Improvement of SME's Manufacturing and Supply Process Flow: A Case Study

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Key words
Flow control, LOGON system, SAP system and Simulation

Abstract
Small Medium Enterprise (SME) within the manufacturing industry of South Africa needs to be nourished as they contribute significantly to economy. Evaluation of a SME manufacturing facility resulted with areas of improvement. The current manufacturing process was manually operated , for instance, from raw materials feeding into a mixing equipment to finished goods packaging, suppliers of raw materials being manually notified and customers placing orders on a manual ordering system. Proposal of a semi-automated manufacturing process was initiated as an improvement of the current traditional process by consideration of design principles and introduction of components such as flow control valves, stock level sensor/detector, conveyor belt, automated guided vehicle and SAP system and LOGON system. Integration of systems that adds to Enterprise Resource Planning were also recommended which can further improve the supply chain network. Simulation and modelling of the traditional manufacturing process and the proposed process of manufacturing that was improved were conducted by making use of Arena simulation software version 16.0. The outcome indicated an improvement potential of higher material input and material outputs at maintained processing efficiencies. It was concluded that the adoption of the proposed manufacturing process improvement can assist in improving the supply chain from raw material acquisition to product availability to customers.

Introduction
Background

The industries of manufacturing and investors of businesses are consistently striving to find ways to optimise manufacturing methods for the purpose of lowering cost, energy and expand their capabilities. Traditional manufacturing entails the subtractive and methods of manufacturing that are long established, assurance of quality and implementation in the commercial space (Pereira, et al., 2019). The regions of manufacturing are categorised and defined by attributes such as complexity advantage, customization, and volume (Da Silveira, et al., 2001).

A complex supply chain hinders the performance of suppliers of raw materials to manufacturing facilities which ultimately affects manufacturer's production output, this subsequently leads to unavailability of finished goods at the right time to market.

Small Medium Enterprise (SME) companies in South Africa contributes about 20% of the total economic growth. The South African government has set naturing initiatives in place to assist in growing and maintaining businesses in the current alerts of electricity load-shedding.

The second and third industrial revolution aimed at continuous improvements in operational excellences in both manufacturing and service sectors which SMEs are still striving to meet in South Africa, to date. Most companies cannot afford to be left behind in the revolution due to the dynamic and competitive markets they operate in. Meanwhile, well established businesses are striving to meet the fourth industrial revolution pillars which include autonomous robot, simulation, system integration, industrial Internet of Things, cybersecurity, cloud computing, additive manufacturing, augmented reality and big data and analytics. SMEs are prone to be left behind for the adoption of the new revolution mainly due to their low capital investment potential.

Any means of potentially improving SMEs operations can assist with further improvement on sustainability of their businesses in the everchanging manufacturing sectors. The designs of smart factories offers productivity enhancement where manufacturers can offer finished goods at relatively competitive pricing due to lower cost potentials. Continuous improvement within existing factories is of great importance to help meet optimised operational excellence.

The new manufacturing processes that have transformed since 1800s resulted with continuous change in the industrial landscape. Changes in the technologies of the industrialization have driven the paradigm shifts of industrial revolutions. In most countries, industries represent key component of economy that carries out the materials and goods production, which can be highly mechanized and automatized. Thus, nowadays production in the manufacturing industries has reached the edge of new revolution and future factories have been painted (Mohamed, 2018).

However, before the current industry 4.0, there have been three revolutions which really revolutionized the industry with respect to water and steam power mechanization, mass production in assembly lines and the use of information technology to automate systems (Tay, et al., 2018). This is further outlined by Figure 1.

