AN EMPIRICAL ANALYSIS OF OPERATIONAL DISTURBANCES AND THEIR IMPACT ON BUSINESS PERFORMANCE IN MANUFACTURING FIRMS: CASE TOOLING INDUSTRY SOUTH AFRICA

M.T. Dewa[1*], S. Matope[2], A.F. Van Der Merwe[3] and L. Nyanga[4]
[1-4]Department of Industrial Engineering
University of Stellenbosch, South Africa
[1]mnce2009@gmail.com
[2]smatope@sun.ac.za
[3]andrevdm@sun.ac.za
[4]inyanga@sun.ac.za

ABSTRACT

Globalization has managed to break trade barriers and the manufacturing environment has become more competitive. Market share is now determined by quality of goods and services irrespective of location. Today's business environment for manufacturers requires flexible, responsive and robust systems, which produce a variety of products at competitive prices. To gain a competitive edge, the paradigms of e-manufacturing and distributed manufacturing have been recently advocated by researchers as potential solutions. However, irrespective of these technological advancements, manufacturing firms in the tool and die sector are still struggling to perform efficiently in the face of recurring operational disturbances. The paper identifies the most prevalent operational disturbances which occur in South Africa's manufacturing firms in the tooling industry and their impact on business performance. A field study was conducted on a number of organizations which form an industrial cluster in the Western Cape manufacturing sector and seven typical disturbances were evaluated together with their root causes. The results gathered portrayed the correlation between identified disturbances and their corresponding consequences. The findings of the study were recommended to be used to develop models and computerized systems to solve the pending pandemic.

[*] Corresponding Author

1 INTRODUCTION

The business world has become a global market. Customers are now able to get their needs met with aid of e-commerce and mobile technologies. With the rapid growth in manufacturing technologies and the internet, most manufacturing firms are now adopting agile manufacturing to improve their productivity, responsiveness and customer service. Production units that have not evolved their manufacturing strategies to adopt best practises are now facing vigorous competition with respect to quality, cost and time to market.

To cope in such a competitve environment, manufacturing firms need to build reactive, scalable and flexible manufacturing systems which are capable of adapting to dynamic market and shop-floor conditions. With these characteristics, firms position themselves competitvely and grow their market share. In an effort to achieve these goals, a lot of research is being conducted on the possibility of South African manufacturing firms in the Tool, Die and Mould-making industry (TDM) implementing e-manufacturing systems. These systems promise to facilitate the sharing of information and resources among manufacturing firms over a collaborative network. An e-manufacturing system model which facilitates enterprise integration, knowledge transfer and resource sharing among manufacturing firms in the Western Cape Province was proposed by Nyanga [1]. However, the efficient and smooth running of TDM organizations remains a major problem irrespective of the human and technological resources they may have at their disposal. This is mainly because these firms continually face internal and external unwanted setbacks during their day to day operations. These operational disturbances compromise the business performance thus upsetting the achievement of set targets and goals.

This paper presents a set of operational disturbances which firms in the South African TDM industry face more frequently. The organization of the paper is as follows: we first discuss the current state of the TDM industry in South Africa, we then discuss different operational disturbances and lastly we present the identified disturbances with their corresponding impact on business performance.

2 CURRENT STATE OF THE SOUTH AFRICAN TDM SECTOR

Tool, Die and Mould manufacturing has long been considered a key industrial sector. It is the sole supplier of basic production equipment for all manufacturing firms. According to Canis [2], tools, dies, and moulds are pivotal to durable-goods manufacturing. Tools are used to cut and form metal and other materials, while dies are metal forms used to shape metal in stamping and forging operations. Moulds are metalic implements used to shape plastics, ceramics, and composite materials.

The Tool, Die and Mould Making industry plays an important role in terms of employment creation and the economic growth in South Africa. Captains in industry and researchers have developed keen interest in developing strategies and methods to improve this sector. The main reasons for this interest in the industry are:

1. Records as highlighted by Geyer and Bruwer [3] reveal that 90% of the South African tooling industry companies comprise of Small, Medium or Micro Enterprises (SMMEs). According to Malherbe [4], SMMEs are the economic backbone of developing economies and account for approximately 60% of all employment in South Africa, with a contribution of 40% to the South African Gross Domestic Product (GDP). In addition, the SMMEs are often the vehicle by which entrepreneurs from all socio-economic levels gain access to economic opportunities [4].
2. The value adding of tooling in the economy is high (estimated 1:19). For every R 1 million invested in TDM equipment and technology, over 250 million components could be manufactured making the industry an important value-added catalyst in the South African economy [3].

The Tool, Die and Mould-making (TDM) industry in South Africa is a critical support industry to the broader manufacturing industry bridging the gap between product development and production. The sector supports different production units with the automotive and packaging industries being its biggest clients [3]. This makes the TDM industry a high value-adding constituent of the supply of manufactured products by being the heart of component manufacturing and by forming the backbone of the manufacturing sector.

