead to a wider range of manufactured goods as a vital response to the dependency on tourism and depleting oil and gas reserves (King and Cameron, 2013).

In order to expand local innovation initiatives, a sound understanding of current local product design practice is necessary. Given that the state of product design in the Trinidad and Tobago industry needs in-depth investigation, the study presented in this paper seeks to identify local manufacturing companies that are engaged in mechanical or electro-mechanical product design, and capture the design processes, product quality, and environmental forces affecting innovative product development. Based on the results of the study, recommendations are made for improving local product design practice.

2. Background

A nation's economy is heavily dependent on effective product design (Sentence and Clarke, 1997; Mynot, 2000). For example, in a study of 60 small engineering firms, it was found that companies with a robust design orientation showed high growth trends (Black and Baker, 1987). A five-year study including 51 companies concluded that firms exhibiting good design were more competitive in all business performance measures (Hertenstein et al., 2001). It is therefore prudent for companies engaged in product design to continually evaluate and improve their design process and product design quality. Studies conducted on the local design and manufacturing context (Chowdary, 2009; King and Cameron, 2013) did not focus specifically on the particular role of the design process and the design environment. In addition, the quality of the designed products was not assessed for potential improvement.

To specifically address this gap, a research strategy was developed to specifically audit the design process (Otto and Wood, 2000, Clarkson and Ekert, 2005, Eppinger and Ulrich, 2007) and the quality of the designed products of local companies engaged in original product design. Moultrie and Fraser (2004) present a comprehensive workbook suited for auditing small to medium manufacturing businesses taking into account the marginalisation of design functions in SME's.

According to Moody (1980), this marginalisation occurs because design activities are viewed as tasks that can be done by anyone with common sense. A symptom of this marginalisation is design activities being performed by individuals with no specific design training referred to as 'Silent Design' (Gorb and Dumas (1987).

Using product and process audits, the workbook allows firms to determine current product performance and design process effectiveness against key design dimensions. A product's design strengths and weaknesses are highlighted from the product audit and represent that product's design quality, from both the company's and consumer's perspectives. The design process audit evaluates 24 significant design activities at four performance levels. The results of each audit (numerical scoring and graphical representations) provide benchmarks from which improvements can be made and tracked. A high-level overview of the audit methodology will be described for the purposes of this paper. For details on the product and process audit, the reader is referred to Moultrie and Fraser (2004).

The product audit assesses the design performance of products using seven key aspects of 'good product design' or 'product design quality' and five key aspects of 'design importance to customers', as shown in Figure 1. Each key aspect, like Engineering Quality, is broken down into more detailed issues, like Reliability or Durability. Each issue is then scored on a scale from 1 to 4, where 1 represents a poor performance and 4 represents great performance. An average of the scores for all the issues is then found resulting in an overall performance score for the respective product's design aspect being considered.

Similarly, the design process audit is used to assess each company's design activities focusing on design execution and design management. These two design headings are broken down into five design areas from which a total of 24 corresponding key activities are identified, shown in Figure 2. Each activity is evaluated across four maturity levels where maturity is defined as, "The degree to which processes and activities are executed following 'good practice' principles and are defined, managed and repeatable." The audit was designed following process maturity principles, using a maturity grid to describe the design behaviours exhibited by a firm. Each activity for a particular area is scored individually using a separate detailed grid. Then, all the activity scores are placed on the respective design area's summary grid shown in Figure 3. Finally, all scores for the design areas and design activities are collated to identify performance gaps for the respective design headings.

By using the process and product audits, a complete picture of the design function and product quality could be ascertained. In addition, a PESTLE analysis (Political, Economic, Social, Technological, Legal and Environmental) is a useful tool to gauge the environmental factors that affect a business's product design plights. Using a combination of these tools, the methodology was developed for determining and hence evaluating the state of product design in Trinidad and Tobago.