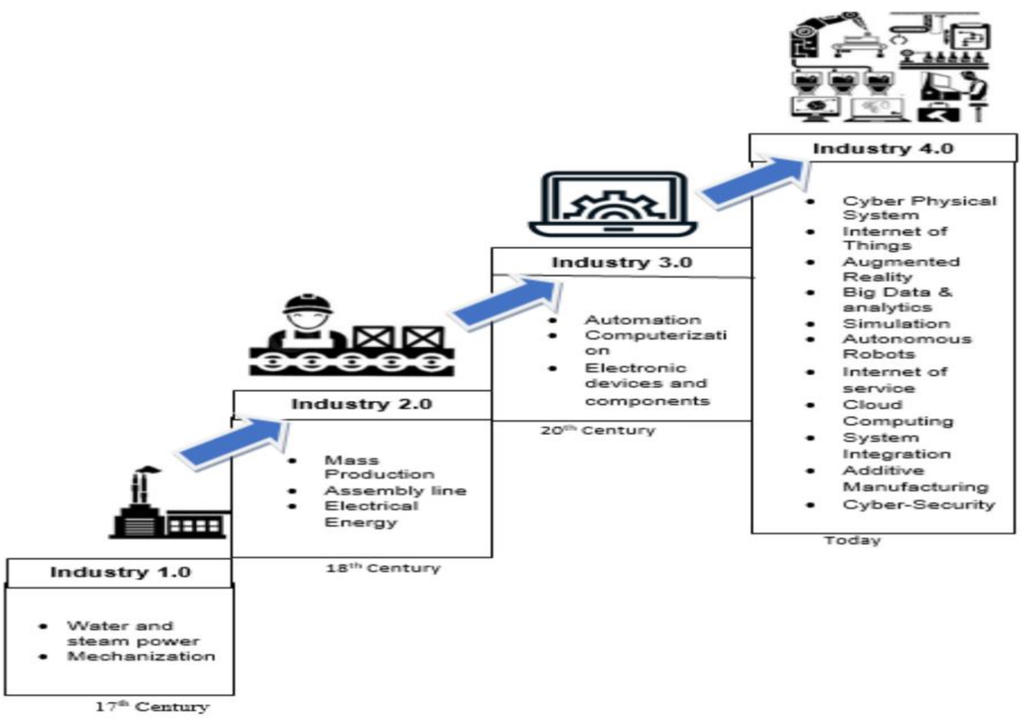

Figure 1: Overview of industrial revolutions ***Source: (Tay, et al., 2018)***

Typically, most SMEs within the South African manufacturing sectors are still stuck on meeting the second industrial revolution. The lower business turnover affects their operational improvement opportunities.

There have been great improvement in the manufacturing sectors through moving towards smart manufacturing. Smart manufacturing entails the application of advanced information and digital technologies (Ghobakhloo, 2019) , together with the use of systems associated with Artificial Intelligence (AI) and cyber-physical systems (Zheng, et al., 2018), for the purpose of achievement of improved efficiency for production of goods with high quality and low cost (Haricha, et al., 2020). Traditional manufacturing has limitations to only a process or a process that is sequential for the conversion of raw materials to finished goods (Mittal, et al., 2019).

Meanwhile, smart manufacturing further includes the process improvement of manufacturing to a smart and fully connected manufacturing process on numerous technologies and solutions such as cyber-physical production systems (CPPS), Internet of Things (IoT), robotics/automation, big data analytics and cloud computing (Thoben, et al., 2017). Deep learning as a subset of machine learning offers real time regulation/maintenance and optimization of production process through collection of data for entire stages on network of supply commencing from shop floor and chain of supply network then transform it into raw knowledge of data (O'Donovan, et al., 2015).

Current manufacturing and supply process flow

A powdered cementitious product manufacturing process plant is a semi-automated system with some of the process equipment requiring some adjustments or improvement to minimize man-machine interaction which is costly. At the discharge side of the raw materials storage silos, there is a flow control valve which is operated manually by pre-setting the amount of material to be discharged. Hopper 1 is also semi-automated in such a way that flow control valve must be manually regulated through raw material weight pre-sets.

This is then followed by a dry mixer which has a discharge valve that is manually operated to discharge the product in the temporary storage silo. The follow control valve on the discharge side of the product storage to the hopper 2 is also manually controlled. The product packer is also manually operated and packing one product at a time which takes longer. After the product is packed, customers' orders are delivered with clients being phone called to collect their orders. Figure 2 illustrates this manufacturing and supply process flow.

