

Quality Control in the Clothing Production Process of an Under-Resourced Sewing Co-operative: Case Study

Mkwanazi Michael Sizwe

Department of Quality and Operations Management
University of Johannesburg
Auckland Park, 2006, South Africa
msmkwanazi@uj.ac.za / sizwel4@gmail.com

Mbohwa Charles

Faculty of Engineering and Built Environment
University of Johannesburg
Auckland Park, 2006, South Africa
cmbohwa@uj.ac.za

Abstract

The availability and ease of access to substitute quality products and services has created an expectation among consumers in different markets to expect a certain standard of quality on any purchase they make. This expectation leaves some small manufacturing enterprises out of the market if they are unable to cope with the dynamic quality requirements of consumers. This paper uses a case study of a clothing manufacturing co-operative which has been operational for 48 years and which with resource constraints had managed to satisfy customers beyond expectation based on available customer feedback. This study shares a lesson which may be not generalizable in other contexts, which is that small manufacturing co-operatives should strive to focus their quality control efforts on the key quality control points mentioned on this paper. This research paper also suggests that more research be done on small manufacturing enterprises regarding Total Quality Management which is a knowledge area largely dominated by research on well-established enterprises. In principle this paper also calls for an increase in research which can benefit the operations management field about the knowledge of small manufacturing social enterprises which are common and beneficial for communities in developing countries.

Keywords

Quality, Co-operative, Manufacturing, Control, Resources

1. Introduction

Quality refers to the ability of a product or service to meet and even exceed the expectations of the customer in terms of product or service efficiency, performance, durability, comfort and ease of use. However, quality has to be consistent and there needs to be resources to support and implement all activities associated with controlling and managing it (Harpa, 2011). In clothing manufacturing a good quality management system would be concerned about the inputs used in the making of clothes, the skill of the workers and also having adequate sewing machines which sew in quality threads (Mahnaz & Ejaz, 2005). Quality clothing is normally rewarded by consumers and the same is for consumers when they receive quality clothes. In early 2000s the South African Department of Trade and Industry launched the Proudly South African campaign, which is an initiative and a body responsible for promoting local production in food, clothing, steel and other key manufacturing sectors. While this is important for a country such as South Africa, quality management is also important. Sewing co-operatives happen to be the local manufacturers of clothing, such as traditional wear, school uniforms, and work-wear and special dress codes. There is a preference for these local manufacturers, although major retailers are more reliant on Chinese and other clothing imports which is thought to be cheap and also of acceptable quality. A challenge for co-operatives in maintaining consistent quality in clothing manufacturing is that they lack certain resources which are important to implementing and for continuous

monitoring of quality practices, these resources as already indicated include capable sewing machines, skilled labour, quality assessment standards, pre and post quality checks and the sewing process outline (Lazim, Salleh, Subramania & Othman, 2013). The interest in clothing co-operatives is as a result of continued investment in social enterprises around the world especially co-operatives and this interest on co-operatives is also driven by their potential to manufacture products which are more appealing to their local markets (Ciavolino, Carpita & Al-Nasser, 2014). The focus on quality in this paper aims to point out the benefits associated with quality management in any size enterprise but also this paper identifies cost effective quality management practices suitable for an under-resourced sewing co-operative which has a plan for continuous improvement in quality management.

1.1 Quality Management and Control in Social Enterprises

Any form of an enterprise in order to remain successful in its business operations it has to maintain acceptable levels of quality (Mahnaz & Ahmed, 2005). The variances in understanding of quality and also ensuring quality clothing production requires close supervision of the production line especially in manufacturing factories where there are not automated systems for quality control (Chopra, 2014). A co-operative may rely on manual quality monitoring and checking if there are not automated systems in place for quality check. Essential to manual control of quality in a social enterprise, such as a co-operative is understanding the contributing factors to quality management in the space of manufacturing these includes labour ergonomics, process layout and product quality assessment (Wicramasinghe & Perera, 2016). In clothing manufacturing the process of quality control involves checking sewability, thread quality and seam quality.

1.2 Research Problem

This problem refers to a case study of a co-operative which has benefited in government and other capital contributions directed to the enhancement of the co-operative manufacturer's ability to deliver quantity and supposedly quality. However, the compromise on quality is still a common reason for the return of clothes manufactured by sewing co-operatives (Aljeeran, Adcock & Hameed, 2016). The problem can be stated as the lack of understanding the crucial quality control points in the sewing process in an under-resourced clothing co-operative.

1.3 Objectives of the study

This paper uses a case study of a clothing manufacturing co-operative that had had a problem in quality management and which had also managed to find ways to ensure implementation of quality practices. This paper aims to identify the areas and points in a sewing process which require a strict quality control supervision and this paper also aims to share a process chart of sewing and to identify points for quality control in a context of an under-resourced clothing manufacturer. This research shall benefit any other co-operative with resource constraints and will help co-operative or small enterprise development practitioners to understand the areas of quality management in an under-resourced clothing enterprise.

