

University of Pretoria
The Department of Industrial and Systems
Engineering

Final Project Report:

The Analysis and Facility Layout Improvement of
Mr. Biscuit's Production Facility

By
Shani van Wyk
13047371

Submitted in partial fulfilment of the requirements for the degree of
BACHELORS OF INDUSTRIAL AND SYSTEMS ENGINEERING

September 2016

DECLARATION OF ORIGINALITY

UNIVERSITY OF PRETORIA

The Department of Industrial and Systems Engineering places great emphasis upon integrity and ethical conduct in the preparation of all written work submitted for academic evaluation.

While academic staff teach you about referencing techniques and how to avoid plagiarism, you too have a responsibility in this regard. If you are at any stage uncertain as to what is required, you should speak to your lecturer before any written work is submitted.

You are guilty of plagiarism if you copy something from another author's work (eg a book, an article or a website) without acknowledging the source and pass it off as your own. In effect you are stealing something that belongs to someone else. This is not only the case when you copy work word-for-word (verbatim), but also when you submit someone else's work in a slightly altered form (paraphrase) or use a line of argument without acknowledging it. You are not allowed to use work previously produced by another student. You are also not allowed to let anybody copy your work with the intention of passing it off as his/her work.

Students who commit plagiarism will not be given any credit for plagiarised work. The matter may also be referred to the Disciplinary Committee (Students) for a ruling. Plagiarism is regarded as a serious contravention of the University's rules and can lead to expulsion from the University.

The declaration which follows must accompany all written work submitted while you are a student of the Department of Industrial and Systems Engineering. No written work will be accepted unless the declaration has been completed and attached.

Full names of student: Shani van Wyk

Student number: 13047371

Topic of work: Final year Project: Project Proposed

Declaration

1. I understand what plagiarism is and am aware of the University's policy in this regard.
2. I declare that this Project Proposed (eg essay, report, project, assignment, dissertation, thesis, etc) is my own original work. Where other people's work has been used (either from a printed source, Internet or any other source), this has been properly acknowledged and referenced in accordance with departmental requirements.
3. I have not used work previously produced by another student or any other person to hand in as my own.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

SIGNATURE

Shani van Wyk



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Executive Summary

This document is the final report for this Final Year Project for the Department of Industrial and Systems Engineering at the University of Pretoria. An as-is process analysis was conducted at the Mr. Biscuit factory in Pretoria East, to identify a problem for which an industrial engineering based solution could be provided. As the company expects a growth in demand within the next year, their aim is to be able to fulfil all orders for the increased demand but has concerns whether current production process have the capacity to do so. From the process analysis it was concluded that a lot of time is wasted on unnecessary movements of workers as workstations are positioned inefficiently on the factory floor. With the application of the industrial engineering approach of facilities planning in combination with Professor Iwao Kobayashi's 5S and waste elimination principles, it is expected that an improved layout will contribute to an improved production process and production operations.

From the literature study done in this document it was concluded that for the project, Muther's Systematic Layout Planning Procedure will be used, as it focuses on the flow of materials and workers within the factory with which alternative layouts can be designed. All requirements for the design of these layouts is established within this document through a structured data analysis which was then used to construct a From-to Chart, a Relationship Chart and a Space Relationship Chart.

The knowledge that was gathered within these first stages of the project was used along with some additional information collected. This, including specific space requirements and research regarding flows within facilities, specifically in connection with the Work Simplification Approach as discussed in the Tompkins text book, was then applied to develop and design four layout alternatives. These designs were constructed using the program TurboCAD*16 Pro, as it provides an easy means to do so. These alternative designs are then compared and evaluated in terms of the flow patterns they produce, and assessed against the criteria set out by the Graph-Based Method. From this a design is chosen that represents the best improved layout from the current facility layout. This is also validated to confirm that the new improved layout does meet the objectives and requirements for this specific project. This layout design will be handed over to the management of Mr. Biscuit for final decision-making.

If management decides to accept the new layout and wishes to implement it, this document also provides a proposed step by step implementation and other requirements on how to obtain the new layout in the most time efficient and safest way. Lastly, recommendations are also included in this document that will assist with further improvements within the Mr. Biscuit facility. All of the recommendations are interlinked with the 5S approach and waste eliminations initiatives, discussed as supplementary methods of improvement in this document. The implementation of these approaches are for the purpose of sustaining a productive and efficient production process within Mr. Biscuit's new improved facility layout.

