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The Effect of Unforeseen Disruption on Different Types of Manufacturing Industry-layout

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Abstract. Consistency and on timely delivery are among some of the factors that can keep a customer loyal and committed to a manufacturing industry. Almost all manufacturing facilities need to use production scheduling systems to increase productivity, reduce production costs and time. Most manufacturing industries invest huge amount of money to manufacture and supply products on time in order to meet customers demand and objectives but due to unforeseen disruptions, these objectives are difficult to achieve. In Real-life, production operations are subject to a large number of unexpected disruptions that may invalidate an original schedule. Being able to cope or react to these disruptions determines a company's out-put and profitability. Productivity expression and simulation models are employed to assist in determining operational characteristics and also by comparing results from undisrupted system with that which is disrupted. These proposed models are tested on different tile manufacturing industry lay-outs in CMR and it is demonstrated that the leading source of disruption varies with different industry-layout and geographical regions. The study revealed that, the most common cause of disruption are power failure, machine breakdown, advert whether and employees absenteeism).This can be concluded from an industrial engineering point of view that, disruption during tile manufacturing is the main cause of low productivity or out-put in CMR tile manufacturing industries.

Introduction

Almost all manufacturing facilities need to use production schedule systems to increase profitability and reduce production cost. Tile manufacturing industries in Cameroon (CMR) spends enormous amount of money and efforts to generate business plans, production schedules based on demand and other operational requirements in order to maximize profitability. Unfortunately, at the operational level, preliminary decisions or plans are often affected by disruptions which are largely unforeseen, such as power failure, machine break down, employee's absenteeism, shortage of raw materials and modification of customer's demands. These disruptions are unpredicted events of various types which may severely impact the performance of a production system and create a deviation from an initial schedule to be absolute and if proper measures are not taken, such deviations may turn to have devastating effects on the industry's performance, out- puts, profitability, market competiveness and customers' satisfaction.

As afore mentioned unforeseen disruptions have been analysed in several research studies. Vieira et al [1] and Li and Lerapetritou [2] reviewed in details rescheduling methods and trends to address the problem of uncertainties in production scheduling. According to Heizer and Barry [3], industrial engineering is more about determining the most effective ways of doing things by ensuring unconstrained flow of material, information and product in order to meet set organizational gaols and out-puts. Most top executive in CMR tile manufacturing industries tend to pay more attention on performance indications because of the reflection of financial implication.

It is an important aspect to measure the performance of an industry and equally important to measure the various implications of disruptions in the industry's out–put and performance. Unfortunately, many top executives in these industries are not comfortable or familiar with disruptions metrics which can assist them in assessing the impacts of all potential disruptions.

According to Bosman [4], it is important for an organization to measure and track the impact of random disruption to effectively manage and control supply chain disruptions.

A partially broken or disconnected chain (as in figure 1 & 2 respectively) depicts a broken production line which stops the whole production process from the flow of information, material and product etc. while the other, the production line is partially broken but production can still continue the only constrain is decreased out-put in terms of production.

A partial disruption can be accepted while a complete disrupted flow cannot be accepted. This paper addresses the following exampled problems during tile manufacturing and aims at proposing a guideline to be used by most production managers in CMR tile manufacturing industries to address critical manufacturing process after disruption.

The issues are:

a. Most common cause of supply chain disruptions in Cameroon tile manufacturing industries.
b. Prove how disruption affects tile manufacturing industries in Cameroon using sciatica methods.
c. Express the monetary implications due to disruptions during tile manufacturing.

The key outcome of most disrupted manufacturing systems is productivity lost, e.g., if this industry does not have the right raw materials to manufacture tiles at the right time and location when required, subsequent workstations come to a standstill. Failure for CMR tile manufacturing industries to deliver consistent and reliable tiles to customers result in significant loss of market share. The success of any manufacturing industry is greatly dependent on the ability to deliver reliable product and service to the customers on time. According to (Hendricks & Singhal [5], Kleindorfer & Saad [6]), a supply chain disruption can be defined as an unplanned and unanticipated situation in comparison with normal supply–demand coordination during manufacturing.