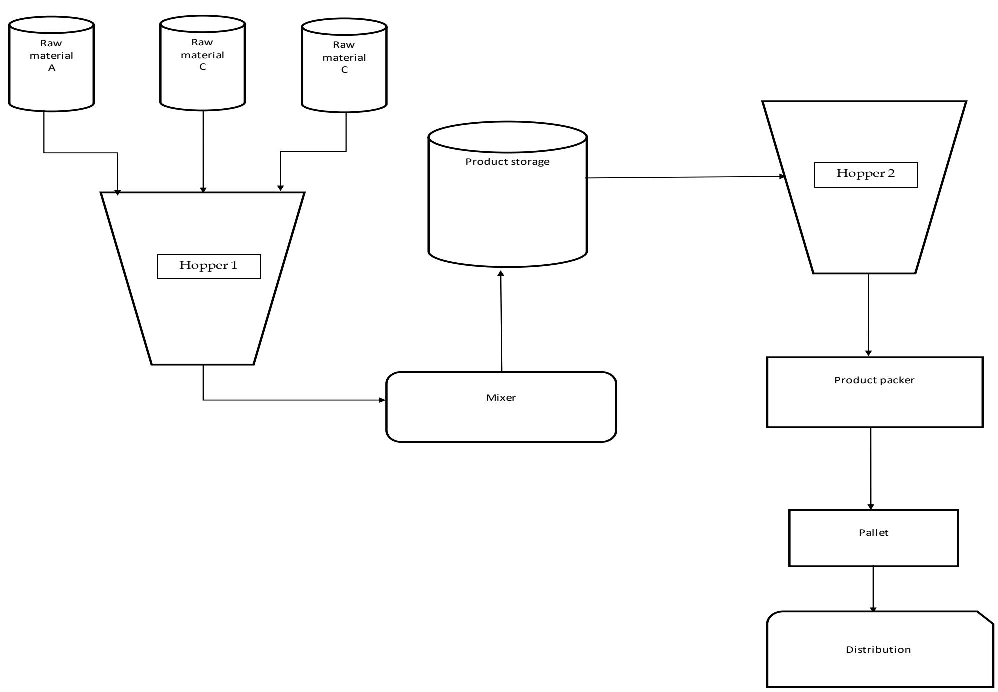

Figure 2: Current traditional manufacturing process flow diagram

As the markets remain competitive, the industry should be innovative through implementation of new facilities and systems of production as well as establish Key Performance Indicators (KPIs) thereof to run sustainable operations. Facility design concept in industry 4.0 considers the improvement on designs that are traditional and are required to be modular and flexible. Configuration must be adoptable to changes in real time without addition of costs, production delays and activities that are non-valued on production lines. Simulation combined with CORELAP algorithm offers generation of a design that results with reduction in time of production, reduction of non-value added activities and increase production efficiencies (Chakroun, et al., 2022). Simulation is an important tool for mimicking the behaviour of a real system thereby finding areas of improvement (Tau, et al., 2022).

Problem statement

Covid 19 pandemic in South Africa has resulted with numerous numbers of job losses across various industries such as mining, construction, building materials and petroleum. In order for the industries to recover and meet their financial targets, products in the market are expensive resulting with consumers being unable to afford. In addition, manufacturers are battling with increased raw materials costs, which makes their product selling prices to increase. Company X is a close corporation enterprise within the cementitious industry in Gauteng province, South Africa. It manufactures various product offering to different application within the building and construction industry.

Being a medium Entreprise, the manufacturer strives to improve production costs, improve quality, and lead time for the purpose of meeting customers' demand and productivity in their operations such that they can be able to compete in the marketplace. Having been established few years ago, continuous improvement is required in order to adjust their operations to a sustainable level, both financially and non-financially. Their work process is required to be improved in order to minimize waste, increase production output at minimal labour usage and ensure that the production operators and workers are not strained throughout their daily duties while at the workplace.

Objectives

The primary objective was to improve a manufacturing process flow of Small Medium Enterprise. The sub-objects were: (i) to incorporate of some of the smart factory designs features in order to improve the traditional manufacturing and supply process (ii) and to simulate the manufacturing process for the purpose of modelling the performance of the smart factory.

Literature review

High volume at low cost of production has been what traditional manufacturing industries are striving to achieve and this has been enabling an economic advantage for countries with low wage for optimization of their capability of manufacturing (Atzeni & Salmi, 2012). Traditional manufacturers are also characterised by batch mode of production instead of continuous mode. For instance, historically, pharmaceutical manufacturing industry has been using batch size operations where transformation of raw material into finished goods can take place at any point over time in a spatially separated unit operations. Manufacturing process is typically disjointed with intermediate checks of quality, accumulation of inventory and transport between two sites within the supply chain. Continuous manufacturing process conditions thereof are classically irrelevant with time at each spatial location and material transformation occurs as the material flow through a production line coupled with processing steps that are continuous (Ende & Mary, 2019).

The industrial facilities design layout impacts the workflow success greatly (Chakroun, et al., 2022). The origin of fourth industry date back in 2011 from a project in high-tech strategy of the German government which promoted the computerization of manufacturing. Overall, the fourth industrial revolution aims at productivity improvement and creation of fields within the industry which depends on acquisition and sharing of data and information within the supply chain (Keller, et al., 2014). Thus digital value chain is contributed by an increase in digitalization, automation and communication (Oesterreich & Teuteberg, 2016). Industry 4.0 stands for a production orientated CPPS integration within production facility, systems of warehousing and logistics. This system is an intelligent system that facilitates production which is flexible, modular and adaptable that assist with customer requirements. This further assist in decentralisation of production control (Varl, et al., 2021).

Facility design is key in the optimization of organisation's workplace, for example through determination of best layout of machines or other production support resources. This further assist with ease of material movement (Chakroun, et al., 2022). The adoption of industry 4.0 enables the manufacturing sectors to be digitalized with sensing devices that are built virtually in all the components, products, and equipment of manufacturing (Tay, et al., 2018).