2. Literature Review

This literature review focuses on quality, the need for quality and also the process of sewing or that of clothes manufacturing. The problem of quality can be described as the lack of consistency in a product's ability to meet customer expectations. Inconsistency in products or services' ability to meet the needs of a buyer has a potential to cost the manufacturer a future opportunity to generate an income (Islam, Khan, & Khanm, 2013). Causes of quality problems in clothing manufacturing are as a result of poor quality inputs such as fabric, labour skill and inadequate process management. The leaders in the field of quality management, namely W. Edwards Deming, Joseph M. Juran, Armand Feigenbaum and Philip B. Crosby are in agreement that quality involves putting an effort in making it part of an organisation and being persistent about it.

2.1 Defining Quality

According to Heizer and Render (2014) quality can be defined as "the ability of a product or service to meet customer needs". However, it takes well designed processes and a skill to deliver quality products and services (Hsu & Yang, 2010). In small manufacturing enterprises due to adverse manufacturing conditions it is not always easy to achieve consistency if an enterprise is not quality robust. A market will not buy a product in sympathy for a small enterprise or any size enterprise, but when they buy they require their needs to be satisfied by a product or service as promised (CAPT, 2011).

2.2 Quality Control Measures

The growth in global manufacturing activities and in international business has made it difficult for small manufacturing enterprises to thrive and to keep up with the technologically advanced quality control practices such as statistical process control. There are basic quality tools which can be used in different settings; these are the PDCA (Plan-Do-Check-Act) Cycle, brainstorming, fishbone diagrams (Ishikawa diagrams), flow-charts, trend-charts, scatter plots, and Pareto charts (Mitreva & Taskov, 2014). In order for manufacturers to derive value for these tools they need to have quality reliability planning in place. Quality reliability planning is defined as “a procedure designed to ensure that when a new product is being introduced, correspondence between all different sections and that a system is in place that will allow the product to consistently meet the requirements of the customer. The procedure consists of the quality design plan, the quality control plan, and the failure mode and effects analysis”(Desai, Desai & Ojode, 2015). The next section describes the process of sewing clothing wear which is the central point of this paper.

2.3 Process of Sewing Clothing Garments and Quality Control Points

Manufacturing relies on processes, which are steps in product making and delivery of final output. Process improvement is another area of achieving a competitive advantage over competing manufacturers as it can contribute to a manufacturer’s ability to deliver a quality output at an affordable rate.