Due to its importance to the economy and manufacturing sector, the South African Government initiated the National Tooling Initiative Programme (NTIP) in March 2002. The NTIP under the Department of Trade and Industry, was mandated to formulate strategies to revive the TDM sector. Two key programmes namely the Skills Development Programme and the Enterprise Development programme were launced by the NTIP so as to improve the sector's competitiveness.As part of the work, the NTIP in collaboration with academic institutions of higher learning conducted a benchmarking programme for the TDM industry so as to establish the status of the sector before strategic interventions could be designed and implemented [4]. As revealed in an Engineering Artisan article [5], the current benchmarking report on the South African TDM Industry indicates that without interventions, many local companies benchmarked will not survive global competition and will eventually struggle.

Results of the benchmarking study conducted indicated that besides producing quality tools, dies and moulds, another key success factor for firms doing well in the TDM sector globally is product time-to-market. Some South African firms are still struggling to deliver customer orders on time or faster than their European and Asian competitors who have altered their businesses to design, manufacture and deliver products fatser and reliably to customers. The work done to date has addressed the aspect of improving quality, minimizing cost of products and the optimal utilization of tool room resources with little emphasis on improving production speed.

In his study, Islam[6] revealed that inorder to meet customer due dates or improve delivery speed to market, high levels of overall system reliability need to be maintained. However, almost all manufacturing organizations face undesirable and unwanted setbacks in their day to day operations. These setbacks, referred to as "operational disturbances" in this paper have the potential to negatively impact business performance. In work done by Mitala [7], Monostori [8] and Monica [9], it was observed that events like the late delivery of raw materials and rush orders can lead to operational disturabnces which render the shop-floor system unavailable, unreliable and delay the production of orders.

To deal with these operational disturbances effectively, companies in the TDM sector need a systematic way to identify and manage these setbacks. The paper focuses on the first step of identifying the main operational disturbances firms in the TDM sector in South Africa have suffered and their possible causes and consequences. Firms in the Western Cape Province forming an industrial cluster were used for this analysis.

3 OPERATIONAL DISTURBANCES

A manufacturing entity is a complex system which includes many functional areas which are mutually dependent on each other from procurement of raw materials to finished products dispatch. The failure of one function can greatly impact other functions. At times, system failure results from operational disturbances. These internal and external disturbances alter the state of the system at any given time rendering it unreliable thus compromising production goals. Islam [10] defined an operational disturbance as:

> "*An undesirable or unplanned event that causes the deviation of system performance in such a way that it incurs a loss*"

In other studies, he used the terms setbacks, disruptions, errors, failures, production risks determinants [11] and unwanted events [12] interchangeably to refer to these disturbances. The consequences of operational disturbances may be experienced through wastage of time and raw materials resulting in high production costs, longer lead times and poor product quality.

3.1 Disturbance mapping

Every operational disturbance, regardless of size is caused by some event and results in a consequence which negatively affects business performance, flow of operations and worker health and safety (Figure 1). Events leading to operational disturbances may be triggered from external factors emanating from a firm's suppliers and customers or from internal factors resulting from incorrect production practices on the shop-floor.

The work discussed in this paper will focus mainly on the impact of identified operational disturbances on the business performance of firms in the TDM sector.

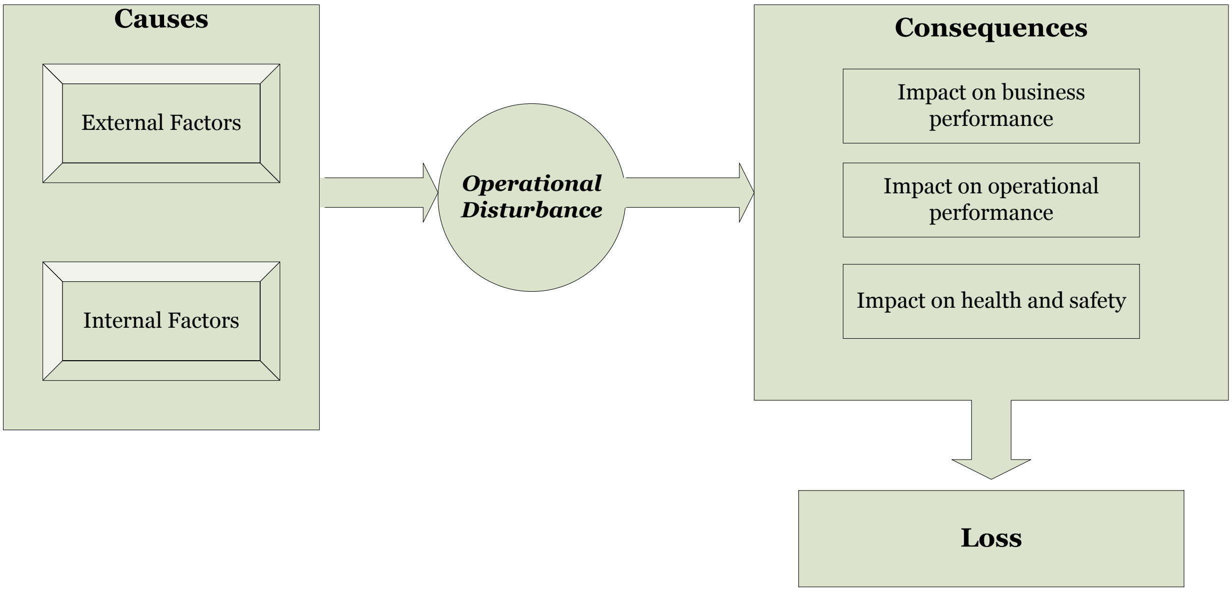

Figure 1: Operational Disturbance mapping Diagram [13]