Key component in industry 4.0 include smart factory designs for productivity improvement. Cloud computing also offers service-orientated network-based function that converts the manufacturing resources and capabilities to manufacturing service. Internet of things enable devices of manufacturing to exchange data between devices of manufacturers and their providers of service or even customers (Mabkhot, et al., 2018). Internet of things further include the combination of sensors such as the RFID, embedded computers, Enterprise Resources Planning (ERP) and technologies for business intelligence. Sensors are really in the physical objects such as vehicle and heavy equipment (i.e. loaders, cranes etc), machines and robots (Mabkhot, et al., 2018)

Fourth industrial revolution is further associated with the intelligent networking of industrial products and processes which add to productivity improvement and potential growth of companies using advanced technologies for smart factories (Nagy, et al., 2018). The industry 4.0 requires human resources with unique qualities than the traditional industries (Heynitz & Bremicker, 2016). Table 1 shows traditional factory and smart factory comparison.

Key	Traditional manufacturing	Smart manufacturing
Data	Not fully exploited, not total accessible	Real time data collection and visualization
Process and operations	Manual optimization	Automatically optimized, and full traceability
Downtime	unpredictable	Predictable
Maintenance	Preventive/Corrective	Preventive/Corrective/Predictive
Supply chain	Traditional	Smart and 100% transparency
Efficiency	Not fully exploited	Fully exploited
Product development	Time wasting and not flexible	Faster developed products even for complex products
Energy optimization	N/A	Yes
Quality	Manual inspection	Hight quality, less cost, automatic inspection
Flexibility	Not totally flexible	Totally flexible
Decision making	Poor data	Real time data, smart algorithm to prediction

Table 1: Traditional factory and smart factory comparison *Source: (Haricha, et al., 2020)*

Smart factory involves shop floor decisions and insights integration with the whole chain of supply and the enterprise by utillization of interconnectivity Information Technology landscape. Fundamentally, this can change the processes of production and better enhance relationships with suppliers and clients. Smart factory can also connect to global network which can be off similar systems of production as the improved systems of industry 4.0 and even encourages the digital supply network (Deloitte, 2017).

A typical transformation of traditional supply network to digital supply can be described by Figure 2 which was adopted by Deloitte Company as part of their improved network.

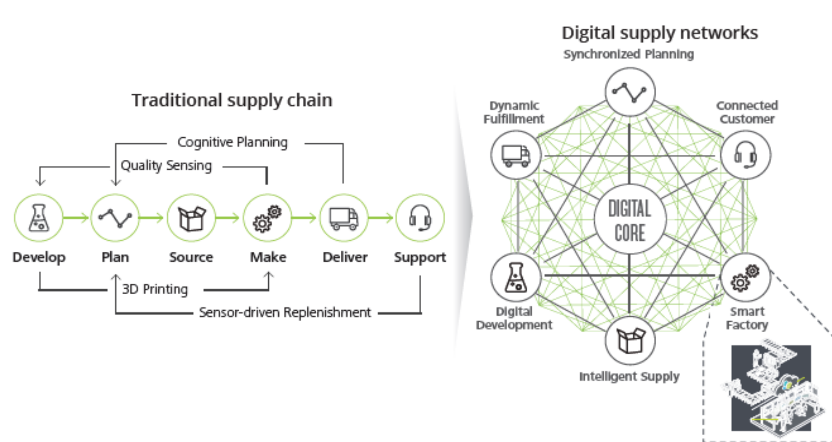

Figure 3: A shift from traditional supply chain network to digital supply network Source: (Deloitte, 2017)

The automation in the smart factory includes the full automation of a system of production, use of three-dimensional scanners, technologies for IoT and controls of machine. Smart factories help to lower customer lead times and reduces overall cots, improves the capacity of production, and reduces amounts of defective products. Furthermore, the features of smart factory also include connectivity, optimization, transparency, proactivity, and agility which has a direct impact in improvement of a production process as outlined in Figure 4 (Deloitte, 2017).