3. Methodology

For inclusion in the study, the main criterion was that a firm should design the products that they manufacture. Participants were sourced from the TTMA's membership directory (August 2016). The criteria used for study suitability screening were as follows:

1) Companies must have their design operations resident in Trinidad and Tobago.
2) Companies must practice 'in house' product design, including design idea generation.
3) Company produces physical products with electrical and/or mechanical properties.
4) Company products are marketed to the end consumer rather than as an input to any other industrial process.

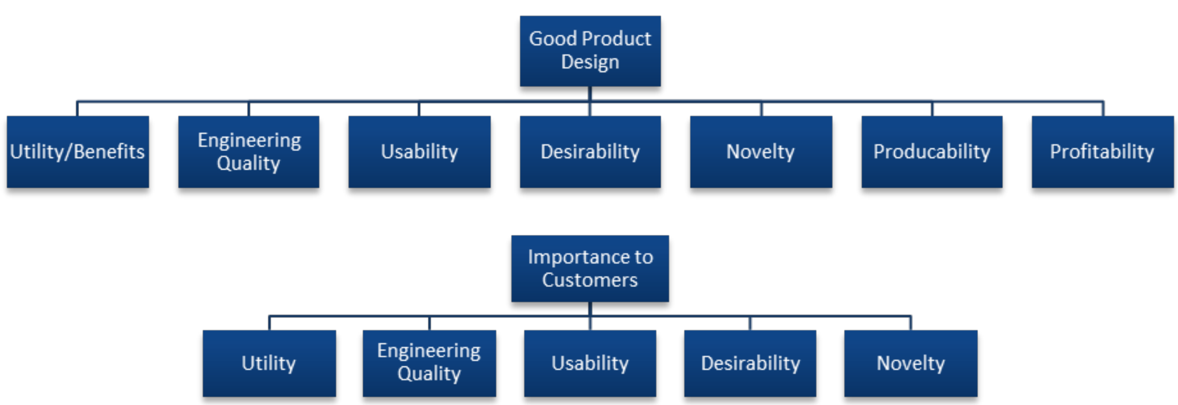


Figure 1. Seven aspects of design quality and five aspects of design importance to customers from Moultrie and Fraser (2004)

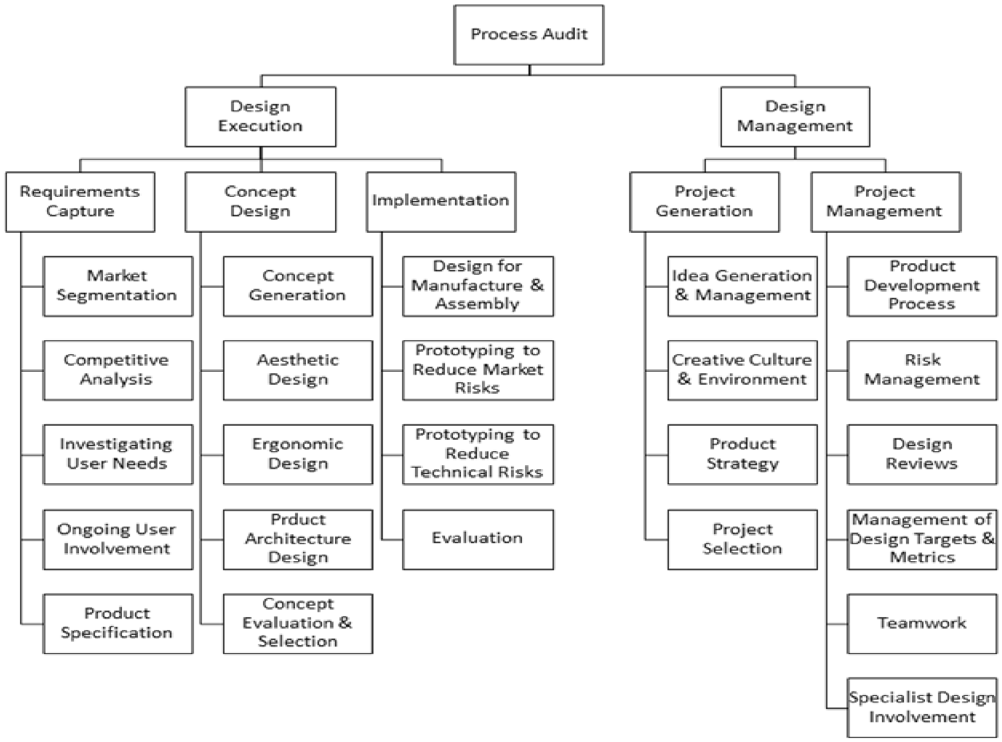


Figure 2. Design process audit categories from Moultrie and Fraser (2004)