Table of Contents

1.	Introduction and Background	1
1.1	Background	1
1.2	Introduction	1
2.	Current Process Analysis.....	2
3.	Problem Investigation	4
3.1	Need Requirement	4
3.2	Problem Statement.....	4
4.	Project Rationale	5
5.	Project Approach, Scope and Deliverables	5
5.1	Scope.....	5
5.2	Approach.....	6
5.3	Deliverables.....	6
6.	Literature Review	7
6.1	Facility Layout	7
6.1.1	Types of Facility Layouts.....	7
6.1.2	Approach to Planning a Facility Layout	8
6.2	Facility Planning Methods	9
6.2.1	Apple’s Plant Layout Procedure	9
6.2.2	Reed’s Plant Layout Procedure	10
6.2.3	Muther’s Systematic Layout Planning (SLP) Procedure.....	10
6.3	The Use of Muther’s Systematic Layout Planning in Previous Projects	12
6.4	Facility Layout Planning using Design Algorithms	13
6.4.1	The Pairwise Exchange Method:.....	13
6.4.2	The Craft Method:	13
6.4.3	The Graph-Based Method:	13
6.4.4	The Blocplan Method:.....	14
6.4.5	Mixed Integer Programming:	14
6.5	A Kanban System as an Industrial Engineering Supporting Tool	14
7.	Development of Supplementary Industrial Engineering Methods	15
8.	Data Analysis	17
8.1	Quantitative Measurement of Flow	17
8.2	Qualitative Measurement of Flow	18
8.3	Conclusion.....	19
9.	Layout Design Development	20
9.1	Activity Relationships	20
9.2	Space Requirements	21
9.3	Facility Layout Constraints	22

10.	Layout Solution Alternatives	23
10.1	Important Flow Considerations	23
10.2	Other Considerations	23
10.3	Description of Layout Alternatives	25
10.3.1	Layout One.....	25
10.3.2	Layout Two.....	26
10.3.3	Layout Three.....	26
10.3.4	Layout Four	27
11.	Evaluation of Alternative Layouts	28
11.1	Application of the Graph-Based Method as Evaluation Criteria.....	29
11.2	Layout One	29
11.2.1	Physical Evaluation.....	29
11.2.2	Flow Evaluation	30
11.2.3	Graph Evaluation	30
11.3	Layout Two	31
11.3.1	Physical Evaluation.....	31
11.3.2	Flow Evaluation	31
11.3.3	Graph Evaluation	32
11.4	Layout Three.....	33
11.4.1	Physical Evaluation.....	33
11.4.2	Flow Evaluation	33
11.4.3	Graph Evaluation	34
11.5	Layout Four.....	34
11.5.1	Physical Evaluation	34
11.5.2	Flow Evaluation	35
11.5.3	Graph Evaluation	36
11.6	Solution Selection: Layout Alternative Four	36
12.	Solution Validation	37
13.	Proposed Implementation	39
14.	Recommendations	41
15.	Conclusion.....	43
16.	References	45
	Appendix A	46
	Appendix B	47
	Appendix C.....	48
	Appendix D.....	49
	Appendix E	53

List of Figures

Figure 1: Flow chart of activities in production	1
Figure 2: Current layout and positioning of workstations.....	3
Figure 3: SLP Framework.....	11
Figure 4: Project Plan	14
Figure 5: Relationship Chart.....	18
Figure 6: Relationship Diagram	20
Figure 7: Space Relationship Diagram	22
Figure 8: a) The Number of Trolleys at the Cooling Area b) The Number of Trolleys waiting at the Cutting Workstation c) The Number of Trolleys waiting in front of the Ovens.....	24
Figure 9: Layout 1 Design Alternative.....	25
Figure 10: Layout 2 Design Alternative	26
Figure 11: Layout 3 Design Alternative	27
Figure 12: Layout 4 Design Alternative	28
Figure 13: Relationship Chart	29
Figure 14: Layout 1 Flow Diagram	30
Figure 15: Adjacency Graph of Layout 1	30
Figure 16: Layout 2 Flow Diagram	32
Figure 17: Adjacency Graph of Layout 2.....	32
Figure 18: Layout 3 Flow Diagram	33
Figure 19: Adjacency Graph of Layout 3.....	34
Figure 20: Layout 4 Flow Diagram	35
Figure 21: Adjacency Graph of Layout 4.....	36
Figure 22: a) Flow Diagram of Current Layout b) Flow Diagram of Improved Layout	37
Figure 23: Adjacency Graph of Current Layout.....	38
Figure 24: Diagram of the 20 Keys depicting the relations between the keys and the three main objectives thereof (Proera, 2015)	47

