Unravelling Impacts of Random Disruptions on Different Company-Layouts from an Industrial Engineering Perspective

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Abstract—Most companies invest largely on research and development to deliver best products on time which are amongst the prerequisites for business success. However, there’s one major problem that many companies often ignore: disrupted supply chain systems. In this paper impact of random disruptions on supply chain systems are unraveled. A company’s profitability is often determined by how it reacts to unforeseen disruptions, i.e. with supply chain, the question is not whether random disruptions will occur, but what will happen and when? What is important is how companies react to disruptions, how they bounce back and recover from the loss and reclaim near optimal performances.

Simulation model is employed to assist in determining operational characteristics. Impacts of random disruptions (expressed in terms of “productivity functions” which are also converted to monetary values) are obtained by comparing results from undisrupted or optimal system with that from random disruptions. Proposed models are tested on different manufacturing company-layouts in South Africa.

It is demonstrated that the leading sources of disruptions vary with industries. For financial service industry and call-centers, unplanned outage of IT, telecommunication systems and unanswered calls are the most common causes of disruptions, etc. It is further revealed that SA economic system is losing hundreds of billions of Rands annually due to these disruptions in the manufacturing sector. It can be concluded that productivity losses can be summarily claimed to be mostly due to supply chain disruptions.

Keywords—Productivity, Random Disruptions, Company-Layouts, Supply Chain, Simulation, Disruption Index

I. INTRODUCTION

COMPANIES are faced with many conflicting interests, e.g. Salesman wants the best product quality for clients, Purchasing Managers want the cheapest, Inventory Manager wants the leanest possible inventory (less inventory costs), but the sales department wants large stocks in order to sell products with shorter lead times.

All these internal conflicts essentially pose problems to supply chain. The subject of Supply Chain (SC) is perceived by many researchers and academics as a non-engineering problem. Is it really the case? Most companies wish that all systems were ‘static’ with all parameters deterministic, which is not the case with SC? Industrial Engineering (IE) is about system optimization, ensuring unconstrained flow of information and materials throughout any system. It is more about determining the most effective ways of doing things.

The use of “industrial” in “industrial engineering” can be somewhat be misleading, since it has grown to encompass any methodical or quantitative approach to optimizing how organization operates, and not only concern with processes in industries.

Senior managers in most companies tend to focus more attention on measurable performance indicators because of the financial implications they reflect. Measuring a company’s performance is important, but it is also important to measure the implications of disruptions. Unfortunately, many top executives are not comfortable or familiar with disruptions metrics which can assist them in assessing the impact of all potential disruptions. The ability of organizations to measure and track the impacts of random disruptions, as well as changes in trends over time are important to effectively manage and control supply chain disruptions (Bosman, 2006). It must be emphasized that by supply chain disruptions we are referring to all disruptions from receipt of an order, order placement, production until a part is delivered to the customer – “this broad process referred to as a value chain”. A partially broken or disconnected chain (as in the figure 1a & b) does not serve the purpose like that of unconstrained flow of materials and information. Some disruptions are acceptable while some are not, i.e., disruption is not extreme in figure 1a at least as compared to figure 1b. This paper addresses the following exampled problems, which is aimed at suggesting a guideline to be used by most managers to address critical services after disruptions. The issues are:

a) Challenges and most common causes of supply chain disruptions
b) Stochastic considerations of these disruptions
c) Prove scientifically how random disruptions impact companies
d) Express random disruptions and their respective impacts in terms of monetary value

Loss of productivity is the key outcome for most supply chain disruptions, e.g., if companies do not have the right raw materials at the right time and location when required, subsequent workstations come to a standstill. Failure by SA Manufacturing sectors to deliver consistent and reliable services to customers result in significant loss in market share. The success of manufacturing industry at large is greatly dependent on the ability to deliver reliable service to the customers on time.
According to a market survey, a 1% improvement in the reliability of goods delivery time could yield up to as much as 5% increase of sale revenue in other markets, (Mapokgole and Tengen, 2011). These statistics shows that South Africa is blindly and massively affected by disruptions. Therefore, failure to deliver a product as promised affect pre-planned operations downstream and robs the country off its well-deserved GDP.