Fig.1 Partial disrupted flow

Fig.2 Disrupted Flow

According to a market survey, a 0.6% improvement in the reliability of tiles delivery on time could yield up to as much as 6% increase of sale revenue for the industry. These statistics shows that Cameroon tile manufacturing industries are blind and massively affected by disruptions. Therefore, failure to deliver tiles as promised affect pre-planned operations downstream and robs the industry off its well- deserved profit and market shares.

Supply Chain Disruptions

Wild goose [7] defines supply chain (SC) as the movement of materials, information, and finances from supplier to manufacturer to wholesaler to retailer and consumer. It is a complex and dynamic supply and demand network and it is developed to express the need to integrate the key business processes within and outside the industry. According to Craighead et al. [8], supply chain disruptions and related issues are considered the most pressing concerns facing manufacturing industries competing in today's global marketplace. Hendricks and Singhal[9] analyzed the effects of supply chain disruptions and empirically showed that these events have a significant negative impact on manufacturing industries and operational performance (i.e., production out-put, sales, and return on assets). This evidence the fact and importance of excavating supply chain disruptions in CMR tile manufacturing industries coupling with the fact that, most executives' in this industries

devote most of their time on handling exceptions (such as overdue orders, solving various problems caused by disruptions, etc). This is further justified below by the statistics at the national level, monetary implications of supply chain disruptions are vast and still remain unknown. For example, the tile manufacturing industries in CMR is roughly a 10.54 Billion France CFA industry, according to Stats CMR [10]. These manufacturing industries spends about 56% of revenue on manufacturing costs, and 41% of manufacturing cost is overhead. Thus, overhead for these industries amounts to approximately 8.4 billion France CFA per year. Similarly huge numbers equally hold in many other sectors. An improvement in these numbers is the motivation for a support of developing improved methodologies and policies for handling and measuring disruptions.

In this paper, supply chain (SC) is described as production flow in Cameroon tile manufacturing industries and figure (3 and 4) illustrates the flow steps of production. This system is affected by an extensive number of random disruptions which some are costly and some are not. According to Ruhul et al. [11], these disruptions can be defined as events that interrupts the material flows in the (SC), resulting in an unexpected interruption of Material and goods movement. Many disruptive factors affect CMR tile manufacturing industries. Section (1.1, 1.2 and 1.3) gives the indications of how three of the most common disruptions (*employee absenteeism, power failure and machine breakdown*) affect the supply chain systems and productivity of these industries during tile manufacturing.

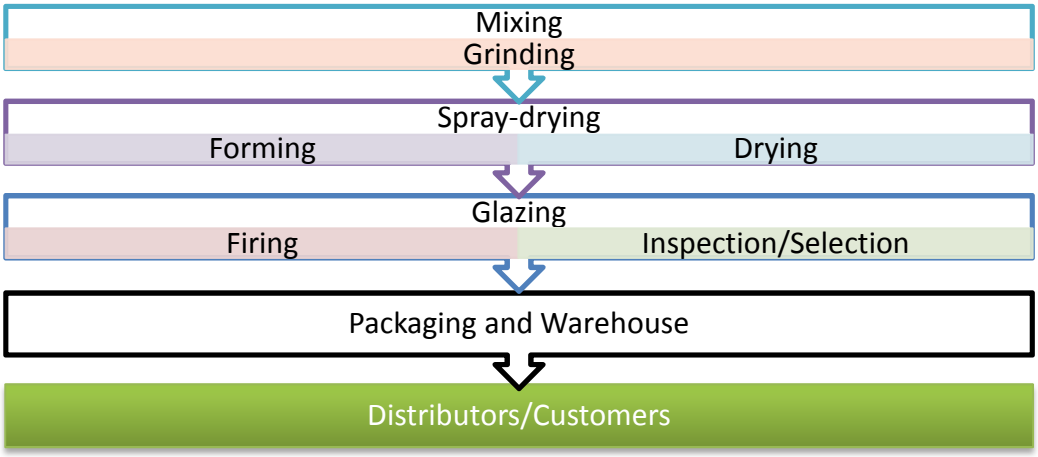

Figure.3. Supply chain process –Flow

Employee Absenteeism. Effective supply chain (SC) operations are the key to sustainable advantage to any manufacturing industry and among other resources, it rely mainly on people and machines and power supply. Until all processes are fully automated, people will always remain an important asset to supply chain. In addition, some leading causes of random disruptions related to an employee who may experience a wide variety of disruptions such as , stuck in traffic, car breakdown on the way to work, bad weather conditions like (floors, land slide) or even absenteeism(as a result of strikes, employee sickness, etc.).