List of Tables

Table 1: The utilisation of workstations	3
Table 2: Apple's 20 steps.....	10
Table 3: Reed's Plan of Attack steps	10
Table 4: The 5S approach	15
Table 5: From-to Chart.....	17
Table 6: Closeness Rating.....	18
Table 7: Reason for Closeness Rating.....	18
Table 8: Space Requirements.....	21
Table 9: Material Flow Path Colours	28
Table 10: Arc Score of Layout 1	30
Table 11: Arc Score of Layout 2	32
Table 12: Arc Score of Layout 3	34
Table 13: Arc Score of Layout 4	36
Table 14: Arc Score of Current Layout	38
Table 15: Implementation Steps	39
Table 16: Cleaning Schedule Example	42
Table 17: Production Schedule Example	43
Table 18: Aisle Allowance Estimates	48
Table 19: Area calculations for Workstation Equipment.....	48
Table 20: Area Calculation of Workstation Materials	48

1. Introduction and Background

1.1 Background

Mr. Biscuit is a company that produces various types of cookies for all South African cookie lovers. The company along with factory were established fifteen years ago by Mr. Jaco Botha, and have been producing cookies ever since. The type of biscuits they produce and sell includes ginger, chocolate, chocolate-chip, shortbread, coconut and even banana flavoured cookies. They possess a client base that includes your larger retail stores such as Food Lovers-Market and Pick n Pay as well as a large group of clients that owns small retail shops within smaller settlements and townships. The factory is located in the Waltloo area in Pretoria east and is approximately 1000 m² in size. According to management they have a very loyal worker base producing cookies each day. Production is a hands-on job and is highly dependent on the productivity of its workers.

1.2 Introduction

Initially a complete production process analysis was required in order to determine any shortcomings and/or inefficiencies within the production process at the factory, to potentially improve the productivity of the process. From this a flow chart was created to showcase an overview of the activities that takes place sequentially during production. The flow chart is shown in Fig.1 and also contains the time it takes as well as the number of workers allocated to each workstation to complete each task.