3.2 Classification of operational disturbances

Scholars have used different methods of classifying operational disturbances. According to De Jong [14], operational disturbances can be resource-related, task-related, supplier-related or job-related. Resource-related setbacks include machine breakdown and worker absenteeism. Cowling and Johansson [15] discussed on job-related disturbances which include work-in-process increase due to sudden demand changes and rush orders. Supplier-related operational disturbances include shortage of raw materials which can result from the late delivery of a required raw material while task-related disturbances include tool malfunction or equipment damage during an operation.

In other studies, Islam and Tedford [12] classified the disturbances are either as internal or external where the former are related to the setbacks which are initiated within the production system while the later disturbances encompass those caused by customers and suppliers. However, Frezzile et al. [16] employed a supply chain approach to classify possible causes of operational disturbances according to their position of occurrence. In his analysis, causes were classified as either coming from upstream events, internal events or downstream events. All approaches are related and help describe the dynamics of operational disturbances in terms of their relation to a manufacturing set-up. In this study, De Jong's approach of classifying operational disturbances is used since it relates a disturbance to different parts of the manufacturing system (customer orders - jobs, suppliers, resources and tasks).

3.3 Types of operational disturbances

The entire supply chain needs to be monitored and managed well to prepare for the occurrence of disruptions, which can be caused by sudden changes in events within a system. This section outlines different types of operational disturbances other researchers have identified in previous studies. The presented set was then used for further analysis in the identification of the most prevalent setbacks the TDM sector in South Africa is experiencing.

3.3.1 Resource-related operational disturbances

Bereiter [17] and Nauro et al. [18] identified machine breakdown as a major setback most manufacturing set-ups encounter. Malfunctions may result from inadequate maintenance procedures or the adoption of a wrong operation during manufacturing. Operator absenteeism is another operational disturbance which can be expensive to any production system. When a worker is absent, the shop-floor is deprived of certain skills and this may delay production or compromise the quality of outputs produced. Possible causes of worker absenteeism include unsafe working conditions, poor motivation, industrial action or untimely family events. When system resources fail to function well, production is slowed down.

3.3.2 Task-related operational disturbances

The damage of tools or equipment during production is a common task-related operational disturbance which can temporarily hinder progress. Wear and tear occurs during use of tool resulting in them becoming obsolete. Tool damage may result from poor procedures during fabrication. Nauro et al. [18] also identified defective raw materials as another task-related setback which may result from receipt of defective parts from suppliers or the use of poor storage and material handling techniques. Occupational accidents are task-related disturbances which can also result from the resources being used.

3.3.3 Supplier-related operational disturbances

Upstream problems or changes can lead to shop-floor disruptions. Shortage of raw materials which may result from delayed supply or unavailability of the resources from suppliers can affect the smooth flowing of operations. In other cases, the firm may be adopting a poor inventory control system hence resulting in untimely stock outs. An erratic supply of power or water is another supplier-related production setback which has the potential to negatively affect performance. Power cuts render the entire system unavailable since most elements in the production system; machinery, equipment and computers depend on a supply of electricity.

3.3.4 Job-related operational disturbances

Downstream changes by customers can result in job-related operational disturbances. These changes include changes in volumes, cancellation of orders, rush orders or changes in due dates. Such events result in work-in-progress increase, which is a major production setback. Table 1 summarizes the operational disturbances identified from the literature.

Table 1: Types of operational disturbances

Category	Operational Disturbance
Supplier-related	• Erratic power supply • Erractic water supply • Shortage of raw materials
Job-related	• Work-in-progress increase • Defective products
Resource-related	• Worker absenteeism • Machine breakdown • Software failure • Machine malfunction • Stalemate due to labour strike
Task-related	• Equipment damage • Tool failure • Material handling disruption • Line blockage

4 RESEARCH METHODS AND MATERIALS

An empirical investigation was selected as the appropriate methodology. Pettigrew et al. [19] and Luis et al. [20] agreed on the fact that empirical studies place special emphasis on affiliated research leading to framework establishment for improvement of an entity's strategies. As such, structured interviews and questionnaires were used as a means for data collection. The purpose of the interviews was to establish the frequently experienced operational disturbances in the tool and die industry in South Africa. The tooling industry in South Africa serves the Packaging, Food, Automotive, Mining and Plastic Forming industries. The Delphi or Expert Opinion methodology was used to select the appropriate respondents who were captains of industry in the South African tooling sector. Five firms were randomly selected for the interviews and all accepted to participate. A set of similar structured questions based on the operational disturbances shown in Table 1 were asked.