The aforementioned events affect tile manufacturing industries in different ways depending on the type of industry-layout that is being used. Employee absenteeism in highly specialized environments could results in zero productivity because available employees are not trained or skilled to operate other machines, an example is the product industry-layout setting which is set-up with specialized machines that can only be operated by trained employees. Production may come to a halt until trained employees are back. In comparing with other industry-layouts (e.g. process industry-layout), the impact of employee absenteeism is not devastating because employees' skills are interchangeable, this implies employees operating machine A are trained to operate machine B and vice versa. In an event of a strike within the industry, administrative staff can also operate these machines until employees are back to work. Strikes and/or employee absenteeism in this case may

not yield "zero" productivity of tiles. This justifies the fact that, disruption of one kind affects various industries-layouts during tile manufacturing, differently.

Power Failure. Electric power is critical to society and manufacturing industries. According to statistics, weather and load shading are responsible for the majority of major power outages frequency that occurs in (CMR). These frequent outages is a much concern to the (SC) as employees absenteeism because it disrupts production runs and extrusion process during tile manufacturing which results to the industry's manufacturing process to a standstill and also with the need to restart each extrusion line frequently. The power failures affects every industry-layout to a standstill except otherwise equipped with a back-up power supply system.

Machine Breakdown. Machine breakdown is of a much concern to supply chain like employee absenteeism at a workstation because when there is a machine breakdown, that particular workstation and production-line goes to a standstill until the machine is repaired which in the process, all the tiles on that production line gets damaged.

Case Study and Methodology

Diverse impacts on supply chain (SC) under different (CMR) tile manufacturing industry- layouts are discussed here including other circumstances that may have impacts on the system. For simplicity sake and ease of understanding, Supply chain is disintegrated into single process flow diagrams.

Process Flow Descriptions

In this report, a multifactor disruption variable approach in one of Cameroon tile manufacturing industry, "BICAM" 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 section 3 for results.

As one might expect, processing a ceramic tile in this manufacturing industry, requires many steps across a couple of workstations (figure. 4) shows the flow diagram of the various manufacturing process. Before a finished tile can even begin to be packaged, there are numerous inputs that have to be properly monitored and accounted for. These steps include batching, mixing and grinding, spray-drying, forming, drying, glazing, and firing. Many of these steps are accomplished using automated equipment. The initial step involves mixing the ingredients (pulverized clay and feldspar minerals) that have been primarily crushed using jaw crusher and classified according to particle size. Sometimes, water is then added and the ingredients are wet milled or ground in a ball mill. If wet milling is used, the excess water is removed using filter pressing followed by spray drying. The resulting powder is then pressed into the desired tile body shape or a squeezing motion between steel plates and cones.

Batching calculations are done and once appropriate in weight of each material is determined, all the raw materials must be mixed together into a shell mixer or ribbon intensive mixer which consists of two cylinders joined of a V shape that rotates to tumble and mix the material. This step further grinds the ingredients, resulting in a finer particle size that improves the subsequent forming process. (Sometimes it is necessary to add water to improve the mixture and achieve a fine grinding). Then if wet milling is first used, the excess water is removed via spray drying which involves pumping the slurry to an atomizer consisting of a rapidly rotating disk or nozzle. This help to make the powder ready for forming. The powder then later flows from a hoper into the forming die which is then compressed in a steel cavity by steal plungers and then ejected by the bottom plunger to the conveyer belt to the next workstation which contains a dryer. These drying processes remove the water at a slow rate from the tile to prevent shrinkage and cracks. After these, the tile goes for glazing; the glaze is fed through a rotating disc that throws the glaze onto the tile (in the bell/waterfall method, a stream of glaze falls onto the tile as it passes on a conveyor underneath). After glazing, the tile must be heated intensely to strengthen it and give it the desired porosity. This

is done by a firing temperature of 2,000 degrees Fahrenheit or more. After firing, the tile goes through the inspection line and is packaged and shipped.