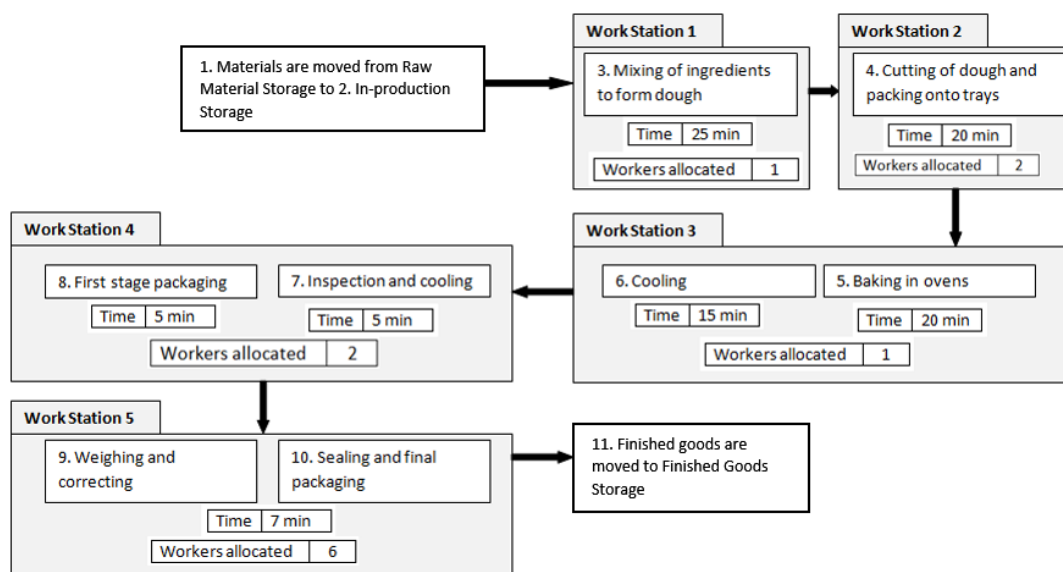


Figure 1: Flow chart of activities in production

The flow chart above visually explains the production process in terms of the activities that takes place. Activities four to ten are grouped into separate workstations as those activities cannot be performed independently, according to the requirements of the process. The time noted at each activity indicates how long it takes to perform that activity by the number of workers allocated to it, for one work-in-progress batch. The scope for this project includes all the activities that forms part of the production process of the six mentioned cookies. A full analysis of this process was thus conducted to identify problem areas.

2. Current Process Analysis

Raw Materials are initially moved from the Raw Materials Storage room to an on-floor space allocated in the factory for raw materials through the use of a forklift. This is done for convenience for workers working within the factory requiring certain raw materials. The forklift has to travel around the outside of the building and manoeuvre itself between production activities to deliver the raw materials as these two locations are separated by some distance.

Workstation one contains two mixing machines used to mix the dough for the type of cookies currently being produced. To mix one batch of dough in a machine takes about 25 minutes. At work station two the dough is cut into the required cookie shape. Each batch of dough produces three trolleys of cookies, each containing 30 trays. It takes 20 minutes to fill three trolleys.

Each of these trolleys is then taken to an oven for the cookies to be baked. There are three ovens being used during production where the factory has six ovens. Each week the set of ovens used are changed so that the unused ovens can undergo maintenance if necessary. Each trolley spends 20 minutes in an oven for the cookies to be baked. After the ovens, the trolleys are taken out and set in front of fans in order to cool down for 15 minutes before it is moved once again. From there the cookies are thrown into crates, where one trolley will fill one crate of cookies. Workstation four consists of three large cooling tables on which a crate of cookies is thrown and undergoes inspection to see if they were baked thoroughly, where after the unbaked cookies are thrown back into the crate and sent back to the ovens. The cookies that were baked properly are then divided into plastic bags containing the name of the type of cookie currently at the station.

Each table of workstation four operates independently and will therefore be referred to as workstation 4A, 4B and 4C. It would be logical to send each workstation four table a crate of cookies from the current batch being produced. Unfortunately, this is not the case and most of the time only two of the three workstations are utilised at a time. It has been calculated though that at one of these tables, it takes about five minutes to inspect a crate of cookies and five minutes to divide the cookies into bags. Lastly it takes workstation five about seven minutes to weigh each bag of cookies in a crate, to ensure the correct weight as required, and then to seal the bags and package an entire crate for finished product storage. In theory it would thus take workstation five about 20 minutes to fulfil their task.

From this overview of the production process it would not seem obvious that any bottlenecks are occurring, however from direct observation within the factory it is clear where work-in-progress builds up between workstations. For example, work-in-progress builds up between workstations two and three where the trolleys sometimes wait for the ovens to finish the previous batch. Because only two of the three tables of workstation four are utilised, it sometimes happens that crates builds up in front of one them, and when this happens it takes that specific workstation an extremely long time to complete its task. There is also some build-up within workstation five due to inefficient workers. These build-ups can definitely be minimized or eliminated if all stations are utilized properly. Unfortunately, they are not currently fully utilized as a result of the work efficiency of the workers. The current utilisation of tasks is given in table 1 on the next page. (Calculations in Appendix B)

Table 1: The utilisation of workstations

Workstation	Utilisation
1	74%
2	59%
3	63% / oven
4	30% / 1 workstation
5	62%

The production process consists primarily of manual labour, with workers performing the required tasks at the different workstations within the production process, meaning that their productivity mainly affects the output per shift, or stated otherwise, the production throughput rate. From the initial analysis it became clear that a lot of time was wasted by workers through performing non-value adding activities such as waiting for the previous batch to be completed or walking around. The question now is, why is so much time being wasted that could be used to perform necessary tasks and increase throughput? Looking at the process as a whole and focussing on the non-value adding activities that wastes time indicated the need to map the movement of materials and workers. Fig. 2 shows a basic diagram of the current layout of the factory and the positions of the workstations on the factory floor.