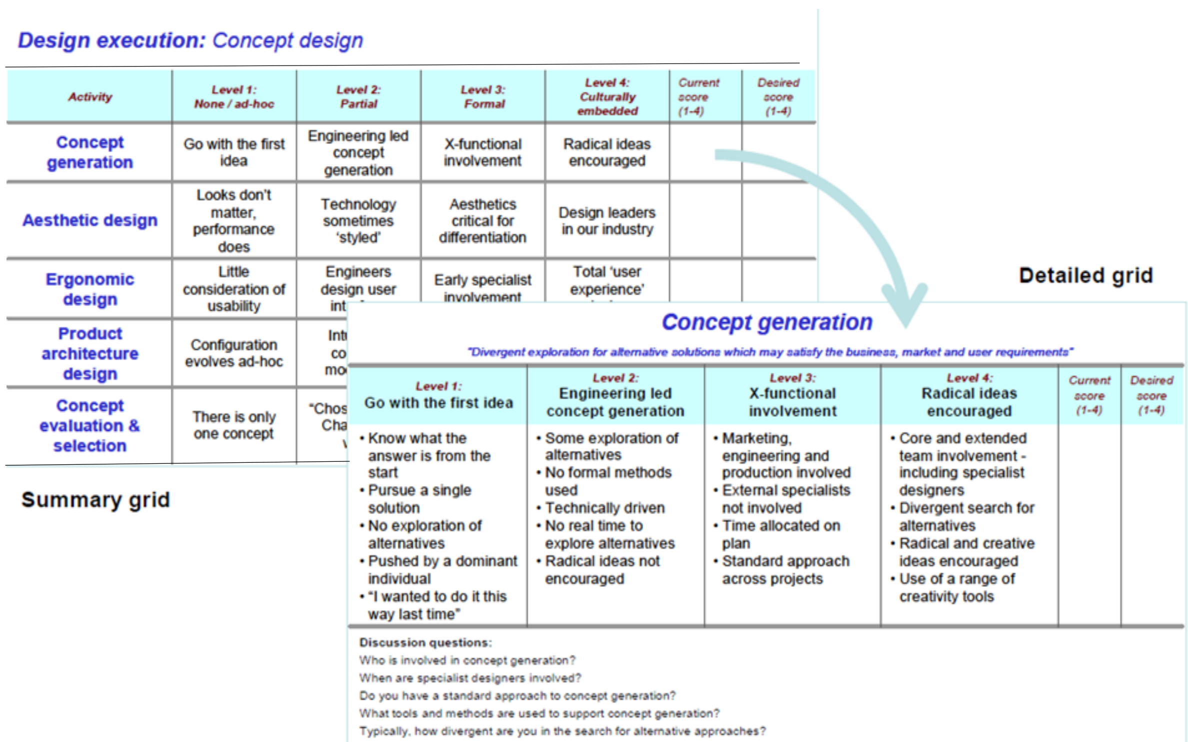


Figure 3. Design process audit scoring (detailed and summary grids) from Moultrie and Fraser (2004)

Companies were contacted by telephone and preliminary screening produced 16 companies who claimed to carry out original product design. The final screening stage separated the companies who merely made this claim from the ones who are actually actively involved in the practice. To achieve this, a questionnaire was developed and disseminated to the 16 companies. The responses received were discussed during interviews with the respondents. The qualitative nature and "product design depth" of the questionnaire and discussions held during interviews allowed for the identification of the companies that are in fact engaged in original design practice.

Out of the 16 companies solicited, nine (9) companies responded, of which three (3) responses were usable for the study. The overall response rate was therefore 56.25% (9/16) and the effective response rate was 18.75% (3/16). Table 1 gives summary details about the company solicitations and final selection.