As aforementioned, production out-put is affected when there is a disruption on the supply chain during manufacturing, the total productivity values is calculated for both ideal production systems, that without disruption and for one with random disruptions. The difference between both states should enable us to get a clearer picture on how the supply chain system in CMR tile manufacturing industry can be affected by random disruption.

$$P_{idealstate} - p_{withrandomdisruptions} \rightarrow D_{impact} \quad (1)$$

Productivity under ideal state should be the objective and productivity function can basically be expressed mathematically as:

$$P = \frac{o}{I} \quad (2)$$

Where, "P" represents productivity function, "D" represents impact of system disruption, "O" is the total output quantity while "I" is the input multivariable quantity.

The severity of various impact of disruption can be calculated with the introduction of a Mathematical Equation which is, the ratio of the performance factors on days with disruptions and total days worked, as follows Groover, 2008 [12]:

$$Df = \frac{Pd}{PT} \quad (3)$$

Where, "Df" represents a disruption factor, "$P_{disrupted\ production\ performance}$" is the actual production, and "$T_{planned\ production}$" is the planned production.

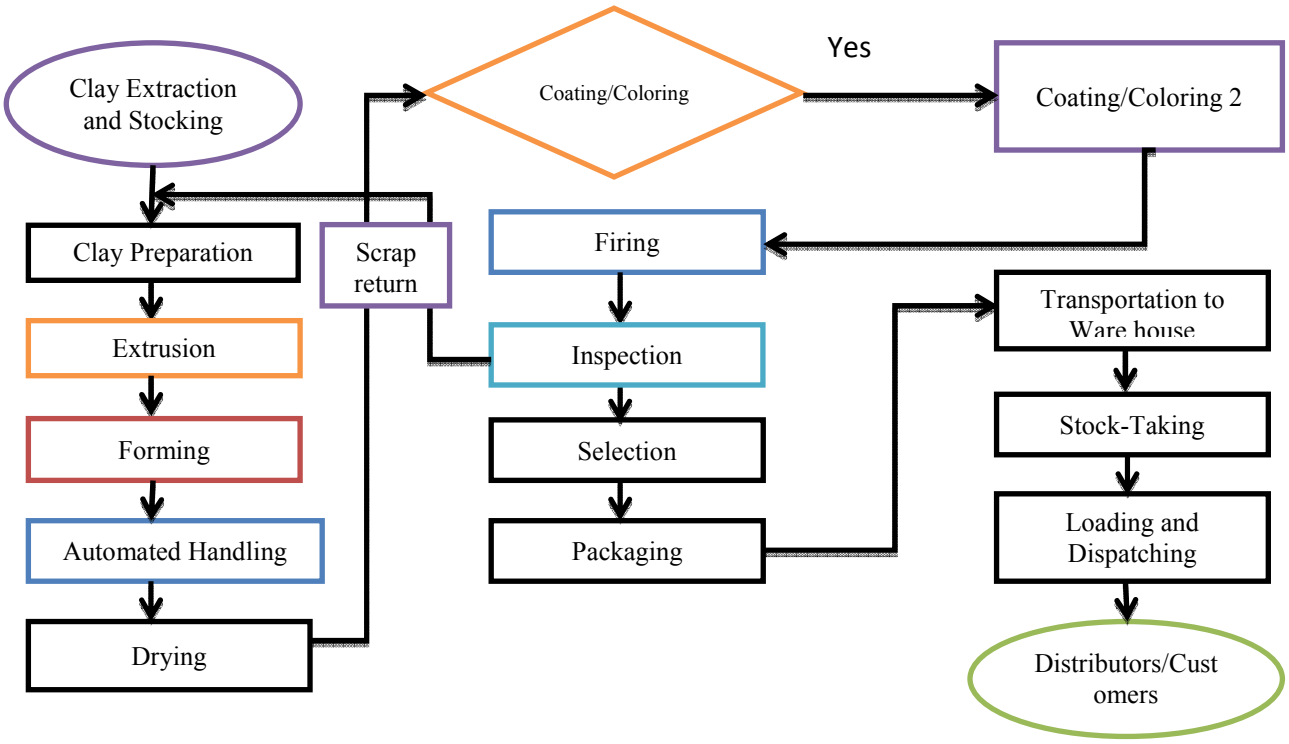

Fig.4. Tile manufacturing process Flow Diagram

Results

In this research, a number of outcomes are articulated after the application of Equation (1) to Equation (3) and simulation of the model for the scenarios under the case study section of (BICAM Ceramic Tile Manufacturing Industry) Cameroon.

