

Modelling and Simulation of a Shearcut Process Flow at a Steel Processing Company

Khelina Swate¹, Goodwell Muyengwa^{1}, and Yvonie N. Mawane¹*

¹University of Johannesburg, Department of Mechanical and Industrial Engineering Technology,
Corner Siemert and Beit Streets, Doornfontein, Johannesburg, South Africa

Abstract. Modelling and simulation of industrial systems have become a conventional method for productivity improvement through optimizing design, operation, performance and troubleshooting. This paper analyses the current Shearcut process flow through modelling and simulation. A case study research was undertaken at a steel processing company that transform steel coils into sheets, plates, slits, tubes, blanks and various roofing products. Two models were created using Arena software. The models were a representation of the process flow found in the Shearcut warehouse. The first model was developed from data obtained from production records and time studies that were carried out on some of the operations. Bottleneck stations and non-value adding operations were identified. The second model was created with some improvements that included reduced non-value adding times. Results from the second model had an improved output. This paper contributes to the use of computer simulation as a tool to improve productivity.

Keywords: arena, modelling, productivity, simulation

1 Introduction

Modelling and simulation are emerging as key technologies in supporting manufacturing in the 21st century. In today's competitive global market, there have been numerous efforts to use modelling and simulation tools and techniques to improve manufacturing efficiency within the dimensions of business [1]. It has been reported that the survival of any business in today's competitive market is based on response time, production cost, market price, and flexibility of manufacturing [2]. Obviously, the manufacturing industry has to respond quickly to these changes and continuously improve manufacturing systems in order to sustain their competitiveness [3]. It is believed that there is a need for pervasive utilization of modelling and simulation for decision support in current and future manufacturing. Hence,

* Corresponding author: gmuyengwa@uj.ac.za

simulation has been adopted in manufacturing systems by a large number of industrial organisations.

Simulation is defined by Kelton et al. [4] as a broad collection of methods and applications to mimic the behaviour of real systems, usually on a computer with the appropriate software. It plays a critical role in the design of products, materials and manufacturing processes. The simulation reproduces the behaviour of a system, which assists to observe, understand and define bottlenecks of the system in order to have adjustments in time [5]. Several authors agree on the simulation potentials which includes, the ability to simulate years of the real system in a much shorter time, potentially dangerous or hypothetical systems can be studied without the physical or financial risks that may be involved in building and studying the real system, the ability to study smaller or larger versions of a system, the ability to integrate complex system components to study their interactions, the ability to study different systems in different or identical environments and everything in a simulated environment can be absolutely monitored and controlled [1, 2, 6].

According to Kelton et al. [4] modelling is the process of producing a model. It is the representation of an object or phenomena, which is utilised by the simulation to predict a future state. A model should be a close approximation to the real system and should incorporate most of its features. The purpose of a model is to enable the analyst to predict the effect of changes to the system [1].

The steel industry is one of the world's industries, which has grown tremendously. This study presents simulation modelling using arena software to improve efficiency in a steel processing company that transform steel coils into sheets, plates, slits, tubes, blanks and various roofing products. The objectives of the company are adjusted to meet the customers' requirements and accomplishing the company strategy. However, the company is faced with several challenges and the key one is to effectively manage the manufacturing system. The study focuses on the Shearcut process, which is a major bottleneck section in the manufacturing system.

2 Literature review

2.1 Arena simulation modelling

Several simulation modelling systems exist in the market and most of them are capable of planning, testing and analyzing a manufacturing system [7]. Arena modelling system is a flexible and powerful tool that allows the creation of animated models that accurately represent virtually any system [1]. Arena is built on the Siman simulation language. Simulation language is a software package that is general in nature and where model development is done by programming [8].

Arena combines the ease of use found in high-level simulators with the flexibility of simulation language and even all the way down to general-purpose procedural languages like the Microsoft Visual Basic programming system [4]. Arena also maintains its modelling flexibility by being fully hierarchical as shown in Figure 1.