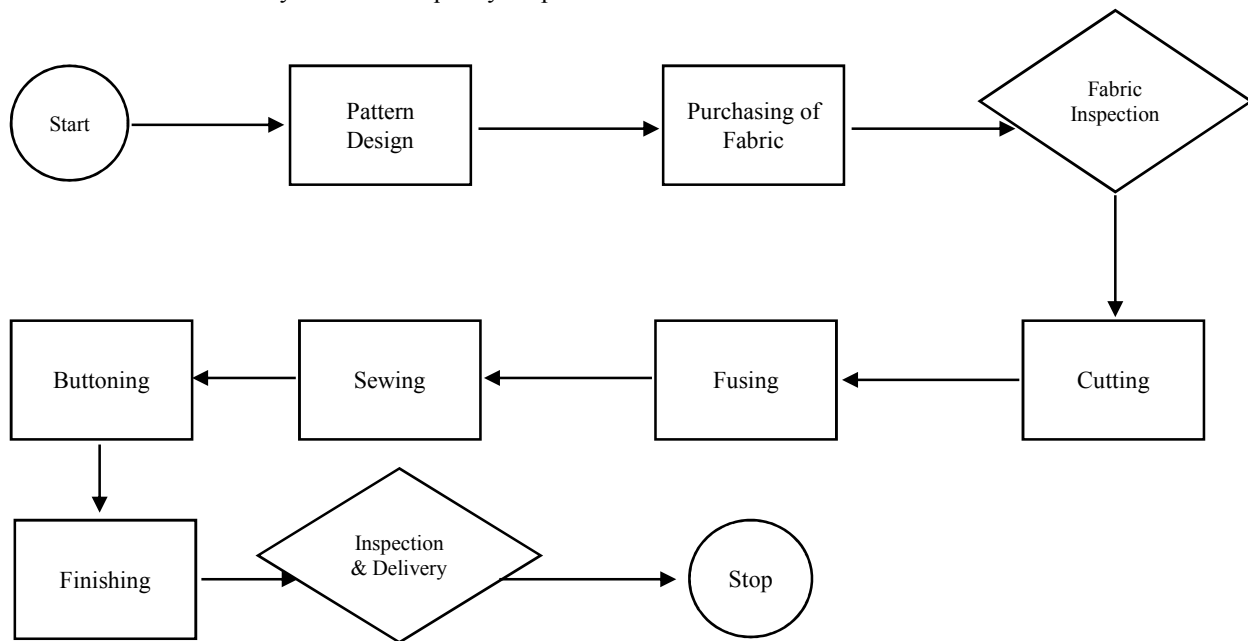


Figure 1 Single Cycle Process Flow in Sewing Chart

The process of sewing garments starts with the receiving of an order with detailed specifications, (2) pattern design, (3) sourcing of fabric, (4) reading of fabric/cloth, (5) cutting, (6) fusing, (7) sewing, (8) buttoning (if needed), (9) finishing and quality inspection at the end of the process (Heizer & Render, 2014:318),(Kmetz, 2012:67). The aim of any sewing process is to deliver a smoothly finished garment or clothing item in case of sewing clothes. Emerging industries in clothing manufacturing such as those in South Africa and Africa, are dependent on the activities of small sewing enterprises mainly co-operatives to deliver local clothing and also to revitalize the clothing manufacturing sector. The lack of process quality management in small clothing-wear manufacturing enterprises can create inconsistencies on the quality of the output delivered. Quality management requires to be managed using resources which include capable human resources, machine resources, a capable workflow and adequate manufacturing facilities.

3. Research Methodology

There is currently limited research about manufacturing co-operatives in the mainstream of operations management and engineering research. There are reasons for this lack of interest in operations management research about manufacturing and production co-operatives, one of the reasons is that co-operatives are democratically worker-owned social enterprises which are not capitalist oriented in their nature while operations management and engineering

research has always focused on profit-oriented enterprises for a long term. However, in the interest of industrial revitalization in developing countries such as South Africa the agenda of reviving the manufacturing sectors is believed to be possible and attainable through co-operatives. These enterprises have shown resilience in sustaining the economy of countries such as Kenya, Canada, Malaysia and India. Policy makers and government stakeholders share the common view that co-operatives can ensure sustainable manufacturing systems in growing economies where trading conditions are volatile. Why so? It is because co-operatives are enterprises owned by workers and the existence of investor-worker tension is not part of an enterprise such as a co-operative and for this reason co-operatives have the capability to instill the attitude of performance and capability development amongst the workers. The methodological procedure of this research is a case study process (USC, 2017). The first stage of development of the case study is based on a (1) observation by the researcher for a period of 6 months, (2) was an interview with the chairperson of the co-operative who is a process controller and chief leader of the clothing making process and finally (3) was to document the information of the co-operative and the process details of a co-operative. This co-operative enterprise was chosen based on a comparison with 83 other sewing co-operatives which have a struggle on quality management while the co-operative referred to here has similar challenges but manages quality adequately and continues to attract substantially bigger contracts from private clients and government sectors.

3.1 Context of Case Study

Quality assurance is not a tick the box activity and it can be a daunting task for under-resourced manufacturers. They may always violate or avoid quality practices. This research paper examined quality control points of a co-operative which is based in a township setting in South Africa, this co-operative operates from a building that was adapted to suit manufacturing activities. The co-operative enterprise was founded in 1969, although small in size it has 40 domestic sewing machines, 2 industrial sewing machines, 4 button hole machines, 4 over-lockers, 2 industrial irons, 2 industrial cutting machines and 2 cutting tables as resources used in their clothing production process. This co-operative has showcased its work in Turkey and the Netherlands in world fashion shows. Given limited resources the co-operative has focused its quality assurance efforts on pattern, stitch and material quality as key quality control points and this has sustained the co-operative's ability to remain in the sewing enterprise for 48 years. It should be noted that this co-operative has had changes in other leadership roles, but the chairperson responsible for operations has never changed a role since the establishment of the co-operative. All efforts of quality management in this co-operative aim to deliver a total quality finish on any garment or set of garments.

3.2 Case Study Process at XYZ Co-operative

The process of collecting this case study information was through bi-monthly visits to the co-operative production line for 6 months, an interview (Welman, Kruger & Mitchell, 2005:118) after this period was conducted with the responsible production coordinator of the enterprise and finally the case study was documented. Key areas of this case study present the need for quality management in any small clothing manufacturing enterprise, ability to study the process of manufacturing and determine key quality control points to maximize value.