The purpose of the questionnaire survey was for further analysis of the identified operational disturbances in terms of their frequency of occurrence and their relationship with the suggested causes and consequences. The questionnaire was developed in two stages which included a pilot study to test and refine the data collection instrument and a formal study to collect the required information.

In the questionnaire survey, a targeted population size of 150 tool rooms forming an industrial cluster in the Western Cape region of South Africa were selected for investigation. Of these, 102 firms agreed to take part in the study making them the sample size for analysis. A total number of 102 questionnaires were sent out to the organizations participating. A follow up on receipt of the questionnaires was done via telephone calls and emails. Of the 102 questionnaires, 71 were returned; hence the response rate was 70%, which is acceptable. Among the 71 returned for analysis, only 58 were in an acceptable format (13 were spoiled or inadequately filled).

The variables in the questionnaire study were the identified operational disturbances (established from the structured-interviews), a set of events that might have caused them and a set of consequences which would result from them. Other questions included tool room specific data like product range, order qualifying and order winning factors. Each operational disturbance and possible consequence was questioned as a closed-ended question requiring responses on a five-point Likert scale proposed by John [21]. This was done so as to determine the frequency of occurrence for the variables in question. A ranking scale of Never = 1, rarely = 2, sometimes =3, often = 4 and always =5 was employed. An open ended question was included at the end of each section for respondents to include additional information they deemed relevant to the study. To establish the relationship between the identified operational disturbances and their consequences, a correlation analysis based on the Pearson correlation analysis was also conducted in SPSS.

5 RESEARCH FINDINGS

5.1 Structured interview results

After the structured interviews, seven operational disturbances affecting the South African tooling industry were established. The possible causes of the identified operational disturbances and their consequences on business performance were also outlined. Table 2 summarises the operational disturbances identified. These results were used for the design of the questionnaire used for further analysis.

Table 2: Summary of identified operational disturbances

Operational Disturbance	Category
Work-In-Process increase	Job-related/Task Related
Shortage of raw materials	Supplier-related
Defective raw materials	Supplier and Task-related
Equipment damage	Task-related
Machine break down	Resource-related
Worker absenteeism	Resource-related
Accidents	Resource/Task-related

5.2 Key Competitive Performance Objectives

Statistical Package for Social Sciences (SPSS – version 21.0) was employed as an engineering tool for data analysis of the questionnaires collected. According to Dewa et al. [22], offering good service to customers involves many different relations between a firm and its customers. These factors, also known as Competitive Performance Objectives (CPOs) determine whether a firm wins market share or remains uncompetitive. According to the results illustrated in Figure 2, 43% of respondents (industrial captains in the TDM sector) believed that product quality was the most important CPO that Tool Room products should possess to win market share. Due date conformance (16%), Product cost (13%) and Speed to Market (12%) was also deemed as critical success factors for firms doing well in the sector.

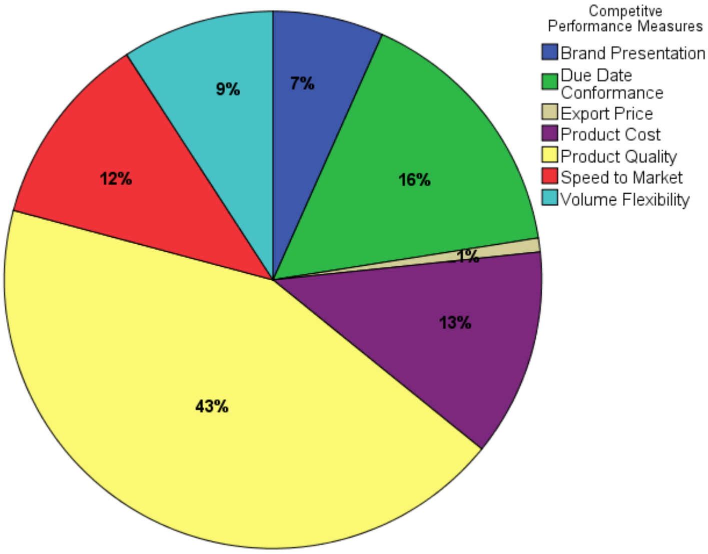

Figure 2: Key Competitive Performance Measures

5.3 Key Operational Disturbances

The seven types of operational disturbances shown in Table 2 were examined in terms of their frequency of occurrence in the studied companies. All organizations (100%) were found to encounter one major disturbance namely machine breakdown and 91% of the firms reported to have experienced equipment damage and raw material shortage. The percentage of investigated firms experiencing each operational disturbance data is presented in Figure 3.