The questionnaires and subsequent interviews used for final screening also gathered data on the respective company's design activities and experiences (Yin, 2003, Robson, 2016). This data was collected in four segments:

1) *Design Process* - In addition to mapping the design process used within the companies, data on the personnel involved and their qualifications was collected along with any resources used for designing (e.g. Equipment, Software and Information Sources). Participants were also asked to describe any improvements that can be made to their design activities, the subsequent results expected and requirements to make these improvements.
2) *Designed Products* - This section examined what factors were considered by the company when assessing the design quality of products and whether the company has been able to attain unique product designs using their respective design process.
3) *Design Environment* - A PESTLE analysis was used to gather information on the environmental forces that affect the business of product design. Financial investments and budgetary allocations toward product design were also investigated.
4) *Current and Future Design Projects* - This section dealt with the willingness to collaborate with tertiary level institutions for ongoing company design projects and the value adding expertise expected from such institutions.

4. Results

4.1 Design Process

None of the three companies were found to have any established protocols for executing or managing design activities. It was found that the discussions held were the first time any thought was being put into this matter. An overall design process and its activities were hence deduced from enquiring about how new product ideas were obtained and their transformations into manufacturable products.

The industry's design process activities were found to be quite similar across the three companies shown in Table 2. The design process involved Ideation, Conceptual Design, Prototyping, Testing and Production. Emphasis is placed on prototyping and testing concepts very early during design projects. This is done to determine product specifications since enhancements are made to the concept after each iteration until a satisfactory design is attained.

It was found that no formal engineering design or market analytical skills resided in any of the companies interviewed. Usually, a director or owner with 20-30 years manufacturing experience and a draughtsman, with primary drawing software certifications (mainly AutoCAD) are involved in design activities. Occasional feedback is sought from shop floor employees.

Table 1. Participant Company Solicitation results

Status	Declined to Participate	No Response	Non-Usable Responses	Usable Responses
No. of Companies	3/16	4\16	6/16	3/16
Details	- Information is too sensitive to divulge. - Respondents too busy. - Study not beneficial to the company.	- No response after receiving the questionnaire.	- Clients provide design specifications. - Information provided about the construction environment. - Information required was not part of daily operations. - Design is done by foreign entities.	**Company 1:** Concrete Products. [Blue] **Company 2:** Construction and Building Materials. [Green] **Company 3:** Wood and Wood related. [Black]

Table 2. Industry Design Process Activity Descriptions

Design Activity	Description
Ideation	Ideas for new products are gained from attending international trade shows, observing competitors and internet articles.
Conceptual Design	Hand sketches are prepared. Usually one concept is generated and developed along the process. Evaluation factors: Product Functions, Aesthetics, Structural Integrity, Producibility and Profitability
Prototyping	Prototypes are made in-house using typical manufacturing equipment. Designs may be altered here to resolve any construction issues.
Testing	Prototypes are tested in-house or sent to external entities for structural testing.
Production	Once testing is complete, the product is marketed and mass produced for sale.

During the "Ideation" phase, companies source new product ideas from international tradeshows and competitors, then alter aspects of existing designs to suit market buying preferences. The absence of engineering design expertise during the design project revealed that standard design methods were unheard of and not used for making design decisions. Instead, decisions are made based on the experience and gut feelings of the individuals involved.

Participants reported the method of designing products for around 50 years and were able to attain unique products and ideas. Any specific engineering expertise required is sourced externally and mainly serves as a validation of the product designed. Companies reported to invest $30,000 to $500,000 (TT dollars) annually in product design projects, from which approximately half is allocated to procuring design expertise and the remaining half used for prototyping and testing.

4.2 Designed Products

Participants reported that they were able to attain product designs that were unique to their respective companies. Unique, in this sense, meant that these designs have different aesthetics and product life spans from competitors. Design quality is assessed in terms of the design's producibility, product functions and structural integrity. This assessment is usually done during testing and comparing with similar competitor products.