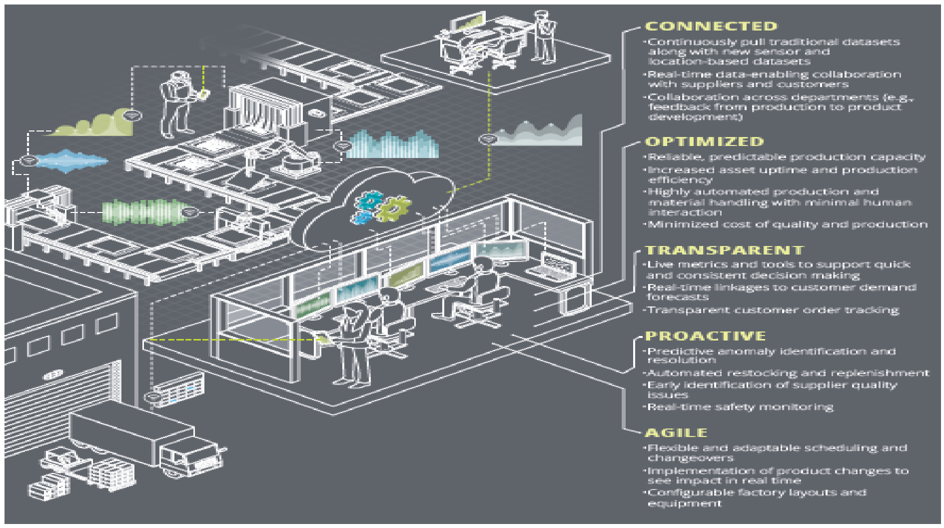

Figure 4: Features of smart factory ***Source: (Deloitte, 2017)***

The design of smart factory is also guided by design principles. The concepts of a factory that is smart assist designers to build new or upgrade traditional factories to be smart. These design principles are based on the requirements of the scope of industry 4.0 and are described as follows (Mabkhot , et al., 2018):

Modularity

Refers to the capability of the components of the system to be separated, combined in a manner that is easy and quick with reconfiguration being on the basis of plug and play principles. For instance, modules can be added, reorganised or replaced on time in a line of production. Thus factory that is smart should consist of modularity that is high, permitting modules integration rapidly that can be offered by various suppliers, for the purpose of responding to the requirements that are changing from customers and to respond positively for the resolution of internal system that can malfunction.

Interoperability

Refers to the ability to exchange data amongst the components of the system which include products and also the ability for information sharing amongst production enterprise together with clients. The Cyber-Physical System (CPS) allows for connectivity over the IoT and Internet of Services (IoS). Enhancement of interoperability can be attained through mechanical, electrical and information communication that are standardized. A controller is another key enabler of interoperability in a smart factory which allows the integration between features such as OPC UA and the smart PLC which allows the connection between the PLC and information technology programs.

Decentralization

It involves the elements of the systems such as modules, materials and product, making self-decisions which are unsubordinated to a control unit. Real time autonomous decision making in exclusion of the violation of goals of organization. Embedded computers assist in autonomous CPS in order to interact with the environment through sensors and actuators.

Visualisation

Involves the creation of an artificial environment of factory with CPS and similarly to the actual environment and also being capable of monitoring ad stimulating the physical process. Transparency with respect to information in CPS and data sensor enables formation of sort of that environment. Thus a virtual system is used for the purpose of monitoring and control of specific physical aspects, convey data in order to update in real time its virtual model and also assist in designs, creativity and digital prototypes implementation which are most the same as the ones that are real. Virtual system as well can be a very helpful method of training workforce, offering of guidance for the workforce through processes that are manual, diagnosis and prediction of faults together with team of maintenance guidance or fixing malfunctioning equipment. Combination of virtual and augmented reality together with mobile devices assist clients with more insight into the product designs and permission to track the process of manufacturing.

Service orientation

Integration of goods and services is achieved and sold as a package. Companies in the manufacturing sectors opt for processes outsourcing and concentrate on main processes. This encourages innovative ways of operations in the main improvements process, which ultimately other manufacturing facilities will sell their products to other industry. CM is the infrastructure that make use of internet as a means of service offers and sales. Meanwhile on the on the other side cloud computing plays a critical role in making sure that on-demand service provision is enabled.

Real-time capability (responsiveness)

This covers ability of the system to response to respond timeously on time such as the alterations in the requirements of the customer or changes in the production systems internally. Access to information and analysis in real time in order to respond to requirements of the clients are achieved. Detection of disturbances in the system should be on time and the system should be stabilized Responses to changes internally, monitoring and regulation should be instantly. Disturbances detection should be on time, and the system should have rapid recovery ability.

Methodology

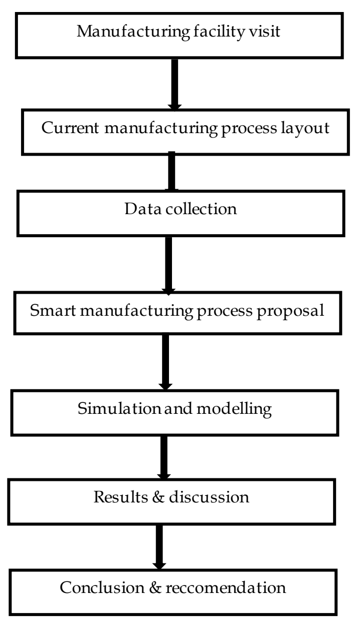

Figure 5: Research methodology

Results and discussion

Improvement proposal of traditional manufacturing process to smart factory

The traditional plant as described by Figure 2 can be improved through addition of other components in order to minimise manual handling, raw material monitoring systems and supplier notifications. The technical specifications which can be added for the improvement were:

Flow control valves (FCV)

The installation of flow control valve across all the equipment such as raw material silos, hopper 1 & 2 and ribbon blender discharge will assist in ensuring that the system is fully automated via system software, and this allows accurate selection and extraction of raw materials at the right quantity. This will reduce man-machine interaction which is costly.