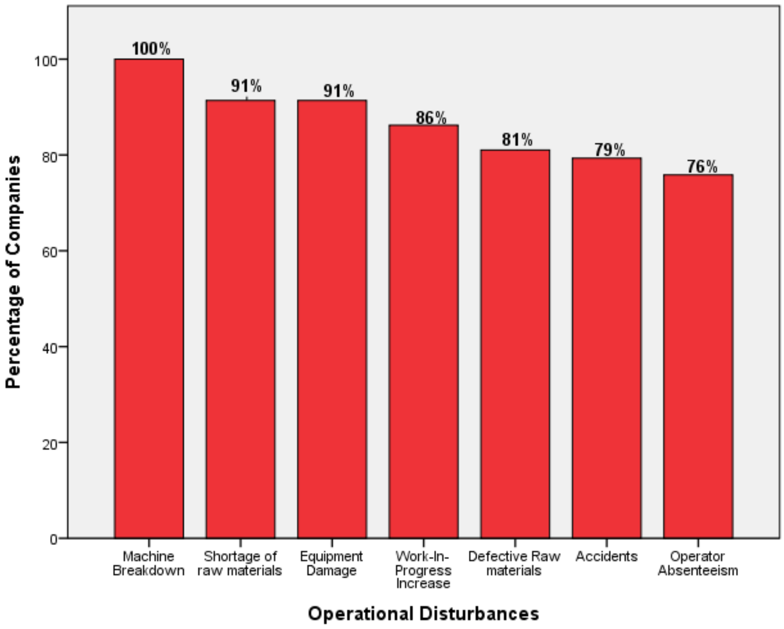

Figure 3: Prevalent operational disturbances

To establish the most prevalent operational disturbances experienced by the TDM sector in South Africa, mean values for each disturbance based on descriptive statistics in SPSS was used to rank the operational disturbances with the disturbance having the highest mean being ranked first. These results are displayed in Table 3.

Table 3: Descriptive Statistics for Operational Disturbances

	Raw Material Shortage	Defective Raw Materials	Work In Process Increase	Machine Breakdown	Equipment Damage	Accident Occurrence	Operator Absenteeism
Sample Size	58	58	58	58	58	58	58
Mean	2.93	2.33	2.61	3.33	2.53	1.96	2.20
Std. Deviation	0.953	0.893	1.013	0.632	0.847	0.660	0.840
Rank	2	5	3	1	4	7	6

Results of the calculated means of each operational disturbance based on the frequency levels gathered from the analysis are displayed in Table 3. The disturbances were ranked according to these means with the highest rank (1) assigned to the setback with the highest mean value and the lowest rank (7) assigned to the lowest mean value. According to the information shown in Figures 3 and Table 3 the most significant operational disturbances experienced by firms in the TDM sector are:

- Machine breakdown
- Shortage of raw materials
- Work build-up
- Equipment damage

Of the four identified operational disturbances, machine breakdown was the most common in terms of frequency.

5.4 Possible Causes of Operational Disturbances

Seventeen possible root causes of the operational disturbances were examined in terms of their frequency of occurrence in the studied firms. The results presented in Figure 4 show that 63% of the firms investigated attributed late delivery of raw materials from suppliers as the major cause of some of the disturbances experienced. Lack of worker motivation, poor machine maintenance and supplier production, quality and transportation challenges were also cited as key causative factors to the experienced setbacks by the participating respondents.

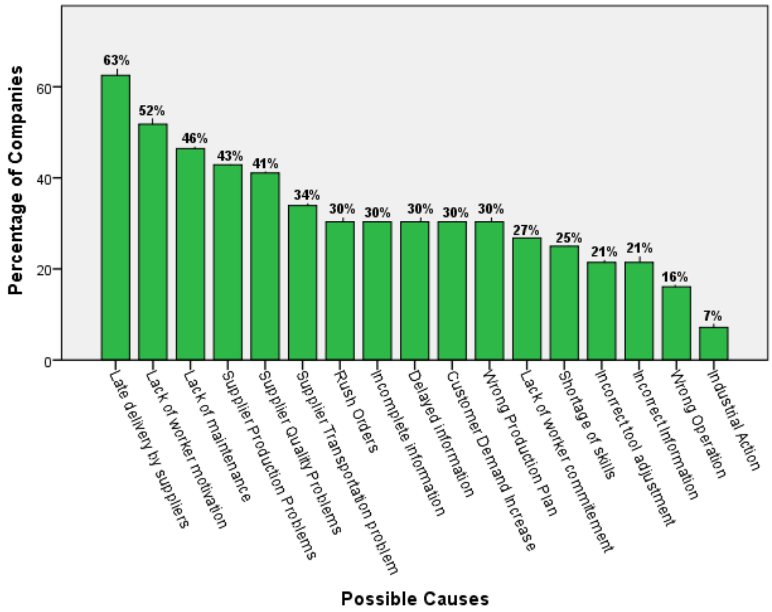

Figure 4: Root causes of operational disturbances

The relationships existing between the operational disturbances and the causes were also established. Results of the correlation analysis illustrate these relationships and are displayed in Table 4.