4.3 Design Environment

With respect to challenges being faced within the larger environment, participant companies described the following:

1) *Political*: Participants expressed concerns for the level of corruption and nepotism they say exists in the country's political system. They explained, for example, inefficient products are purchased from other companies as a means of repaying political favours. This happens despite having proposed newly designed products that would achieve better outcomes at reduced material costs for numerous government projects. They also mentioned that the product design practice itself is not genuinely supported by government. This position was taken due to the lack of a national policy or ministerial body, to their knowledge, to guide businesses in their design activities. The same was said for design incentives.
2) *Economic*: Profitability is problematic given the current high cost of design mainly due to numerous prototype reiterations and accessing design expertise. Participants reported that they do not know of any support systems, from any entity, that can assist with lowering these costs and reducing time to market periods. The country's current unfavourable economic situation has made conducting business more challenging, even with the increased need for local solutions. Unfortunately, locally designed products are far less competitive when compared to cheaper imports that are heavily incentivised. A swift culture change to a more informed and rational one would be required to set the country's current economic state on a path to resolution.
3) *Social/Cultural*: Participants were of the view that the local product design culture is not as vibrant as it should be or at least not heading in any successful direction. From their experiences, consumers prefer to use traditional products and methods, even though they may be less efficient. As such, any proactive developments created are generally not appreciated or financially rewarding. This, participants said, contributed to the current creativity-deficient population as there are not many people in the "design-manufacture-market" business. This culture thrived under the current failed "fossil fuel-overdependent" economy from which recovery is slow since Oil and Gas revenues may not ever be the same. Respondents also believed that the design engineering education being taught in institutions does not practically address the issues facing SME's. Most graduates are not capable for hire, in their opinion, since the solutions proposed are not practically achievable or profitable.
4) *Technology*: It was found that respondents were limited in their active knowledge and use of design technologies. According to them, although these technologies are accessible, the hardware and its required skills are too expensive to justify the investments.
5) *Legal*: The companies surveyed reported that some of their designed products are unique and patentable. However, local patenting procedures are too long, expensive and at times, corrupted. Even judicial processes, respondents say, are quite inefficient and outdated when it comes to dealing with intellectual property issues. For these reasons, respondents would prefer to patent and license their inventions abroad (mainly the United States), where these issues are more seriously addressed.
6) *Environmental*: Participants are aware of using eco-friendly materials in their products, however, using these materials would result in a higher product cost since they are not readily available. Also, the skills necessary to use these materials, like engineering and manufacturing, do not reside in the company. Participants also mentioned that the current local culture is not environmentally conscious enough to even venture into such avenues.

In treating with these issues, companies currently outsource necessary skills and seek new product inspirations from international tradeshows and symposiums. Participants have indicated that there is little they can individually do to effect any meaningful change with the above issues that are negatively affecting the local design environment. They have suggested that these issues be culturally addressed in homes and educational systems, particularly at the tertiary level. In a national sense, political entities need to consult with industry to produce and effect meaningful policies and regulations that foster diversified product creations.

4.4 Current and Future Design Projects

Participants have indicated that they are willing to work with educational entities to improve any industry situation, and have done so in the past, but they have yet to realise any material benefit. Prototyping and technical insights were pinpointed as the main expectations from current and future collaborations.

4.5 Product and Process Audits

After interviewing participants, product and process audits, as outlined by Moultrie and Fraser (2004), were conducted at the respective participant's design locations. The results of these audits are presented in the following sections.

4.5.1 Product Audits

From each company, one product was selected and audited. The selected products, according to participants, were designed in-house and were unique to the respective company. The summarised results of the product audits are shown in Table 3. Current Performance vs. Importance to Customers was then plotted as shown in Figure 4. From this, the Product Design Performances of each product were identified and are shown in Table 4.

Excess design performances in the areas of "Benefits" and "Engineering Quality" were seen for Company 1 because the product audited was overdesigned for its function. These results show that product design specifications were not properly determined, a symptom of not involving engineering design expertise and/or conducting adequate market requirements research. It was later confirmed that the owner alone designed this product using his experience and thought that the product's exceptional performance during testing was a sign of good design. The product also scored low "Profitability" ratings due to a high material cost to produce the item (it was being sold at a low profit margin to be competitive).