The importance of unearthing supply chain disruptions is evidenced by the fact that a major fraction of most manufacturing executives’ time in SA is devoted on handling exceptions (such as overdue orders, solving various problems caused by disruptions, etc). This is justified by the statistics below. At the national level, monetary implications of supply chain disruptions are immense and still remain unknown. For instance, automotive manufacturing industry in SA is roughly a R118.4 billion industry, according to Stats SA (2010). A typical manufacturer spends about 55% of revenue on manufacturing costs, and 40% of manufacturing cost is overhead. Thus, overhead for automotive industry amounts to approximately R26.4 billion per year. Similarly huge numbers equally hold in many other sectors. An improvement in these numbers is the motivation for global support for the development of improved methodologies and policies for handling and measuring disruptions.

Order-to-cash conversion performance is at the very heart of almost all companies, i.e. how inventory is converted to cash. When planning departments configure incorrect bill of material, it results in incorrect parts procured and supplied, resulting in customers choosing to find alternative suppliers and company loses its share of the market. For some make-to-order companies, failure to deliver products on time results in penalties. These shows how expensive supply chain disruptions are (e.g., costs associated with rectifying the problems).

II. SUPPLY CHAIN DECOMPOSITION

Generally, movement of materials, information, and finances from supplier to manufacturer to wholesaler to retailer to consumer is regarded to as supply chain, (Wildgoose, 2011). It is a complex and dynamic supply and demand network - SC is developed to express the need to integrate the key business processes. Supply chain involves coordinating and integrating these flows both within and outside companies. Supply chain in this paper is depicted by order workflow (Figure 2a and 2b), depicting workflow steps. The order workflow process in the value chain business model is similar to that of the direct sales business model, in that order is placed, payment approved, and the order is released to fulfillment. This system is haunted by a wide variety of random disruptions, some costly some not. Many disruption factors affect the manufacturing sectors. Below are indications of how two of the most common disruptions (employee absenteeism and machine) affect the supply chain systems and productivity.

A. Employee Absenteeism

Supply chains among other resources rely mainly on people and machines. People will always remain as important assets to supply chain until all processes are fully automated. Among other causes of random disruptions, below is as an example - an employee may experience a wide variety of disruptions such as tire puncher on a way to work, stuck in traffic, or even absenteeism(as a result of strikes, employee sickness, etc).

Depending on the type of company layout, this disruption type affects companies differently. In highly specialized environments employee absenteeism results in zero productivity because available employees are not trained or skilled to operate or carry out other machines, e.g. in productlayout setting, operations comes to a standstill until trained employees are back to operate this specialized machines, since the layout design focus is on alleviating raw materials related problem. As for other company layouts (e.g. process layout planning department), impact following employee absenteeism is envisaged not to be that massive because employees’ skills are interchangeable, that is to say employee from machine A are trained to operate machine B and vice versa. During strike admin staff can also operate these machines until employees are back in process layout. Strikes and/or employee absenteeism in this casemay not yield “zero” productivity. These just prove that “same” disruption affects various company-layouts differently.

B. Machine Breakdown

Machine breakdown is of much concern to supply chain like employee absenteeism at the workstation.

![Fig. 2a Supply Chain Process - Order Flow](image-url)
III. CASE STUDY AND METHODOLOGY

Different scenarios that may have impacts on supply chain and their respective probable impacts on Supply Chain under different company layouts are discussed here. Supply chain is decomposed into single process flow diagrams for ease of analysis.

A. Process Flow Description

In this report, a multifactor disruption variable approach in one of South African giant refreshment company, “Coca-Cola” is dealt with. ARENA application is employed to simulate the actual dynamics of the production flow. Two different models are developed; one representing an undisrupted flow which is used as a baseline and the second model representing a system that is subject to random disruptions (see the result section).

As one might expect, processing any one bottle of any Coca-Cola product requires many steps across many workstations (figure 3). Before the finished product can even begin to be assembled, there are numerous inputs that have to be properly monitored and accounted for, including the bottles, water, syrups, and caps. The main process following bottling are de-palletizing, cleaning, filling, capping, heating, labeling, packaging and re-palletizing. Water has to be tested and treated many times to ensure the precise quantities or amount of various minerals and elements that may affect the longevity and taste of water, along with the temperature. Syrups must also be stored at very exact temperatures, get mixed with water in a side process before bottling can begin. Additionally, caps go through a test to ensure conformation to specifications and durability before being entered into the system.