Stock level sensor/detector

The installation of stock level sensor assists in checking the level of stock in the system as managed on the floor at the warehouse, this will assist in ensuring that the customers make informed order quantities based on the current stock level, thus avoiding delays.

Conveyor belt

The conveyor belt assist in material handling which will improve for the ergonomics requirements as there will be less manual handling of the material by human. Also the conveyor belt will reach larger areas within the warehouse.

Automated guided vehicle

It will assist in material movement such as the material being packed at the correct shelves depending on the packing procedure being pre-set. These will ultimately result with reduction in cost of labour, reduces costs of utilities, increased work safety and also results with possible reduction of some of the product damages due less manual handling.

SAP system and LOGON system

These software assist in improving the order placement by the clients. Clients can be able to place orders online and monitor the status of their orders daily to check progress. Clients can also be able to trace their credit account limit facility available which will guide them when to make interim payment were required. Figure 6 depicts the improvement of the current traditional factory to smart factory.

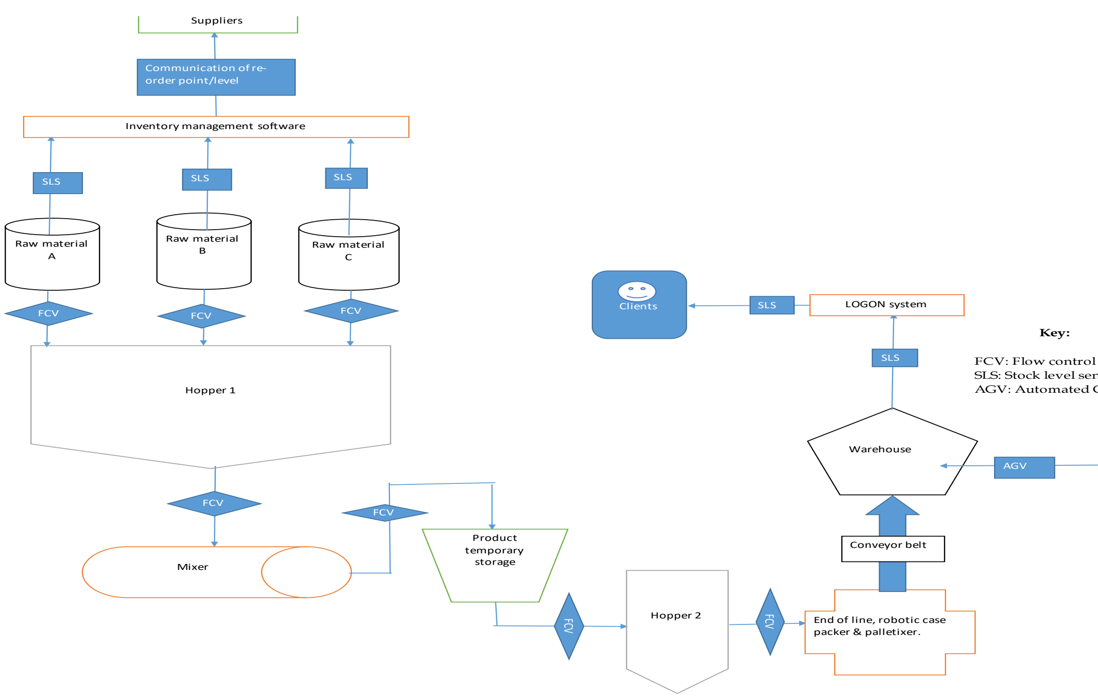

Figure 6: Proposed fully/semi-automated system at company X

Modelling and simulation using Arena simulation software 16.0

To suit the modelling exercise, some of the process steps in the factory layout were simplified in order to suite the software capability.

Current traditional plant

In the current traditional plant, raw material feed enters the system at a random average time interval of 13 minutes, then the material proceeds to the blending process in the ribbon blender at a uniformly distributed time of a minimum of 8 minutes and maximum of 10 minutes. The blending process also is operated by an operator. After the material is being process in the blending process, it then proceeds to a packing process which is uniformly distributed at a minimum time interval of 5 minutes and maximum time of 7 minutes with the process also making use of packing operator. Now that the material is being packed in 25kg bags, it then proceed to a palletising process where it is triangularly distributed at a minimum of 1.033 minutes, median of 1.0833 and a maximum of 1.167 minutes. Thus, the palletizing process also make use of palletizing operator.