Low usability scores were attained due to unconventional product installation procedures and troublesome in-service product maintenance. This suggests that product testing results did not include feedback from intended users. Products with low "Desirability" performances were noted to be similar to the company's other products and did not cater for the personal expectations of users. Participants stated that "Novelty" was considered during the design of the products audited and that industry experiences were used to evaluate this feature. However, the results of the product audits show either excess or low novelty performance. Excess novelty can result in a lot of marketing required to sensitise consumers about the product whereas low novelty could result in the product being easily copied or overlooked by alternatives.

Table 3. Product Audit Summary Results [Company 1 - blue, Company 2 - green, Company 3 – black]

Product performance

Issue	Poor performance	Score (1-4)				Great performance	● (blue)	● (green)	● (black)
Producibility	Overall poor producibility	1	2	3	4	Overall good producibility	2.4	2.3	2
Profitability	Overall poor profitability	1	2	3	4	Overall good profitability	1.4	2	1.8
Benefits	Overall few real benefits	1	2	3	4	Overall significant benefits	2.75	2	1.75
Engineering quality	Overall poor engineering quality	1	2	3	4	Overall great engineering quality	3.25	2.75	2.5
Usability	Overall poor usability	1	2	3	4	Overall highly usable	1.6	1.8	2.3
Desirability	Overall low desirability	1	2	3	4	Overall highly desirable	1.5	2.2	2.6
Novelty	Overall little novelty	1	2	3	4	Overall highly novel	2.2	1.8	2

Importance to customers

Issue	Poor performance	Score (1-4)				Great performance	● (blue)	● (green)	● (black)
Benefits	Overall few real benefits	1	2	3	4	Overall significant benefits	1.5	2	1.5
Engineering quality	Overall poor engineering quality	1	2	3	4	Overall great engineering quality	2	3	2.5
Usability	Usability not important	1	2	3	4	Usability highly important	3.5	3	3
Desirability	Desirability not important	1	2	3	4	Desirability highly important	3.5	4	2.5
Novelty	Novelty not important	1	2	3	4	Novelty highly important	1	3.5	3.5