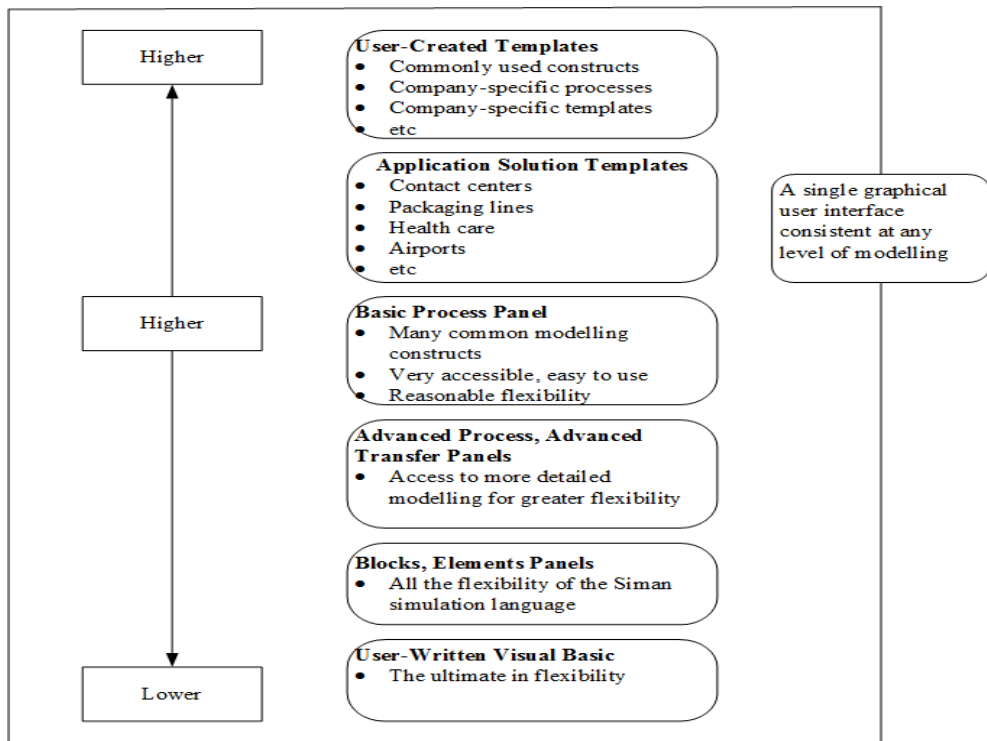


Fig. 1. Arena’s Hierarchical Structure [4]

Modules in Arena are composed of Siman components. Further, Arena includes dynamic animation and also provides integrated support, including 3D graphics and business dashboards for some of the statistical design and analysis issues that are part and parcel of a good simulation study [4].

Abeya and Mulugeta [1], identified eleven steps involved in developing a simulation model, designing a simulation experiment and performing simulation analysis.

The steps are:

- 1) Identify the problem
- 2) Formulate the problem
- 3) Collect and process real system data
- 4) Formulate and develop a model
- 5) Validate the model
- 6) Document model for future use
- 7) Select an appropriate experimental design
- 8) Establish experimental conditions for runs
- 9) Perform simulation runs
- 10) Interpret and present results
- 11) Recommend a further course of action.

Depending on the type of simulation study and methodology used, not all steps may be required and on the other hand, additional steps may be required.

Owen and Greasley [9], carried out a literature review on the use of discrete-event simulation in modelling and simulating people’s behaviour in a manufacturing set-up. Their results highlighted that the following attributes can be considered: “modelling people’s decisions, availability, task performance, customer arrival rate and people movement within the studied process”. They emphasized that accurate results can be obtained from models that

incorporate human behaviours that included issues such as worker turnover and absenteeism. Neumann and Medbo [10], used discrete-event simulation in evaluating the operator’s performance based on the operator’s learning rate. However, their results were not conclusive because they lacked data on “inter-individual learning rate variability in assembly work”. Kasie et al. [11], undertook a literature review on decision support systems within modelling and simulation studies. They developed a framework that incorporated artificial intelligence, decision support system database and simulation. Gopalakrishnan and Skoogh [12], carried out a simulation experiment that assessed “productivity potentials of machine criticality based maintenance”. It is clear that modelling and simulation can be used in a variety of ways and can incorporate various data such as worker behaviour and machine availability in identifying areas of improvement. However, this paper focuses on the modelling and simulation of a Shearcut process in a steel manufacturing plant and does not include worker behaviour and machine availability.