The palletized product then leaves the system.

Based on this information, simulation and modelling was conducted using Arena simulation software in order to quantify the amount of product that can be produced in a replication length of 8 hours (480 minutes) and number of replications of 1. Figure 7 shows the traditional plant layout in the Arena simulation software.

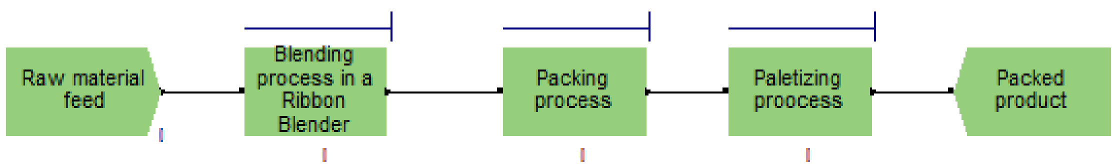

Figure 7: Traditional plant layout simulation in arena 16.0

Improved traditional manufacturing process to smart factory.

In the smart factory, raw material feed enters the system at a constant average time interval of 6 minutes, then the material proceeds to the blending process in the ribbon blender at a constant time interval of 4 minutes. After the material is being process in the blending process, it then proceeds to a packing process which include the palletizing process and it takes place at constant time interval of 2 minutes. Now that the material is being packed in 25kg bags leaves the system. All process step fully automated, only at packing process where there is only an Inspector who visually inspected the packed product.

Based on this information, simulation and modelling was conducted using Arena simulation software in order to quantify the amount of product that can be produced in a replication length of 8 hours (480 minutes) and number of replications of 1. Figure 8 shows the improved factory layout in the Arena simulation software.

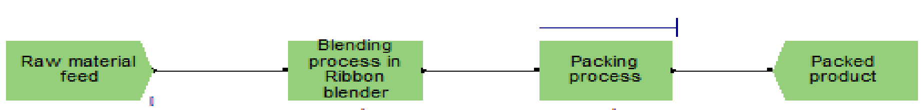

Figure 8: Smart factory simulation using Area.

Table 2 shows the comparison of modelling results on traditional system and improved system.

KPI	Traditional factory	Smart factory
Material input	34	81
Material output	33	80
% Process efficiency = $\frac{\textbf{Material input}}{\textbf{Material output}} \times 100$	$\frac{33}{34} \times 100 = 97$	$\frac{80}{81} \times 100 = 97$

Table 2: Plant performance comparison

In the improved system, the number of packed products has improved from 33 to 80, an increment of 47 packed products due to the automated system. Though the efficiency is similar, the total output is improved.

Key observations and areas of improvement

- The manual operations of the valve results with lots of wastages where the materials leaks, which ultimately results with continuous financial loses. This was observed as one of the operators was opening the valves, then as the material flows from hopper 1 into ribbon blender. Despite partially opening the valve, the material continued to spill from the discharge side of the hopper and also on the connection line between the mixer and the silo. This was due to the continued material flow pressure and welding of the leakages does not last.
- Also as the material become over fed into the mixer the whole batch size is lost as it is either has to be discarded or the whole product reworked by the experienced plant manager, however the product reworking waste time and also does not add any value as some times the rework is at higher cost of production.
- The measurement of raw material stock level in the storage silos is still being carried out in the old technique of using a rubber hummer, metallic sound indicating the area where there is no product. This is also not a good method of inventory management as sometimes it's not accurate, 30% of the time it gives wrong indication and the plant manager becomes under pressure to place orders with suppliers and sometimes suppliers need 48 hours order placement notification before the raw material is being delivered.

Conclusions

The design of a smart factory as per the requirements of Industry 4.0 can reduce some of the operational cost as the productivity of the factory is improved or optimized which then further improves the customer service. Smart factory design also reduces the man-machine intervention which can sometimes become a concern from the perspective of health and safety.

Recommendations

- The proposed system recommended the installation of flow control valves on each raw material storage silo for raw material A, B and C, hopper 1 discharge side, mixer discharge side, product temporary storage discharge side and hoper 2 discharge side. This should be operated via computer process control software which will adjust both pressure and mass flow rate of the respective material such that there is no wastage.
- The system will be automated and will have components working under the principle of Poka-Yoke in order to minimize potential errors affecting the manufacturing process lines.
- On each raw material storage silo, stock level sensor should be installed for better management of the inventory which with the stock figures being depicted on a computer screen or any form of application such as one from another company
- Also at the product packing line and palletizing, this process can also be carried by making use of a packer that is operated pneumatically and can pack the material on pallets at the targeted 60 bags on a pallet. This will maximize productivity and ensures good product availability to clients.
- Software or applications such as LOGON is recommended for order placement, this will also assist in material stock talking thus to avoid manual counting at the end of the month.
- If suppliers have access to this inventory management software, it will be easy for them to delivery raw material timeously and the adoption of JIT management philosophy will be applicable at Company X. This will also meet the concepts of E-commerce and E-procurement as compared to traditional procurement.
- Simulation and modelling is recommended to be ran based on the new process layout in order to quantify the productivity improvement as a function the number of 25kg bagged product being made. With the current system, the daily production is about 480 bags in 8 hour shift.