Based on the fact that CMR tile manufacturing industry systems are subjected to variety of random disruptions, it is essential to find out how these disruptions affect the various industry-layouts during tile manufacturing. This was analyzed based on questionnaires and model simulation. It was apparent that leading sources of disruptions may vary from different industry-layouts. In the case study, machines' breakdowns, power failure, employee absenteeism and raw material shortages are the frequent causes of disruptions. The primary cause of productivity losses was identified to be caused by supply chain disruptions.

For production industry-layout, product family industry-layout and process industry-layout the most recorded disruption is power failure followed by employee absenteeism and machine breakdowns at less than 1.7% of the total time then by 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 workstation 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. As presented in the previous sections, disruption impacts are also assessed by using Equation (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 simulated model are presented in Table: 1. These industries encounter many disruptive factors, and for this study only the significant disruptions are presented.

Table.1. highlights of various leading disruptions per industry-layout during tile manufacturing.

Industry-Layout	Leading Disruption					Total
	Machine Breakdown	Power Failure	**Employee Absenteeism**	Material Shortage	Rework	
Production	0.341	0.219	0.031	0.009	0	0.68
Process	0.478	0.487	0.586	0.098	0.121	1.73
Product	0.465	0.281	0.341	0.097	0.165	1.46
Fixed	0.283	0.334	0.097	0.863	0.213	1.67

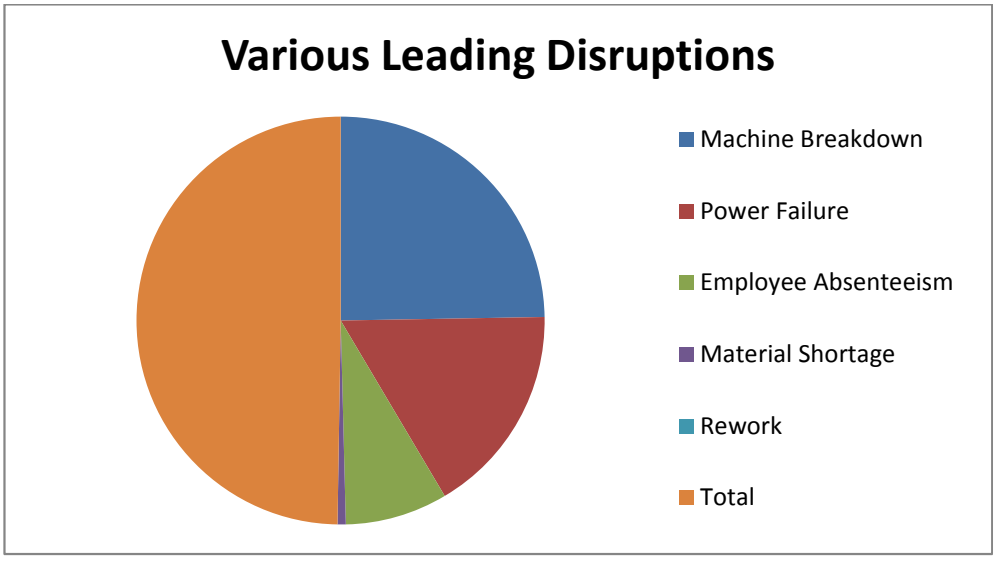

Figure.5. Disruption per industry-layouts

As can be seen from figure 5, machine failure is the leading source of disruption 30% of total disruptions, followed by power failure at 26%, then employee absenteeism by 22%, etc. This has the greatest impact on performance of the production system. In this case study, overall production performances dropped massively by 32% following unforeseen disruptions.