4. Discussion

This discussion seeks to point out a few lessons which are not generalizable for all forms of enterprises, but for co-operative clothing manufacturers operating under similar circumstances of the township based clothing manufacturing co-operative referred to here. This discussion shares how a manufacturing co-operative has kept quality management besides limited resources, the source of the co-operatives ability to study the process of manufacturing and also the determinants of key quality control points to ensure a smooth finish on garments manufactured. This discussion also responds to the key objectives of this research paper. The cause of this research was to address the problem associated with up-keeping and maintaining quality in adverse production conditions through the identification of key points of quality control. The table one (1) below displays and describes the key quality control points in an under-resourced manufacturing enterprise and suggests ways on how these can be managed beyond controlling for quality output. In the interviews with the respective co-operative enterprise the following points were described as reasons for their interest on quality management and control through knowledge and focus on specific areas on the sewing process

"As a co-operative we aim to grow our operations by sewing uniforms for the police force, prisoner uniforms, and workwear for airline staff"

This response from the co-operative reflects a commitment to quality management and control and, this type of commitment is essential to quality maintenance and continuous improvement for any size enterprise.

Table 1 Key Quality Control Points in Sewing

Available Resource(s)	Key Quality Control Points (KQCPs)	Description
Industrial Sewing Machine(s)	<ul style="list-style-type: none"> • Machine Maintenance • Selection of correct settings 	Machine and Resource Maintenance is key to quality management in a sewing process. A sewing enterprise with limited resources shall focus on the maintenance of the available machine resource and setting it correct for each job.
Cutters	<ul style="list-style-type: none"> • Accuracy based on measurement • Balance in saving of fabric and quality cuts 	Cutters as resources in a sewing process have a potential of saving material if adequately used. Cut-men should cut-to-size and also not compromise on quality cuts with an aim to save fabric. Quality and accurate cuts should be simultaneous.
Fabric /Cloth	<ul style="list-style-type: none"> • Correct reading and assessment of fabric prints and, designs. 	The inspection and reading of quality shall be done by the buyer while making purchase inspection at the suppliers' site. The fabric design influences the quality look of a garment.
Facility	<ul style="list-style-type: none"> • Adequate protective storage 	Safekeeping of fabric in non-damp conditions protects it and other resources from damage that can compromise quality.
Labour skill	<ul style="list-style-type: none"> • Inspection and application of job knowledge 	Labour should use formal and tacit knowledge in managing a process of sewing as well as the associated resources.

“Due to cheap imports of clothing wear, we are left with no choice but to compete on the basis of quality and we use our knowledge of fashion to deliver quality and satisfy those who buy our garments. We measure this based on feedback that our customers give us and the zero returns of our clothing wear”

The co-operative enterprise is aware of the external forces of the business environment and the impact of the cheap imports on the internal operations of the co-operative. XYZ Co-operative operations leader focuses on quality management within the sewing process and this is the basis on which the co-operative competes with cheap imports of clothing and other garments. It is also easy for mass clothing manufacturers with adequate capital resources to acquire bigger manufacturing plants and offer lower prices and good quality at the same time. However, it is not always easy to interact with their clients or bulk buyers, but XYZ Co-operative uses the advantage of interacting with buyers of their clothing in single units or bulk sets to get feedback on the garments or clothing manufactured and this allows for improvements where necessary. The next response is about skill sharing on quality control.

“We train all our members and other co-operatives on pattern making, cutting, sewing machine controls and settings. The aim is on continuous training of the members of the co-operative on the process of sewing different types of garments and continuous re-skilling of worker-members about process development when new types of garments are introduced, this also encompasses quality management through process development”

The reflection here is that process control training is key to the success of a sewing enterprise that is dependent on process knowledge and skill to control and maintain quality. The role of sophisticated quality control through technology is essential but for an enterprise with limited resources it can be costly to acquire quality maintenance technology such as Computer Aided Manufacturing and process stoppers, but investing and improving the available skill enables the co-operative to maintain and control quality. The next interview point is on the area of facility layout and its impact on process quality control.

“The cost of leasing manufacturing facilities prevented our co-operative from acquiring large open manufacturing premises. Instead we opted for a subsidized facility at a local skills centre and focused on acquiring sewing machine equipment. The facility allows for redesign of the sewing process layout depending on the size of bulk orders received and amount of manual labour available, this is done to ensure speed in delivering an order and for ensuring the provision of acceptable quality clothing wear”

The ability to maximize return on investment is a compulsory feature to operational and business performance. Enterprises use their capital resources to generate income and profit margins. Some enterprises invest in buildings to house their operations and to be able to operate freely from restrictions on process change and improvement. The high cost of acquiring manufacturing facilities has shifted the social enterprises' focus on leasing privately owned-properties to focusing on identifying subsidized and shared manufacturing facilities. Therefore, XYZ co-operative has focused its efforts on maximizing value from using subsidized facilities which enables the co-operative to generate an income to acquire new facilities in a long-term. The final interview point addressed the interest of the co-operative to trading internationally.