- Feedback from customers based on product performance as part of the quality functional deployment is also can rise important areas of improvement by incorporating the voice of the customer in everyday manufacturing activities.

Limitations and direction for future study

The findings of the study were only applicable to the case being studied. However, the deployment of lean manufacturing tools in similar case studies are encouraged to be evaluated for continuous improvement initiative for Small Medium Enterprises in order to best prepare them for industrial revolution.

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Appendix

A. Simulation results of a traditional factory

Traditional factory

Replications: 1 Time Units: Minutes

Key Performance Indicators

System	Average
Number Out	33

Traditional factory

Replications: 1 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	16.1990	(Insufficient)	14.2793	17.5902

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	4.4685	(Insufficient)	0.00	17.8414

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Other Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	20.6675	(Insufficient)	14.2793	34.7823

Other

Number In	Value
Entity 1	34.0000

Number Out	Value
Entity 1	33.0000

WIP	Average	Half Width	Minimum Value	Maximum Value
Entity 1	1.4747	(Insufficient)	0.00	4.0000

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Blending process in a Ribbon Blender.Queue	4.7230	(Insufficient)	0.00	17.8414
Packing process.Queue	0.00	(Insufficient)	0.00	0.00
Palletizing process.Queue	0.00	(Insufficient)	0.00	0.00

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Blending process in a Ribbon Blender.Queue	0.3345	(Insufficient)	0.00	2.0000
Packing process.Queue	0.00	(Insufficient)	0.00	0.00
Palletizing process.Queue	0.00	(Insufficient)	0.00	0.00

Traditional factory

Replications: 1 Time Units: Minutes

Resource

Usage

Instantaneous Utilization

	Average	Half Width	Minimum Value	Maximum Value
Packing operator	0.4230	(Insufficient)	0.00	1.0000
Palletizing operator	0.07561497	(Insufficient)	0.00	1.0000
Ribbon blender operator	0.6415	(Insufficient)	0.00	1.0000

Number Busy

	Average	Half Width	Minimum Value	Maximum Value
Packing operator	0.4230	(Insufficient)	0.00	1.0000
Palletizing operator	0.07561497	(Insufficient)	0.00	1.0000
Ribbon blender operator	0.6415	(Insufficient)	0.00	1.0000

Number Scheduled

	Average	Half Width	Minimum Value	Maximum Value
Packing operator	1.0000	(Insufficient)	1.0000	1.0000
Palletizing operator	1.0000	(Insufficient)	1.0000	1.0000
Ribbon blender operator	1.0000	(Insufficient)	1.0000	1.0000

Scheduled Utilization

	Value
Packing operator	0.4230
Palletizing operator	0.07561497
Ribbon blender operator	0.6415

Traditional factory

Replications: 1 Time Units: Minutes

Resource

Usage

Total Number Seized

	Value
Packing operator	34.0000
Palletizing operator	33.0000
Ribbon blender operator	34.0000

Unnamed Project

Replications: 1 Time Units: Minutes

A. Simulation results of a smart factory

Smart factory design

Replications: 1 Time Units: Minutes

Key Performance Indicators

System	Average
Number Out	80

Smart factory design

Replications: 1 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	6.0000	(Insufficient)	6.0000	6.0000

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Other Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	(Insufficient)	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	6.0000	(Insufficient)	6.0000	6.0000

Other

Number In	Value
Entity 1	81.0000

Number Out	Value
Entity 1	80.0000

WIP	Average	Half Width	Minimum Value	Maximum Value
Entity 1	1.0000	(Insufficient)	0.00	2.0000

Smart factory design

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Packing process.Queue	0.00	(Insufficient)	0.00	0.00

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Packing process.Queue	0.00	(Insufficient)	0.00	0.00

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Packing Inspector	0.3333	(Insufficient)	0.00	1.0000

Number Busy	Average	Half Width	Minimum Value	Maximum Value
Packing Inspector	0.3333	(Insufficient)	0.00	1.0000

Number Scheduled	Average	Half Width	Minimum Value	Maximum Value
Packing Inspector	1.0000	(Insufficient)	1.0000	1.0000

Scheduled Utilization	Value
Packing Inspector	0.3333

Total Number Seized	Value
Packing Inspector	80.0000

Traditional factory

Replications: 1 Time Units: Minutes