Table 4: Operational Disturbances and causes correlation

Causes / Disturbance	Late delivery by suppliers	Supplier Production Problems	Supplier Quality Problems	Supplier Transportation problem	Shortage of skills	Industrial Action	Lack of worker commitment	Lack of worker motivation	Wrong Operation	Incorrect tool adjustment	Lack of maintenance	Rush Orders	Customer Demand Increase	Incorrect Information	Incomplete information	Delayed information	Wrong Production Plan
Shortage of raw materials	.380**	-.047	-.002	-.116	.030	.084	-.128	-.184	-.072	.005	-.217	-.376**	.063	.157	.067	-.072	.063
Defective Raw materials	.147	.139	.212	.150	.067	.132	.085	-.044	-.276*	.139	-.006	.118	.215	-.079	-.070	-.075	.022
WIP Increase	.187	.336**	.120	.066	.226	.109	.122	.200	.036	.204	.059	.148	-.072	.081	.153	.148	.038
Machine Breakdown	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]	.380**	.[b]	.[b]	.[b]	.[b]	.[b]	.[b]
Equipment Damage	-.123	-.116	-.128	-.047	.030	-.159	.041	.184	-.069	.005	.153**	.063	-.207	.157	-.069	-.072	.063
Accidents	-.240	.170	.240	-.369**	.089	-.029	.204	.085	.090	.054	.118	-.232	-.045	.051	.027	-.045	-.045
Operator Absenteeism	-.045	.228	.128	.136	.318*	.154	-.035	.242	.121	.010	.184	.186	.009	.288*	.105	.098	.363**

**correlation is significant at the 0.01 level (2 tailed). *correlation is significant at the 0.05 level (2 tailed)

5.5 Impact of disturbances on business performance

Sixteen experienced consequences due to the operational disturbances were examined in terms of their frequency of occurrence in the studied companies. The results presented in Figure 5 show that 91% of the firms investigated experienced long downtime as the major result of some of the disturbances experienced. This is possibly due to machine breakdowns experiences which stop production and slow down operations. Eventually, orders are delivered late to customers while maintenance, inventory and production cost are increased. Upstream quality related problems result in the production of defective products thus resulting in waste of time and materials.

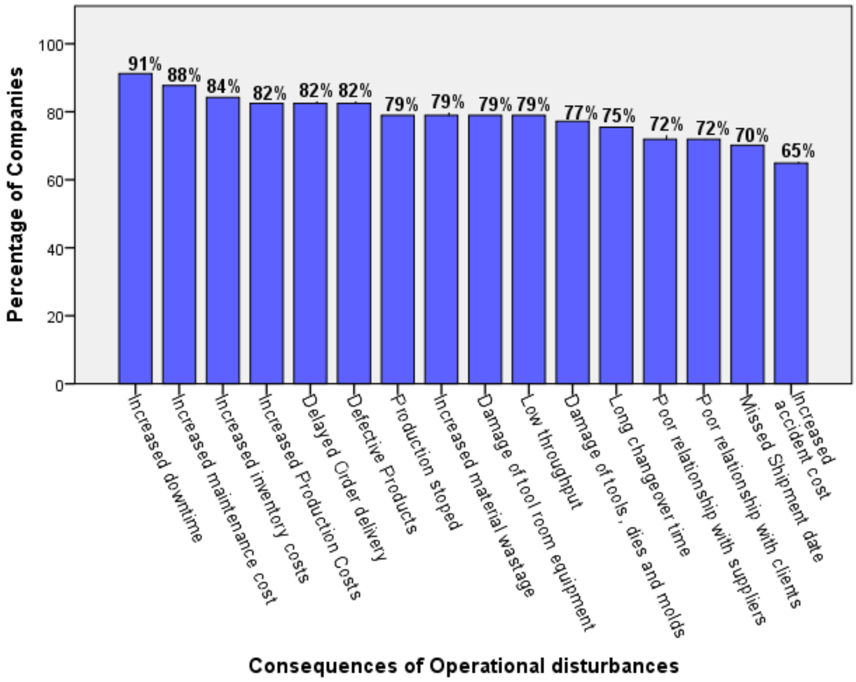

Figure 5: Consequences of operational disturbances

The mean values of each operational consequence were also determined and the results of the ranks are presented in Table 5. Increased downtime, increased inventory cost, increased production cost, late delivery of orders, increased maintenance cost and increased production cost were identified as the main consequences experienced in the sector.

Table 5: Descriptive Statistics for Consequences

Consequences	Sample Size	Mean	Std. Deviation	Rank
Defective Products	58	2.43	0.920	7
Low throughput	58	2.52	0.978	5
Delayed Order delivery	58	2.50	0.996	6
Long changeover time	58	2.36	1.038	8
Increased downtime	58	2.90	1.038	1
Missed Shipment date	58	2.12	0.900	13
Production stopped	58	2.10	0.912	14
Increased Production Costs	58	2.59	0.992	3
Increased material wastage	58	2.21	0.932	11
Increased accident cost	58	1.84	0.745	16
Increased maintenance cost	58	2.77	1.000	2
Increased inventory costs	58	2.53	1.037	4
Operator Absenteeism	58	.83	0.566	17
Poor relationship with clients	58	2.00	0.926	15
Poor relationship with suppliers	58	2.14	1.043	12
Damage of tools, dies and moulds	58	2.23	0.945	10
Damage of tool room equipment	58	2.35	0.973	9

The identified relationships existing between the operational disturbances and the consequences were also established. Results of the correlation analysis illustrate these relationships and are displayed in Table 6.