"We have plans to trade African wear internationally once we have acquired bigger facilities and new machinery resources"

XYZ co-operative holds that international trade is driven by an ability to deliver both unique and quality clothing garments. African fashion and fabric is not available in major retailers. However, a small manufacturer such as XYZ co-operative and others have an interest to manufacture and distribute this unique fashion range, which signals and interest in growth and quality improvement for international trade. The following process flow chart shows the essential quality control points in the process and it is a revised single process flow of sewing.

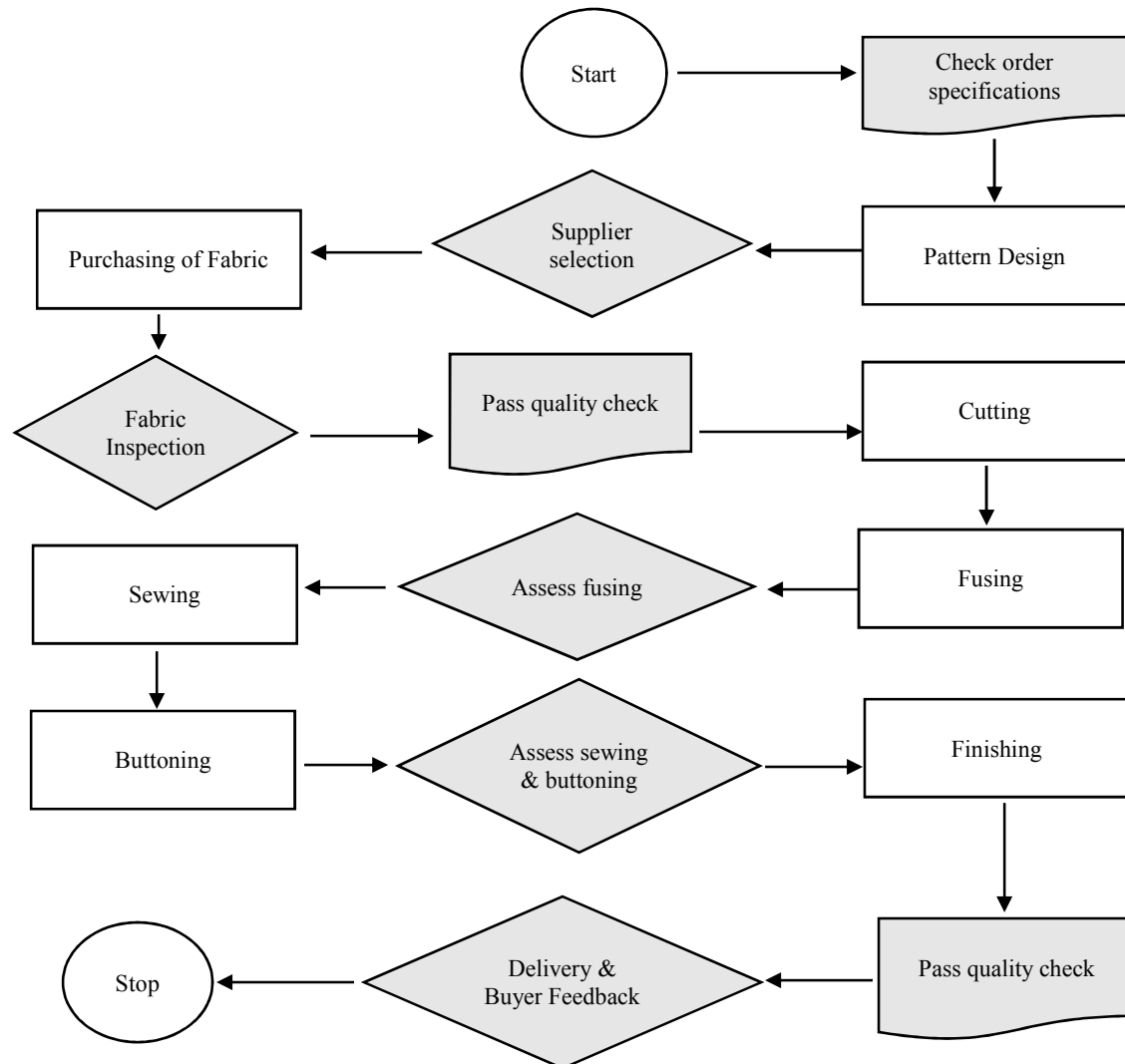


Figure 2 Quality Control in a Single Process Flow of Sewing Chart

The above quality control single process flow chart displays the key points for quality management within a process of sewing in an under-resourced sewing co-operative. Resource scarcity is common to businesses and to other forms of organisations. Manufacturers require certain resources to control process quality and one of the resources at the disposal of co-operatives such as XYZ co-operative is the knowledge of the sewing process and meaning of quality. The quality control points identified and which can be maintained on the basis of process and product knowledge are (1) checking of order specifications provided by the client, (2) selecting and evaluating the supplier of fabric, (3) inspection of the required fabric, (4) fabric is assessed based on a quality checklist which it should pass to be used for manufacturing of garments, (5) the next quality control area is on fusing which is a key component in the preparation of a garment for sewing, the quality of a garment is dependent on this stage of quality control to achieve a smooth finishing of a garment, (6) assess sewing and buttoning, (7) a checklist is used to give a go ahead to either package or disqualify an item for packaging and delivery, but the point of quality control throughout the process is to prevent returns of garments into the sewing process or loss of fabric due to bad cuts and finishing, (8), the final quality control