The main process starts with transporting empty bottles, which are on pallets, from the stockpile to a machine that takes them off and rechanneled them down to a single line. Bottles are then cleaned and dried to make sure that they are crystal clear. Immediately before filling, syrup or water mixture is mixed with carbon dioxide. The bottles are then filled in a filling machine that is precisely timed to ensure the same amount of product is put in any bottle. The caps are then forced onto the bottles by another machine. The product and bottles are kept at a very cold temperature. The bottles go through hot-winding machine to ensure they do not condensate during the labeling process. The bottles are then labeled using a machine that applies adhesive substance to the bottle, wraps on the label, and cuts the label tape. From there, bottles are grouped together per size, 12 at a time, onto a piece of cardboard, shelled with a designed plastic casing put through a warmer to melt the plastic shell, palletized and then wrapped.

As mentioned already, the occurrences of disruptions on the supply chain systems affect productivities of the systems under consideration. On the impact of disruption, productivity values should be calculated for both ideal production systems, (that without disruptions) and for one obscured by random
disruptions, and the difference between both states should enable researcher to measure how random disruptions affect supply chain systems, as illustrated by the expressions below:

\[ P_{\text{ideal state}} - P_{\text{with random disruptions}} \xrightarrow{\text{yield}} D_{\text{impact}} \]  

(1)

The ideal state should be the target. The basic productivity function can be expressed mathematically as:

\[ P = \frac{O}{I} \]  

(2)

Where, “P” represents productivity function, “D” represents impact of system disruption, “O” is the output quantity, and “I” is the multivariable input quantity.

To determine the severity or degree of various impacts of disruptions, the disruption index is introduced.

Mathematically, disruption index is given as the ratio of the performance factors on days with disruptions and total days worked, as follows (Groover, 2008):

\[ DI = \frac{P_{\text{disrupted}}}{P_{\text{planned}}} \]  

(3)

Where, “DI” represents a disruption index, “P_{\text{disrupted}}” is the actual production, and “P_{\text{planned}}” is the planned production.

IV. RESULTS

Several important conclusions can be formulated following above expressions and simulation model for the scenarios under case study section. These are summarized in the following:

A. Impact Of Disruptions

Since systems are subject to a variety of random disruptions, it is important to find out per company layout how these disruption affect them. Supply chain encompasses all different types of company layouts, for that reason different companies were considered for analysis. Based on questionnaires, it was apparent that leading sources of disruptions may vary from industry to industry. For financial service industries and call-centers, unplanned outage of IT, telecom systems and unanswered calls are the most common causes of disruptions. In service industry like hospitals, shortage of medication and shifts change-over are recorded as the most common causes of disruption. In manufacturing industries, machines’ breakdowns, raw material shortages and employee absenteeism are the frequent causes of disruptions. For retail and wholesale, IT and communications; adverse weather, transport networks and storage are the most common cause of disruption. Supply chain disruptions are identified as the primary cause of productivity losses. Productivity is indirectly proportional to supply chain disruptions, i.e. an increase supply chain disruptions results yields loss in productivity. Any company layout experiencing worsening degrees of distress and disruptions, loss of productivity proved to be greater.

For production line department, product family and process department the most recorded disruption is employee absenteeism followed by machine breakdowns at less than 1.5% of the total time then by perishable raw materials shortage following late deliveries by suppliers. Employee absenteeism may occur more often, but it’s not as expensive as machine breakdown and late deliveries because in some companies employees are cross-trained to operate or work on other production lines. With a fixed layout where all processes and materials required for production are brought to a product; severe weathers conditions proved to be costly and leading disruptions in raining seasons, i.e. construction of a new building – work comes to a complete halt or standstill.

As presented in the previous sections, disruption impacts are also assessed by determining a disruption index using expression (3), which is the ratio of the planned production on...
days when disruption occurred, divided by the average planned production performances on days when no disruption occurred. The results for simulation model and disruption indices are presented succinctly in table I, II and III. Companies encounter many disruptive factors, and for this study only top rated “A” significant disruptions are presented.

Below are highlights of various leading disruptions per industry.