Table 6: Correlation between disturbances and Consequences

	Defective Products	Low throughput	Delayed Order delivery	Long changeover	Increased downtime	Missed Shipment date	Production stopped	Increased Production Costs	Increased material wastage	Increased accident cost	Increased maintenance cost	Increased inventory costs	Poor relationship with clients	Poor relationship with suppliers	Damage of tools, dies and moulds	Damage of tool room equipment
Raw material shortage	.014	-.066	-.067	-.168	-.185	-.032	.015	-.011	-.018	-.147	-.166	-.062	.049	-.068	-.110	-.229
Defective Raw materials	.416**	.196	.324*	.161	.220	.164	.254	.133	.201	-.096	.173	.236	.302*	.286*	.211	.072
Work-In-Progress Increase	-.208	.066	.067	-.047	-.115	-.166	-.162	-.214	-.173	.028	-.104	-.198	-.146	-.147	-.175	.090
Equipment Breakdown	-.052	.130	.042	.110	-.049	-.129	-.037	-.077	-.072	-.074	-.188	-.235	.000	.006	-.036	.062
Accidents	-.120	.128	.118	.051	.141	-.154	.053	.119	.188	.374**	.247	.012	.170	.139	.239	.333*
Operator Absenteeism	.179	.417**	.156	-.041	.089	-.027	.273*	.121	.135	-.023	-.009	.068	.135	.162	.109	.145
Machine Breakdown	1	.177	.354**	.367**	.562**	-.043	.239	.295*	.488**	-.080	.313*	.310*	.510**	.535**	.522**	.341**

**correlation is significant at the 0.01 level (2 tailed). *correlation is significant at the 0.05 level (2tailed).

As illustrated in Table 6, it was noted that the production of defective products is strongly correlated to defective raw materials. Machine breakdowns are strongly correlated to delayed order delivery, increased downtime, wastage of raw materials, and damage of equipment resulting in poor relationships with clients. Figure 7 summarizes the relationships established from the correlation analysis.

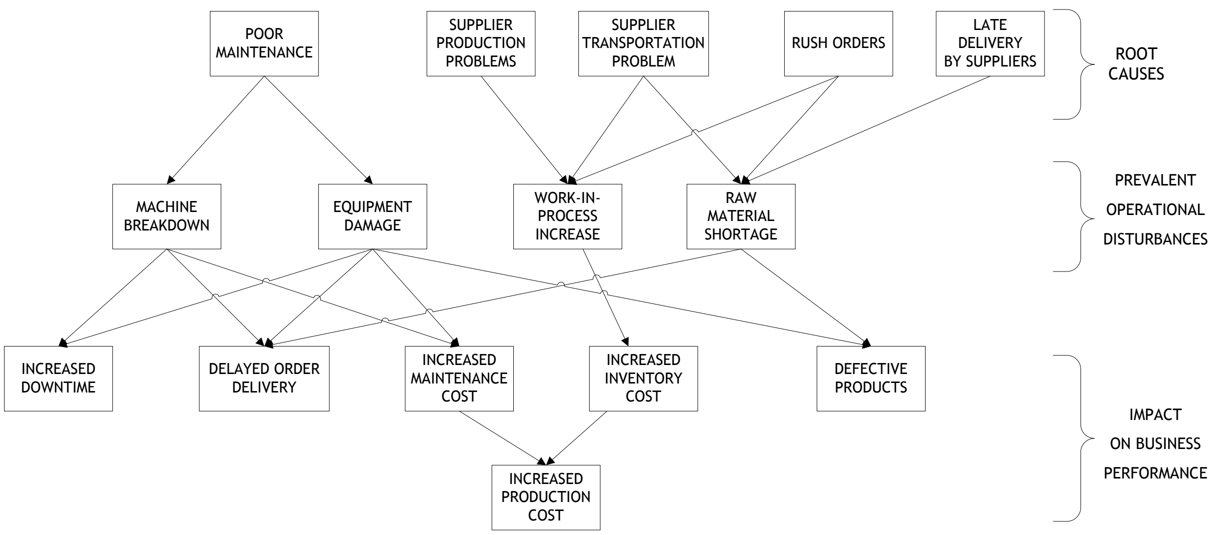

Figure 6: Cause-disturbance-consequence mapping

6 CONCLUSION AND RECOMMENDATIONS

The purpose of the study was to identify a set of common operational disturbances experienced by the Tool, Die and Mould making industry in South Africa's Western Cape Province. Due to the increased frequency of disturbances in manufacturing systems, techniques to minimize the impact of changes and disturbances on the manufacturing system performance are being developed. Most recently, researchers have proposed the design of holonic manufacturing and control systems (Bal and Hashemipour, [23]) to be a viable solution to the problem. Zhao et al. [24] confirmed the notion by mentioning that holonic systems are computerized models which provide a flexible and decentralized manufacturing environment to accommodate changes dynamically. The findings of this study are a key step to realising the goal of developing holonic systems.

7 REFERENCES

[1] **Nyanga, L., Van Der Merwe A. and Matope S., Tlale, N.** 2012. E-Manufacturing: A Framework for increasing Manufacturing Resource Utilization, *CIE 42 Proceedings*, Vol. 70, pp 1–12.