point is based on buyer feedback, if a customer returns items due to inadequate quality that is negative feedback and calls for a review of quality control within the process. The following section is an analysis of the sewing processes effect on the ability of the sewing co-operative to deliver quality garments besides resource constraints.

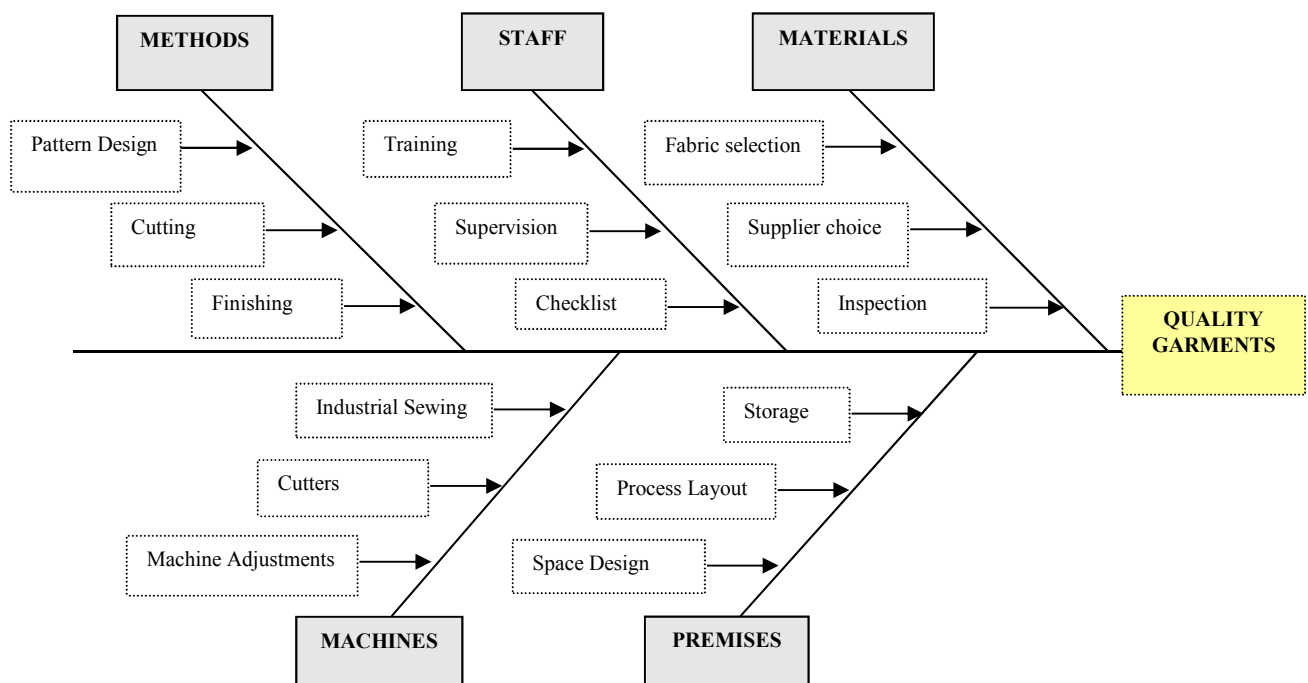


Figure: 3 The Quality Garments Cause and Effect Analysis

The above Ishikawa diagram is an illustrative analysis of how the sewing co-operative studied for this research has managed to produce quality garments besides having resource constraints. The focus of the co-operative is on the known elements of the fishbone diagram, however, there is an inclusion of premises as one of the key resources an enterprise requires (Stefanic & Stanojevic, 2014). The premises are relatively small for a manufacturing enterprise. The co-operative focuses greatly on how the space is utilized based on the process design already presented here, but also the layout of the process ensures efficient use of the available space and storage. The methods of production employed by the co-operative are such that pattern design, cutting and finishing is done to customer specification and correct detail when the order is received. Another reason for quality garments is the role played by staff and their willingness to participate in quality training programs, receiving supervision with a positive attitude of achieving quality output and the use of quality checklists on garments as well as the set-up of the sewing process for each job received. The sewing process key quality control points identify fabric supply, selection of supplier and inspection as essential check points for material quality and the garment quality is highly dependent on the material used. The ability to use industrial sewing machines and which are also coupled with digital technology is a must for both small and big clothing manufacturers. Therefore, the co-operative referred to in this study capitalizes on this knowledge and use the same machine resources to sew different batches and orders, but this is done through adjustment of machine settings,