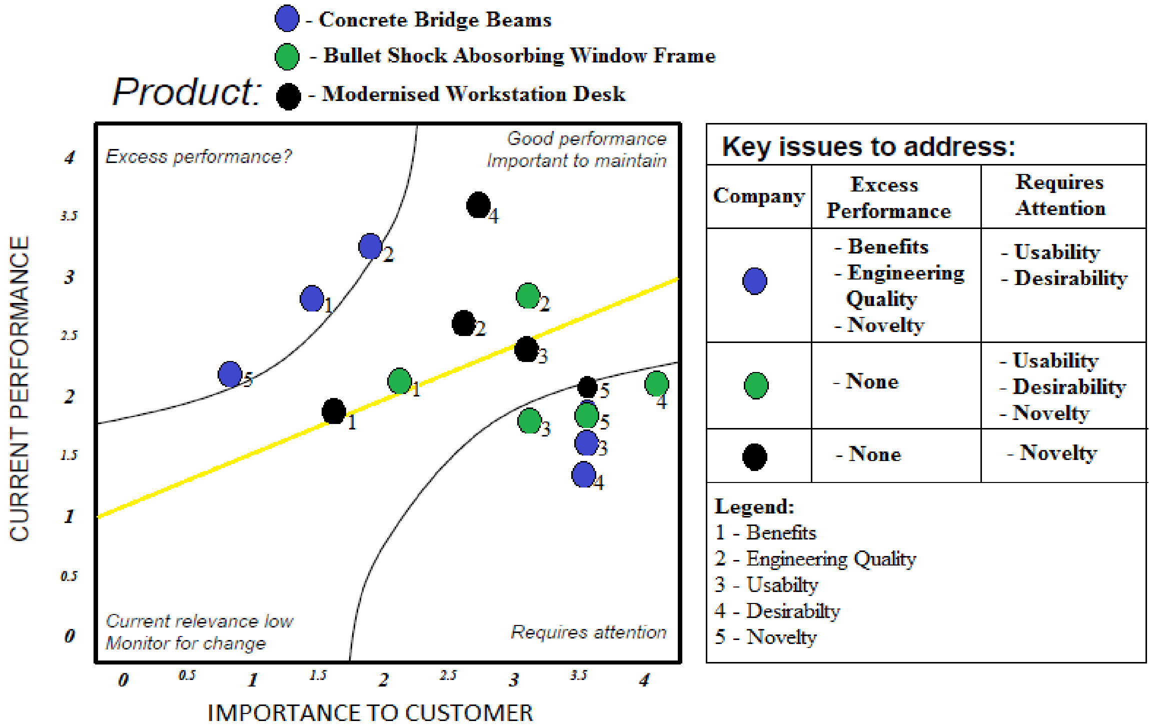


Figure 4. Product Performance vs. Importance to Customer

Table 4. Product Design Performance

Participant	Design Issue Performance		
	Excess	Good	Low
Company #1	Core Benefits Engineering Quality Novelty	None	Usability Desirability
Company #2	None	Core Benefits Engineering Quality	Usability Desirability Novelty
Company #3	None	Core Benefits Engineering Quality Usability Desirability	Novelty

Good product design ratings attained served to not discredit the design decisions made based on the participants' experiences. However, participants admitted to not having considered these issues as comprehensively in relation to how the issues were being audited since they simply reused features from other successful products.

4.5.2 Process Audits

For this aspect of data collection, ongoing product design projects were observed in addition to further discussing the design process relayed in the questionnaire stage. Company representatives explained prior actions leading up to the project's current status as well as future design intentions. Any design documentation available was reviewed (mainly sketches) to get a better understanding of the design project being undertaken. This information was collectively used to rate the respective Design Execution and Management activities of the process audit. The audit summary results are presented in Tables 5 and 6, respectively.

The process audit results highlight several deficiencies in the execution and management of design projects. These deficiencies confirmed the reasons for the undesirable design performances attained during the product audits. For instance, companies were found to be weak in conducting market research for the purpose of capturing design requirements. The marketing staffs' roles were mainly aligned with advertising and sales support. As such, specifications are set by the persons involved, based on experience, and are later changed based on prototype testing results. Intended product users are hardly involved in design projects.

No concept generation methods were being used resulting in usually one concept being generated and enhanced along the project. This makes concept evaluation and selection either a biased or non-existent decision. Designs are produced with some manufacturing and assembly considerations. However, these aspects do not carry much decision-making weight during the project and are dealt with in more detail after the design is complete. As discovered earlier, no formal design process was established in any of the companies. Creativity, project generation and selection rested mainly with the business owners who used no methods, aside from industry experience and common sense, to manage or conceptualise generated ideas.

Table 5. Process Audit Summary Results - Design Execution

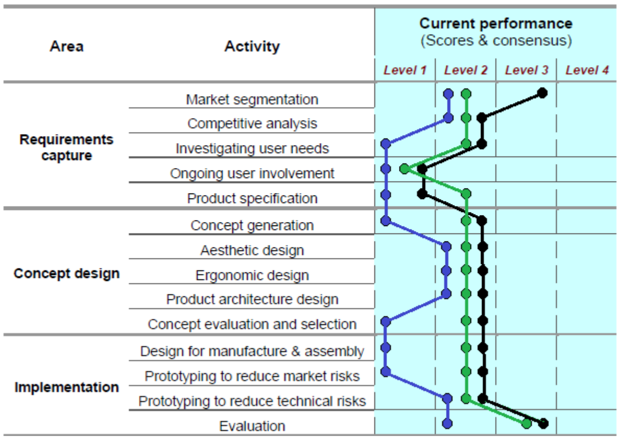
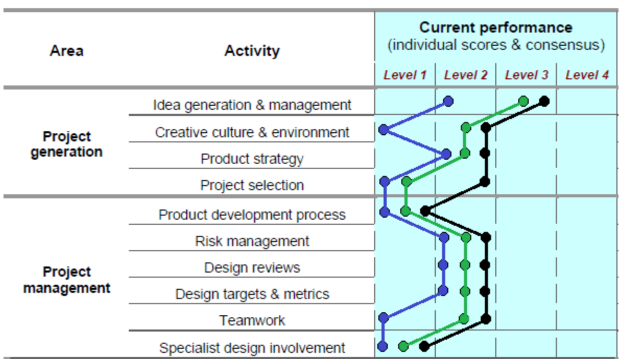