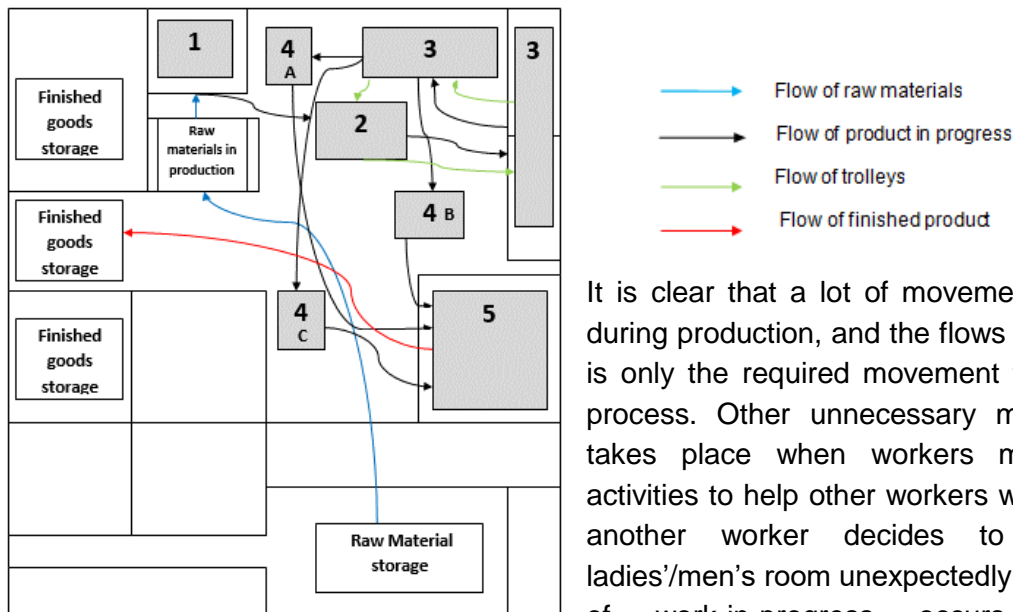


Figure 2: Current layout and positioning of workstations

It is clear that a lot of movement takes place during production, and the flows shown in Fig.2 is only the required movement for the current process. Other unnecessary movement also takes place when workers move between activities to help other workers with their task if another worker decides to go to the ladies'/men's room unexpectedly and a build-up of work-in-progress occurs. All these movements and unscheduled breaks results in a less productive facility and a lower throughput for the company.

According to the action manual written by J. Hiba and first published in 1998, improving working conditions and productivity in the garment industry; which is based on production through manual labour, time and energy is lost each time a worker handles or moves a product, which means unnecessary material handling or motion is a loss of time and energy and essentially adds to the production costs. Handling operations are closely linked to the number of tasks in the production and any material handling or movement not closely related to these activities must be identified and eliminated. (Hiba, 1998) Production processes could thus be better organised and workstations positioned in a more logical manner in order to minimise all this wasted time.

3. Problem Investigation

3.1 Need Requirement

During a discussion with the factory management it was stated that demand has significantly increased over the past year of production with the introduction of a new brand of biscuits called Biscuits for Africa. This product is sold to customers in more informal settlements whose customer satisfaction is focused on low prices. These products are made with alternative ingredients such as the essence of an ingredient rather than the real one itself, or with the use of less expensive flour in order to lower the cost of the product. In addition to the current demand growth, the company is planning on employing another sales representative within the following year, and thus expects sales to increase even further over the next two years.

The factory currently produces batches of cookies based on orders placed rather than on forecasted values, as the introduction of the new product brand has changed their demand values drastically in a short period of time. The daily target of the factory is to make two truck deliveries to clients based on orders, and up until this point in time they have succeeded to do so, but only just in time, as finished products placed in the finished products section of the factory does not stay there long before they are loaded onto the trucks. This is especially true for the Biscuits for Africa products. The manager in charge for the delivery of finished goods has concerns regarding a minimum finished goods inventory level that has been non-existent in the recent past. With the expected rise in demand he is uneasy to whether or not they will be able to have orders ready for delivery on time.