the use of industrial cutters to meet the pattern specifications and the actual quality of the stitch of the industrial sewing machines is recognized as essential to the overall quality of a garment (Fang, Ye, Cheng, Zhang, Liu & Xu, 2015). The following table is an analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) associated with managing quality in a resource constrained co-operative enterprise.

Table: 1 SWOT Analysis of Quality Management in a Resources Constrained Co-operative Enterprise

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> • Understanding of quality focus areas. • Clear sewing process with critical quality control focus points. • Zero return on sold garments and positive feedback from bulk buyers. • Internal skill and strong supervision of staff. 	<ul style="list-style-type: none"> • Limited production space. • Inability to produce large quantities given the constraint of manual quality check. • Inability to service large orders from corporate clients.
OPPORTUNITIES	THREATS
<ul style="list-style-type: none"> • Expand production capacity through a shift work system. • Adopt automated quality check systems in the production of bulk orders (Poka-Yoke devices) • Upskill more co-operative members to understand quality and its application to their work or contributions in the sewing process. • Promote quality at all levels. 	<ul style="list-style-type: none"> • The rapid introduction of advanced and technological quality management techniques in clothing design and manufacturing can be costly for small manufacturing enterprises. • Mass production of popular brands and reduction in their prices limits co-operatives from entering the space of clothing retail.

Small manufacturing co-operative enterprises around the world share some similarities when it comes to their SWOT analyses (Russu, 2013). However, there can be no compromise on quality and small enterprises may focus on growing from their strengths and utilization of available opportunities to acquire more resources until they are able to put in place necessary automated quality control systems. The section which follows is a conclusion of this paper with the component of key recommendations and direction for future research.

5. Conclusion

In conclusion the key quality control points are not the only reasons for the success of a small manufacturing co-operative such as the one referred to in this study. It should be noted that there are other contributing factors to operational excellence and performance in terms of quality in the operations of a small clothing manufacturer focused on sewing, these factors include tacit knowledge, flexibility of the sewing process, repeat orders and the small quantity of orders processed.

5.1 Key recommendations

A recommendation which can be made from this non-generalizable case study is that each under-resourced enterprise should study its production processes to improve them either by accumulating new resources or using the limited available resources. This paper also recognizes that it may be costly for some subsistence co-operatives to keep up with latest quality management trends but it is possible to maintain a skill of quality management which guides the system operators about common areas of focus in the process of managing and controlling quality.

5.2 Focus of future research

This research paper has a limitation of a single case study and a future study could also focus on evaluation of quality practices in sewing co-operatives. A quality practice such as Total Quality Management could be a viable study area as most small manufacturers have not kept up with TQM and understanding the underlying reasons and also filling the gaps in the knowledge area of quality management in small manufacturing enterprises is relevant in our life-time where all opportunities and all size businesses form part of bigger economies.

Acknowledgements

This paper was made possible through the information provided by the co-operative referred to on this case-study research paper. The co-operative also allowed the researchers to gain access to records regarding quality management.