2.2 Shearcut process flow

The Shearcut department studied is equipped with a computer logging system that records data. This information includes data on steel coil arriving from the mill. Information on Shearcut operating elements including value and non-value adding activities were collected manually from the Shearcut department. Figure 2, shows the Shearcut process flow.

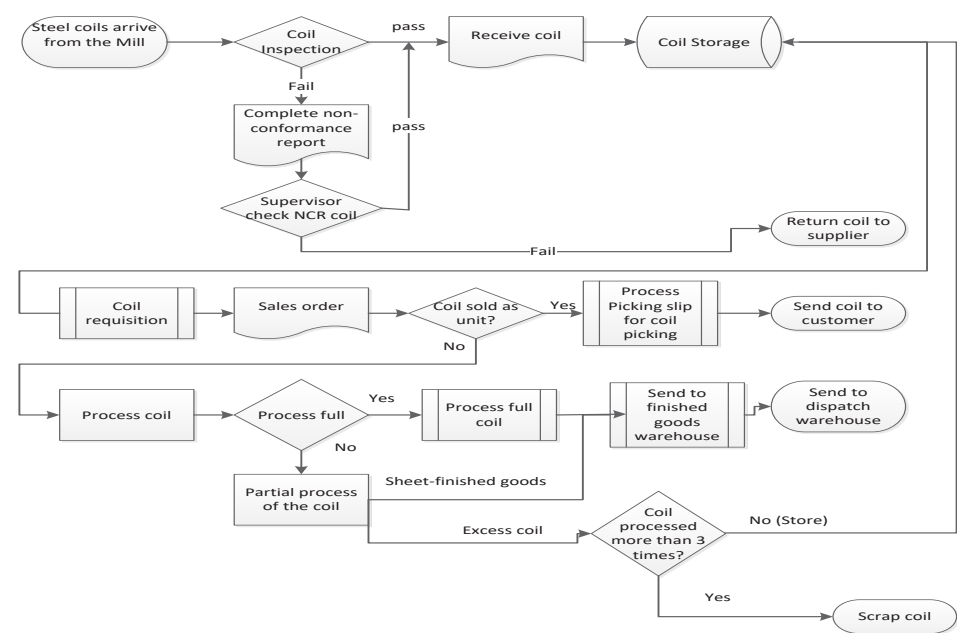


Fig. 2. Shearcut Process Flow.

3 Methodology

The major objective of this paper is to analyse and improve the current Shearcut process through modelling and simulation. The research questions for this are: To what extent can modelling and simulation be used to analyse a Sheracut process? How can modelling and simulation be used to improve productivity and resources utilization?

A case study approach was done for this paper. The standard methodology used for this study is a general computer simulation model, where two models were created using Arena software at a steel manufacturing company. Eleven tasks were identified in the Shearcut process, and these tasks are shown in Table 1. An average of ten observations was carried out on each task to improve the accuracy of the model. Input data to the model was triangulated from observations, time studies and production records. The first model was a representation of the current process. The model was first validated by experts working within the Shearcut department and these included the managers, supervisors and shop floor workers. The second validation was done through a comparison of model output results and the results from production records. The second model was an improved process, which optimized the current process. Data were collected regarding the total number of tasks, servicing time for each task, transfer of Work-in-process between stations, priorities between processes, arrival frequencies of entities or time between arrival, production output and defect rate. The parameters of the distribution used in both the current and improved model are the Triangular (TRIA) distribution, which has parameter values (Min, Mode, Max), which are the minimum time, the most likely time and the maximum time a task takes. TRIA is one of the probabilities built within the Arena software. Table 1 shows lists of the task, resources used and collected servicing time to be utilized in the first model. Table 2 shows the time durations that were used in developing the improved Shearcut process.