Table 6. Process Audit Summary Results - Design Management



5. Discussion and Recommendations

5.1 Design Education

A major problem affecting the design practice is the lack of, or an appreciation for, product design knowledge in the industry, especially among SME owners/management. Product design workshops seeking to generate awareness and appreciation for what "good product design" entails with its associated benefits might be useful. Market data collection and interpretation methods, design process execution and management as well as design methods for key design process stages would be useful focus areas for these workshops. These elements would serve to assist business owners with engaging the market for possible product innovations and then convey these ideas constructively to design personnel.

It was noted that SME owners could not afford to hire and retain full-time experienced design engineers. However, engineering technicians with design proficiencies (design technicians) may be a suitable alternative. Technical institutes could incorporate relevant design theories and technological practical training courses into their programme deliverables to provide these skills. Innovation and Entrepreneurship education would also compliment design competencies to produce well-rounded individuals capable of developing effective and profitable solutions.

5.2 Training in Industry Product and Process Audits

Participants in this study responded well to the proceedings of the product and process audits conducted. Though many aspects of good product design were not being performed, participants were able to grasp the general idea of what was required and were able to give examples of how they could perform these actions as well as the perceived benefits. The audits also provide a means to benchmark design capabilities, as demonstrated in this project, and should now be used to track the improvements of the product design practice alongside companies.

5.3 New Product Development Incentives and Partnerships

In an effort to encourage business owners to pursue new product development projects, relevant governmental entities should consider incentivising beneficial aspects of the design trade. For instance, tax exemptions can be granted to help with the purchasing of prototyping equipment or modelling software. Companies that already owned these technologies can also be encouraged to enter into arrangements with individual entrepreneurs to combine resources to materialise and market innovative product ideas.

5.4 Company Cataloguing by Product Types

Finding participants for this study was somewhat challenging since no database of product design companies existed. The TTMA's membership directory was useful in finding study participants but required multiple screening phases against several criteria. Overlapping of different company categories was encountered for the same product types. For example, some companies were replicated under both "Construction and Building Materials" and "Concrete Products" when the company produces concrete building blocks. Cataloguing company data by product type rather than company category is a more efficient way to collate and present this information. GS1 presents a comprehensive list of standardised Global Product Classifications for such a purpose (GS1, 2017). Formulating a database using these standards would aid in finding appropriate participants for future industry research activities.

5.5 Product Design in other Manufacturing Sectors

This scope of this research was restricted to companies that design and manufacture products that possess electrical and/or mechanical properties. However, the research methodology in this paper can also be utilised to investigate product design practices in other manufacturing sectors with adjustments of the audit to take into account the type of products being audited.

6. Conclusion

The research findings present some evidence that electro-mechanical product design capabilities are relatively poor within SME's in Trinidad and Tobago. Companies not being able to afford full-time product design expertise and formal design skills not being appreciated by business owners seem to be the main reasons. Product design was found to be carried out by the business owners themselves who do not possess any design skills or training aside from their relevant industry experiences.

It was found that companies were incapable of conducting and analysing market research for the purposes of identifying avenues for product innovations and determining effective product requirements. Design decisions are made based on gut feelings and experience rather than through any design method or evaluations. Altering foreign product designs to suit local market purchasing behaviours is widely practiced. In order to improve this situation, much work remains to be done in terms of educating business owners on how to design new products, how to carry out process and product audits, and how Government and Tertiary Institutions could assist in making the product development process easier.

Acknowledgements:

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