References

- Harpa, R., Quality Garment by means of quality seam, *The 7th International Conference on Management of Technological Changes – MTC*, 2011.
- Mahnaz, F., and Ejaz, A., Quality Management in Pakistan's ready-made garments' industry, *Quality Engineering*, 17:459 – 465, 2005.
- Heizer, J., and Render, B., Operations Management: Sustainability and Supply Chain Management, *Pearson: England*, 2014.
- Center for the Advancement of Process Technology (CAPT)., Process Quality, *Pearson: United States of America*, 2011.
- Mitreva, E., and Taskov, N., Projection and Implementation of Total Quality Management systems within the textile production, *Business Systems and Economics*, vol. 4(1), 2014
- Desai, K.J., Desai, M.S., and Ojode, L., Supply Chain Risk Management Framework: A Fishbone Analysis Approach, *SAM Advanced Management Journal – Summer 2015*
- Islam, M., Khan, A.M., and Khan, M., Minimization of reworks in quality and productivity improvement in the apparel industry, *International Journal of Engineering and Applied Sciences*, 2013.
- Hsu, C., and Yang, C., Applying Process Capability Analysis Chart in measuring sewing machine quality, *African Journal of Business Management*, vol. 4(11), pp. 2296 – 2301, 2010.
- Lazim, H.M., Salleh, M.N., Subramaniam, C., and Othman, S.N., Total Productive Maintenance and Manufacturing Performance: Does technical complexity in the production process matter?, *International Journal of Trade, Economics and Finance*, vol. 4, no. 6, 2013.
- Ciavolino, E., Carpita, M., and Al-Naseri., Modelling the quality of work in the Italian social co-operatives combining NPCA-RSM and SEM-GME approaches, *Journal of Applied Statistics*, vol. 42, no. 1, pp. 161-179, 2015.
- Wickramasinghe, G.L.D., and Perera, A., Effect of Total Productive maintenance practices on manufacturing performance: Investigation of textile and apparel manufacturing firms, *Journal of Manufacturing Technology Management*, vol. 27, no. 5, pp. 713 – 729, 2016
- Aljeeran, I.K., Adcock, R., and Hameed, A., Application of System Engineering by Armored Vehicles Manufacturers in Developing Countries, *IEEE*, 2015
- Chopra, S., Quality Management Practices in Manufacturing Sector, *International Journal of Research in Commerce and Management*, vol. 5, issue 5
- Kmetz, J.L., Mapping Workflows and Managing Knowledge: Capturing formal and tacit knowledge to improve performance, *Business Expert: New York*, 2012.
- Welman, C., Kruger, F., and Mitchell, B., Research Methodology: Third Edition, *Oxford University Press: Southern Africa*
- Stefanovic, S., Kiss, I., Stanojevic, D., and Janjic, N., Analysis of Technological Process of Cutting Logs Using Ishikawa Diagram, *Acta Technica Corviniensis – Bulletin of Engineering*, vol. VII, no. 4, pp. 93-98
- Fang, Z., Ye, W., Cheng, Y., Zhang, N., Liu, X., and Xu, L., Study on Quality Risk Control of Large-scale Complex Equipment based on a “Game-Fishbone Diagram” Model, *Journal of Grey System*, vol. 27, no. 2, 2015
- Russu, C., SWOT Analysis of the State and Prospects of the Romanian Manufacturing Industry Sectors, *Economic Insights – Trends and Challenges*, vol. 2, no. 4, pp. 27 – 37, 2013

Biography

Michael S. Mkwazi is a Junior Lecturer in the Department of Business Management at the University of Johannesburg in South Africa. Mr. Mkwazi holds a National Diploma in Entrepreneurship, Bachelor of Technology Degree in Operations Management, and Master of Technology Degree in Operations Management from the University of Johannesburg and a Postgraduate Diploma from North West University. He was awarded the Prestigious Mandela Rhodes Scholarship in pursuit of his Master of Technology Degree in Operations Management and during this time was recognized as a runner up for the Queens Young Leaders Initiative which is managed by the Cambridge University Institute for Continuing Education. He has published some conference papers in the field of co-operatives and on system reliability under IEEM. Currently, Mr. Mkwazi is a 2017 Rhodes Scholar Elect and he plans to pursue an MSc Degree at Oxford University.

Charles Mbohwa Professor Charles Mbohwa is the Vice-Dean Postgraduate Studies, Research and Innovation at University of Johannesburg's (UJ) Faculty of Engineering and the Built Environment (FEBE). As an established researcher and professor in the field of sustainability engineering and energy, his specializations include sustainable engineering, energy systems, life cycle assessment and bio-energy/fuel feasibility and sustainability with general research interests in renewable energies and sustainability issues. Professor Mbohwa has presented at numerous conferences and published more than 150 papers in peer-reviewed journals and conferences, 6 book chapters and one book. Upon graduating with his B.Sc. Honors in Mechanical Engineering from the University of Zimbabwe in 1986, he was employed as a mechanical engineer by the National Railways of Zimbabwe. He holds a Masters in Operations Management and Manufacturing Systems from University of Nottingham and completed his doctoral studies at Tokyo Metropolitan Institute of Technology in Japan. Prof Mbohwa was a Fulbright Scholar visiting the Supply Chain and Logistics Institute at the School of Industrial and Systems Engineering, Georgia Institute of Technology, is a fellow of the Zimbabwean Institution of Engineers and is a registered mechanical engineer with the Engineering Council of Zimbabwe. He has been a collaborator to the United Nations Environment Programme, and Visiting Exchange Professor at Universidade Tecnológica Federal do Paraná. He has also visited many countries on research and training engagements including the United Kingdom, Japan, Germany, France, the USA, Brazil, Sweden, Ghana, Nigeria, Kenya, Tanzania, Malawi, Mauritius, Austria, the Netherlands, Uganda, Namibia and Australia.