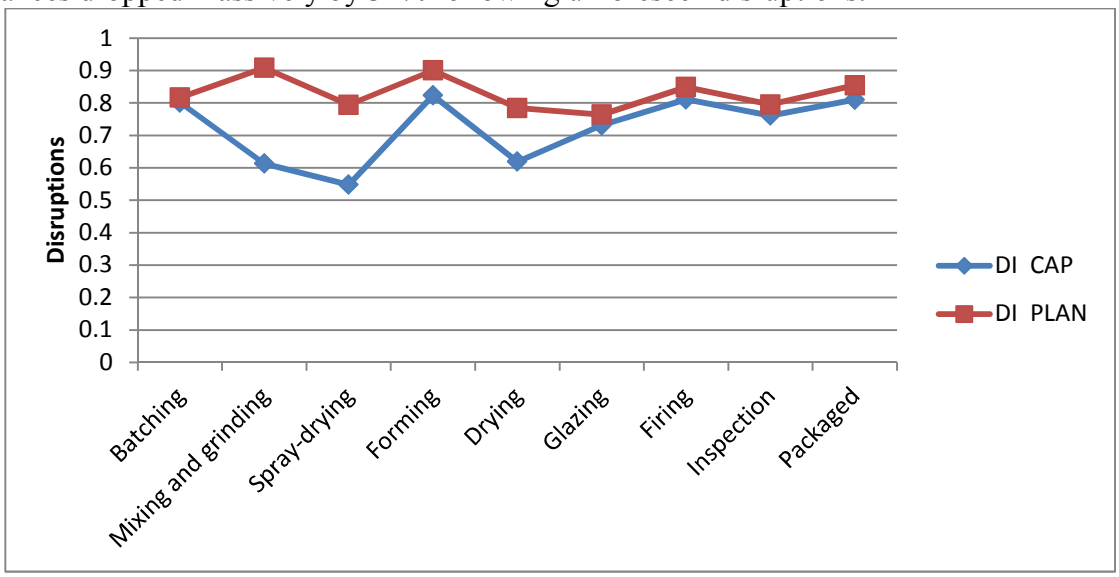

Fig.6. Relationship between capacity & planned production

According to statistic [13], the total turnover of all ceramic tile manufacturing industries in CMR was estimated at 4.7 Billion France CFA. An increment of 10, 4% compared with the revised estimates for 2011 (4, 2 Billion France CFA)" key findings by Stats CMR [14]. The importance of focusing more on tile manufacturing industry is further accentuated by its contribution to the national gross domestic product which is currently standing at +10%. 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: 2 and Figure: 6, these industries resources are not fully utilized. A total of 1800 units of tile per day were scheduled for production, which is determined based on the lowest processing work-station. This high level production decision is costing the industry off its deserved return on investment as utilization rate for some machines is only 51%. 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 ineffective).

Table.2.ActualProductionData

Operations	Capacities	Planned Performance	Actual Performance	Prod. Losses	DI CAP	DI PLAN
Batching	2100	1850	1509	341	0.801	0.816
Mixing and grinding	2900	1850	1680	170	0.613	0.908
Spray-drying	1820	1850	1469	381	0.548	0.794
Forming	1950	1850	1666	184	0.823	0.900
Drying	1810	1850	1450	400	0.619	0.784
Glazing	2000	1850	1413	437	0.731	0.764
Firing	1806	1850	1571	279	0.811	0.849
Inspection	2030	1850	1471	379	0.761	0.795
Packaged	19000	1850	1580	270	0.810	0.854

From an industrial engineering perspective, researchers suggest that these industries should consider line balancing to claim lost production on the under-utilized resources.

Failure for the organization to pre-balance the production line during tile manufacturing leads to a deviation of the production plan. From an industrial engineering point of view, the theory of line balancing can be combined to determining the required number of resources needed in the production line in order to reduce disruption and optimize the systems 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 deviation in number of additional required resources to meet the initial production objective. In addition a back-up power supply should also be introduced to the manufacturing system in-order to cater for the regular power failure.

Limitations

There are a number of limitations for the generalizability of this study. First, this study is limited only on manufacturing industries. A future study will replicate this study across multiple industries and sector. This will help to increase the understanding of supply chain system globally.

Conclusion

In this paper, we have studied various types of supply chain disruptions and their respective impacts with an emphasis on CMR tile manufacturing industry systems with an objective among others to unload and minimize the degree of disruptions that ultimately determines organizational gains and/or loss. It is further demonstrated how disruptions affect different tile manufacturing industry-layouts in CMR and their implications. Methodology presented herein covers only two types due to the limitations of the scope.

The results show that, the leading sources of disruptions may vary from different industry-layout; i.e. Machines' breakdowns, Power failure, raw material shortages and employee absenteeism are the frequent causes of disruptions. And it can further be analyzed that, the cost of supply chain increases as the movement of materials are often disrupted and the production system has to be adjusted from time to time after disruption.

Acknowledgements

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