[2] **Canis, B.** 2012. The Tool and Die Industry: Contribution to US Manufacturing and Federal Policy Considerations. *CRS Report for congress*,pp 1-17.

[3] **Geyer, J.J. and Bruwer, R**. 2006. Role of collaboration in the South African tooling industry, *Journal for new generation sciences*, 4(1), pp 64-71.

[4] **Malherbe, D.C.** 2007. Benchmarking in the South African Tool and die manufacturing sector, *Masters Thesis Report*, SUN.

[5] **The Engineering Artisan**. Date read (2012-01-06). *The state of benchmarking in the TDM sector*,http://www.skillsportal.co.za/page/training/training_companies/engineering_artisan/1192300 -The-state-of-benchmarking-in-the-TDM-sector

[6] **Islam, M.A., Tedford J.D., Haemmerele, E.** 2006. Strategic risk management approach for small and medium manufacturing enterprises (SMEs) - a theoretical framework, *Proceedings of the 2006 IEEE International Conference on Management and Innovation Technolgy*,2nd Edition, pp 694.

[7] **Mitala, A. and Pennaturb, A.** 2004. Advanced Technologies and humans in manufacturing workplaces: an independent relationship, *International Journal of Industrial Ergonomic*, Vol. 33, pp 295-313.

[8] **Monostori, L., Szelke, E., Kadar, B.** 1998. Management of changes and disturbances in manufacturing systems, *Annual Reviews in Control 22*, pp 85-97.

[9] **Monica, P.B. and John, R.W.** 1999. HEDOMS – human errors and disturbance occurance in manufacturing systems: towards the development of an analytical framework, *Human Factors and Ergonomics in Manufacturing*, 1(9), pp 87 -104.

[10] **Islam, A., Tedford, J.D., and Haermmerle, E.** 2008. Managing operational risks in small and medium-sized Enterprises (SMEs) engaged in manufacturing – an integrated approach, *International Journal of Technology, Policy and Management*, 8(4), pp 420-441.

[11] **Islam, A., Tedford, J.D., and Haermmerle, E.** 2012. Risk determinants of small and medium-sized manufacturing enterprises (SMEs) – an exploratory study in New Zealand, *International Journal of Industrial Engineering*, pp 1-13.

[12] **Islam, A. and Tedford, J.D.** 2012. Implementation of risk management in industry – An empirical investigation, *International Journal of Research in Management & Technology (IJRMT)*, 2 (3), pp 258-267.

[13] **Islam, A.** 2011. Managing operational risks in small and medium manufacturing enterprises – a strategic approach. *In Engemann, K.J. (ed), Business Continuity and Risk management: The marketing & management collection, Henry Stewart Talks Ltd, London.*

[14] **De Jong, J.** 2012. *Heuristics in dynamic scheduling a practical framework with a case study in elevator dispatching*, Publishers.

[15] **Cowling, P. and Johansson, M.** 2002. Using real time information for effective dynamic Scheduling, *European Journal of Operational Research,* 139(2), pp 230–244.

[16] **Frezille, G., McFarlane, D. and Bongaerts, L.** 1998. Disturbance measurements in Production Manufacturing systems, *In Proceedings of ASI '98, Bremen, Germany*,pp 1-12.

[17] **Bereiter, S.R.** 1990. Difficulties in troubleshooting automated manufacuturing systems, *International Journal of Industrial Ergonomics,* Vol. 5, pp 91-104.

[18] **Nauro, N., Lehto, M. and Salvendy, G.** 1990. Development of knowledge-based decision support system for diagnosing malfunctions of advanced production equipment, *International Journal of Production Research,* Vol. 28, pp 2259-2276.

[19] **Pettigrew, A.M., Whipp, R. and Rosenfeld, R.** 1989. Competitiveness and the management of a strategic change process: a research agenda, *In Francis A, Tharakan M (eds) The competitiveness of European industry: country policies and company strategies*, pp 36, *London*

[20] **Luis, E.Q., Felisa, M.C., Serge, W. and Christopher, O.B.** 1999. A methodology for formulating a business strategy in manufacturing firms, *International Journal of Production Economics,* Vol. 60, pp 261 – 271.

[21] **John, D.** 2008. Do Data Characteristics Change According to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales, *International Journal of Market Research*. 50(1), pp 61 -77.

[22] **Dewa, M., Mhlanga, S., Masiyazi, L. and Museka, D.** 2013. Design of a Finite Capacity Scheduling System for bakery operations. *International Journal of Innovative Research in Science, Engineering and Technology,* 2(11), pp 6631-6640.

[23] **Bal, M. and Hashemipour, M.** 2011. Implementation of holonic scheduling and control in flow-line manufacturing systems: die casting case study, *Journal of Production Planning and Control,* 22(2), pp 108-123.

[24] **Zhao, F., Hong, Y., Yu, D., Yang, Y. and Zhang, Q.** 2010. A hybrid particle swarm optimization algorithm and fuzzy logic for process planning and production scheduling integration in holonic manufacturing systems, *International Journal of Computer Integrated Manufacturing*, 23 (1), pp 1-12.