4 Results

The researchers obtained the processing times and the actual time is taken for all the activities that are carried out in the Shearcut processing line. All the times were standardized to Triangular (TRIA) times, which represents the minimum expected time, the most likely and the maximum expected time. These are the durations that were uploaded in the first model which represented the current Shearcut process. It is important to note that the current model was built with the average time frames obtained from the production records and skilled workers’ knowledge including time studies. Included to the prototype model was also the resources involved in executing the process.

Table 1, shows Shearcut operating elements, both value-adding and non-value adding but necessary activities. Storage and picking are some of the non-value adding but are necessary to get the job done, they, however, take considerable long processing time. The prolonged times are due to factors outside the Shearcut department but can be controlled.

Table 1. Shearcut input operating elements- Current process.

Task	Resource	Service Time (mins) TRIA
Inspect coil	Overhead crane operator	(2, 2.5,5)
Receive coil	Coil logistics supervisor	(4, 5, 12)
Complete NCR	Crane operator	(1, 1.8, 2.3)
Storage	-	(120, 240,300)
Process Sales Order	Planner	(3, 7, 11)
Process picking slip	Supervisor	(2, 3, 5)
Pick coil	Picker	(20, 45, 120)
Set Machine according to the job card	Machine Operator	(5, 7, 19)
Process Full Coil	Machine	(13, 25, 45)
Process partial coil	Machine	(13, 25, 45)
Receive finished goods into finish goods warehouse	Dispatch clerk	(13, 25, 45)

Discrete event simulation was used to create the Shearcut process. Coils are delivered to the Shearcut process truck arrival station at a rate of 49 minutes (Random Exponential), a probability distribution found in Arena. The coils are routed for inspection. Normally 95% of the coils are found to be in good condition and are released to pre-storage. The inspector completes a non-conformance report (NCR) on coils found to be of poor quality (5%). The supervisor further inspects coils with NCR, and usually, 70% of these coils are approved by the supervisor for release to pre-storage. 30% of the NCR coils are returned to suppliers as defects. A process sales order is generated as per customer requirements. The sales order indicates if the coil is sold as a unit or if it needs some processing. Shop floor workers pick the sales order, the coil and go on to record if the coil is sold as a unit or not. Normally 70% of the coils are sold as a unit with 30% processed as per machine job card issued by the sales office. Of the 30% processed coils, only 605 coils get full processing into sheets and 40% coils are partially processed. Processed coils are then recorded and released to the finished goods warehouse. The partially processed coils are sent to the pre-storage. The researchers used the basic, advanced process and advanced transfer modules found in the Arena software. The Shearcut process model was animated and it was run for a replication length of 6 hours per day for 20 days, giving 7200 minutes. This was the estimated time the Shearcut process operates in a month. Simulation results from the current model gave an output of 99. Bottlenecks were identified in the storage area, coil picking time, slow overhead crane and time taken by the warehousing clerk. An Arena flowchart for the current model is shown in Appendix 1.

In the improved Shearcut process model, the following durations were reduced: storage, pick coil and receiving finished goods into the warehouse, as shown in Table 2. The research team proposed a new warehouse layout and suggested that the company purchases a new and faster overhead crane. 5S a tool and technique to properly arrange the warehouse was also introduced. This approach reduced the time taken in the storage and the picking uptime. Furthermore, on receiving finished goods there was an opportunity to reduce the time by introducing the barcoding system which can capture the coil transfer to a different warehouse by scanning the finished goods serial numbers. The process would take the clerk a constant 5 minutes instead of the current times (6, 12 and 25 minutes). The output from the improved model was 120 which gave an increase of 21.

Table 2. Shearcut input operating elements – Improved process.

Task	Resource	Service Time TRIA (mins)
Inspect coil	Overhead crane operator	(2, 2.5,5)
Receive coil	Coil logistics supervisor	(4, 5, 12)
Complete NCR	Crane operator	(1, 1.8, 2.3)
Storage	-	(60, 120,150)
Process Sales Order	Planner	(3, 7, 11)
Process picking slip	Supervisor	(2, 3, 5)
Pick coil	Picker	(10, 22.5, 60)
Set Machine according to the job card	Machine Operator	(5, 7, 18)
Process Full Coil	Machine	(13, 25, 45)
Process partial coil	Machine	(13, 25, 45)
Receive finished goods into finish goods warehouse	Dispatch clerk	(13, 25, 45)

Figure 3, shows a comparison of how the resources were seized in the two models. It can be seen from the results that in the improved model resources were seized for longer periods compared to the initial model, hence the output of the improved model is 120 an increase of 21 from an output of 99 in the current model. The increment shows that the improved process has more value-adding to the system.