The manager in charge of production activities implied that he suspects that a lot of time is being wasted on non-production activities, just as concluded during the current process analysis. If these wastages could be reduced it would surely contribute to better production. The manager also stated that they attempt to keep the factory environment clean but workers can sometimes be lethargic when it comes to this aspect, contributing to untidy surroundings. This might seem like a non-sufficient problem but can have a great impact on the overall productivity of the production process.

3.2 Problem Statement

The main concern for the company is thus to deliver all orders on time in the future. The current orders are met just in time and a risk exists to whether or not the future demand will be met with the current system. Thus, this concern might not be a current problem, but as demand increases, complications can and will possibly arise regarding the production system's ability to provide for this demand. From the as-is analysis of the process it was found that a lot of unnecessary movement is taking place on the factory floor between consecutive and non-consecutive activities. The primary reason for this was found to be the current layout of the factory floor and the positioning of workstations. The human-factor has also been taken into consideration as people display different levels of productivity.

A lack in productivity of workers are caused by various reasons, the obvious one being time wasted on unnecessary excess movement and inefficient flow between activities due to the unstructured positioning of workstations. Other factors include sometimes non-standard activity methods followed, time wasted on searching for misplaced items and also due to the uncertainty pertaining what is currently being produced and what to do next.

These are the main contributing factors to the cause of idle time within the factory. Build-up of work-in-progress also occurred due to inconsistent number of batches moving through the production process as they tend to accumulate through the process, again mainly because of the current structuring of workstations. All of these elements contribute to an inefficient facilities layout, which in turn causes inefficient flow, wasted time and energy.

4. Project Rationale

The production capacity is currently not being utilized to its full potential, due to high levels of idle time within the entire process. Because of this it is expected that, with an increase of demand, the current process will not be able to produce the required number of products for on-time-delivery, which will ultimately lead to customer dissatisfaction and could possibly cause the loss of clients.

When placing a new representative in a new part of the country in order to grow the client base, one wants to make an impression of reliability. The company would be at risk of not performing at their current operating capacity, which will give new customers the sense that the company is unreliable. This would place the company in an un-ideal situation, making it a problem that can very possibly occur in the nearby future.

According to Stevenson, order fulfilment, which refers to the process involved in responding to customer orders, greatly depends on the logistics of that order fulfilment process. In this case we can refer to the flow of movement within a facility, which should be coordinated properly for order fulfilment to be done correctly and in time. (Stevenson,2012) The flow of workers and materials within a facility is directly influenced by the facility layout. Which means that facilities planning also plays an important role in the contribution to order fulfilment. Facilities planning is thus an appropriate industrial engineering approach to improving problems such as flows within the facility and ultimately order fulfilment.

5. Project Approach, Scope and Deliverables

5.1 Scope

The scope for this project will include the activities taking place at the different workstations for the production procedure. The primary focus will be on the interactions between these activities starting from material handling movements from the raw material storage section through to the delivery of the packaged finished product to the final goods storage space on the factory floor. These activities are included within the boundary of the scope as they play the most important role within the facility and thus within the layout of the facility. They will be critically observed and studied for the purpose of improving the current layout of the facility.

The scope will also include a possible means of eliminating wastes such as time wasted as well as wasted movements through the use of other industrial engineering techniques that will support the newly improved facility layout. A means of organising and keeping the facility clean and neat will also be investigated to contribute to better operating conditions within the facility.

5.2 Approach

A structured approach to this problem would be to do a thorough investigation of the actual flow of workers and material handling within the facility and specifically in between consecutive and non-consecutive workstations, due to the fact that the current layout of the factory is somewhat unstructured thus causing unnecessary movement and delays.

The indication of inefficient flow within the facility gave rise to considering a facility planning technique called Muther's Systematic Layout Planning Procedure. (Tompkins et al., 2010) This procedure's aim is to establish efficient facility layouts based on the relationship between activities and the movement demand between workstations or departments within a facility.

It fundamentally makes use of an Activity Relationship Chart and a material flow analysis to determine the movements between activities and their importance. This forms the core part on which the rest of the procedure will be based and thus requires a detailed analysis of the movements occurring in the production process. Confirmation of the use of this method will be made at the end of the literature study.