<table>
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<tr>
<th>Table I Manufacturing Process Industry</th>
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<tr>
<td>Company Layout</td>
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<tr>
<td>Production</td>
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<tr>
<td>Process</td>
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<tr>
<td>Product</td>
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<td>Fixed</td>
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As can be seen, machine breakdown is a leading source of disruption occupying 28% of the total disruptions, followed by raw materials shortage at 22%, then employee absenteeism by 21%, etc, has the greatest impact on performance of the production system. In this case study, overall production performances dropped massively by 29% following random or unforeseen disruptions.

“The total SA turnover of all industries for 2009 was estimated at R5.7 trillion, an increment of 15.4% compared with the revised estimates for 2008 (R4.9 trillion)” key findings by Stats SA (2009). The largest percentage increase of 22.8% was reported by manufacturing industries, followed by electricity, gas and water supply at 21.2%, construction at 17.1%, mining industry at 15.6%, etc. The importance of focusing more on manufacturing industry is further accentuated by its contribution to the national gross domestic product which is currently standing at +23%. Therefore, an increment in these figures shall yield an impressive GDP, which is partly a motivation for carrying out this study. As it can be seen on table III that company’s resources are not fully utilized, i.e., production line is not balanced. Overall planned production rate per scheduling horizon is set to 1800 units, which is determined based on the lowest processing station. This high level production decision is costing the company off its deserved return on investment as utilization rate for some machines is only 60%. Another disruption is ‘order change’, it depends on the stage at which disruption occurs, i.e., a disruption at the beginning of the production cycle phase proved not to be as expensive as compared to a disruption occurring towards the end of the production cycle (all production efforts are vain).

From an industrial engineering perspective, researcher suggests that a company should consider line balancing to claim lost production on the under-utilized resources.

Deviation between both indices represents lost production due to organizational failure to pre-balance the production line. Once again from industrial engineering perspective, this can be merged by employing theory of line balancing that deals with determining required number of resources (for example
the required number of resources in production line that minimize bottlenecks and optimize available resources performances). The ability to meet target demand is based on planned availability of resources which is underutilized in this case. Thus, knowing the variation in production rate and production time, and using knowledge of line balancing, one can determine the variation in number of additional required resources to meet the initial production target.

V. CONCLUSION

In this work, different stages of supply chain and their respective impacts following various disruptions with emphasis on manufacturing systems is discussed. An objective among others is to unpack and lessen degree of disruptions that ultimately determines organizational gains and/or loss. It is demonstrated how disruptions affect different company layouts and their implications thereof. Methodology presented herein covers only two types due to the limitations of the scope.

It is shown by other researchers that leading sources of disruptions may vary from industry to industry; i.e. for financial service industries and call-centers, unplanned outage of IT, telecom systems and unanswered calls are the most common causes of disruptions. In service industry like hospitals, shortage of medication and shifts change-over are recorded as the most common causes of disruption. In manufacturing industries, machines’ breakdowns, raw material shortages and employee absenteeism are the frequent causes of disruptions. For retail and wholesale, IT and communications; adverse weather, transport networks and storage are the most common cause of disruption. Supply chain disruptions are identified as the primary cause of productivity losses. Productivity is indirectly proportional to supply chain disruptions, i.e. an increase supply chain disruptions results yields loss in productivity. Any company layout experiencing worsening degrees of distress and disruptions, loss of productivity proved to be greater.

It can further be analyzed that the impact of disruptions on all different types of company layouts. In as far as sales order changes are concerned; there is only5% loss of efficiency and production performance when order changes are being performed, although it is possible to perform many changes without a loss of efficiency. It is believed the key variable affecting efficiency is the time of the change (i.e. at what phase or stage the down the process an order is changed). An order change requested before production commences affect supply chain one way or the other, i.e. materials might have been ordered and delivered, order close to completion phase, or completed pending shipment, etc. An “order change” is one of costly disruption factors in the supply chain more than it is solely for the manufacturing process. Because disruptions are the root cause of loss of efficiency, it is concluded that to manage order cancellations or changes for improved efficiency, it is important to avoid and manage disruptions.

Disruptions increase supply chain costs; as they move system away from its optimal settings. For future research endeavours, it can be suggested that more research must be done on relating production disruptions with their economic implications more in detail.

REFERENCES