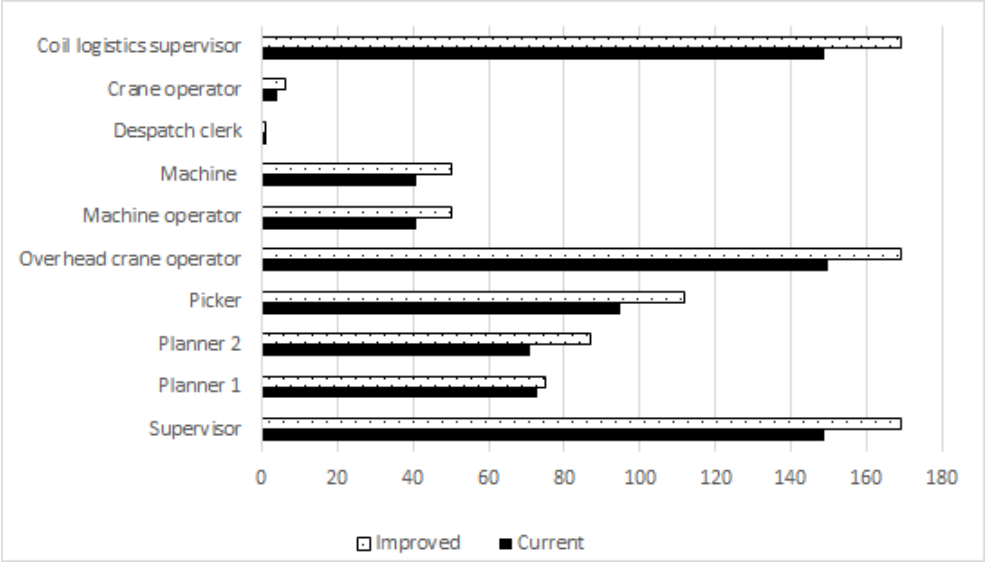


Fig. 3. Comparison of Process Value Adding (Seized Times).

Table 3 illustrates the counts of entities exiting the system. The table shows both current and improved, the figures reflect an increase except for a record of coils returned to the supplier.

Table 3. Count of entities existing in the system.

Count	Current Model	Improved Model
Record coils returned to the supplier	1.0000	0.0000
Record coils sold as a unit	94.00	112.00
Record processed coils	1.0000	1.0000
Record scrapped coil	3.0000	7.0000

5 Recommendations and future work

This research recommends that all activities that led to the improvement in the Shearcut process be considered in order to run the department efficiently and effectively. The department should use the model to track bottlenecks and their effect on the overall business. Just as reflected with the storage and picking process. Although the model and simulation practice is mostly applied for training purpose it is a good tool to use to analyse the system thus recommended for use in feasibility studies and decision analysis.

Future work will focus on connecting the simulation model with aspects of demand forecasting and human behaviour in Shearcut process. It is planned to lengthen the model with the possibility to attach explanations to processes and resources. Also, the simulation

will be extended with addressing the uncertainty of the number of coils arriving at coil logistics on a daily basis.

6 Conclusion

This paper provided a basic knowledge of the Shearcut process flow. The use of Arena software to model and simulate the process made it easy to be able to manipulate what would be impossible, too expensive, or too impractical to perform on the system which it portrays. However, what the presented model does not simplify is data gathering. To recreate a realistic scenario in a simulation, it is still necessary to find out the values and numbers that are used by the simulation. For example, to map the Shearcut process flow, the sub-process within it that is the production process, the machinery runtime, duration, raw materials and all resource activities have to be gathered.

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Appendix 1: Shearcut Process model