Time Sampling is a method that will most likely be used to observe and collect data on the movements made by the workers. Simply stated, time sampling is a method used to determine when and how much of certain activities take place by watching and observing participants, or in this case workers, for a specific amount of time and record if or how much an activity took place, such as the movements of workers between workstations. (Time Sampling: Definition & Examples, 2003)

A relationship diagram can now be formulated, which positions the activities spatially and shows the relationship significance between all activities. Other factors can now be taken into account such as the space requirements for each activity, the available space on the factory floor and also the space requirements for workers at each activity. Taking all of this into account one can start to develop facility layout alternatives and evaluate each alternative using an appropriate algorithmic approach. There are various evaluation approaches and the best suited approach will have to be selected after a proper literature study on the various types to determine the best approach.

Additionally, as stated within the project scope, standards will have to be implemented within the new facility in order to keep the work environment clean and free of wastes. Approaches for these implementations will be considered within the development of supplementary industrial engineering methods section of the document.

5.3 Deliverables

The main deliverable for this project is to provide management with the alternative facility layouts that will be developed and then evaluated. This is more of qualitative deliverable and the final implementation will be based on the subjective decision of management. The potential difficulty and cost to implement will also be determined as contributing factor for decision-making. A means to contribute to a better and standardised facility layout related to the reduction and possible elimination of wastes currently visible in the factory will also be provided.

6. Literature Review

The literature study primarily focuses on achieving a better understanding of facilities planning and the impact it can have on the facility and its operations. Previously used and known methods will be researched with the aim of possibly applying those methods to the current project problem. How the layout of a facility and the positioning of workstations greatly impacts the production performance of the plant will also specifically be investigated.

6.1 Facility Layout

The textbook, *Fundamentals of Manufacturing* by Philip D. Rufe defines facilities planning accurately as the planning and integration of the paths that the components and parts of a certain product or products follow, in order to achieve the most effective and economical interrelationship between equipment, staff, and the movement of materials from the receiving point, through production until the dispatch of the finished products. (Rufe, 2016) According to Philip D Rufe the facility layout is critical to the productivity of the plant, and if not optimal, negatively effects many aspects of the production process. For instance, a non-optimal layout affects non-operating time, the level of man-power used to move parts, as well as the capital investment for the material handling of equipment. Thus non-operating time will increase, causing the production lead time to increase which in turn causes an increase in the work-in-progress inventory. Additionally, non-value-adding material handling and movement takes place within the facility, contributing to more labour hours and finally a costlier product.

The layout of a facility also has a significant impact on the performance of the production operations of the facility. An appropriate facility layout and process flow is critical to ensuring effective movement, work space utilization and thus the facility throughput and performance. (Zheng et al., 2013) It is extremely important that the facility layout is applicable to the type of product being produced as it greatly effects the successes of production. An applicable layout must thus be determined.

6.1.1 Types of Facility Layouts

According to William J. Stevenson in the global edition of *Operations Management: Theory and Practice*, there are four primary types of layouts, namely, Product Layouts, Process Layouts, Fixed Position Layouts, as well as Cellular Layouts (Stevenson, 2012). Tompkins, one of the authors of the book: *Facilities planning*, used by industrial engineering students at the University of Pretoria (Tompkins et al., 2010), almost similarly defines facility layouts. They are described as follows:

- 1. Product Layout:**

A layout that uses standardised processing operations to achieve flow of large volumes of goods within the system. The flow of work within a product layout usually follows the product production sequence, which forms a pattern that is repeated during production.

- 2. Process Layout:**

Process layouts are designed to handle varied processing requirements. A variety of jobs being produced on this layout frequently requires equipment to be adjusted which can cause production interruptions. Usually similar processes are grouped together and placed as departments relative to each other on the factory floor to create interdepartmental flow.

3. Fixed Position Layout:

In this layout the product or project remains stationary on the factory floor, usually due to its enormous size or impracticality to be moved, where the workers, equipment, materials and other workstation resources usually moves around it.

4. Cellular Layout:

This is a type of layout in which workstations are grouped into what is called a cell, at which items can be processed that has similar processing requirements. A cell takes on the shape of a small product layout.

As Mr. Biscuit's factory consists of workstations through which the biscuits move as they are being produced it is clear from the above definitions that Mr. Biscuit's production makes use of a product layout. One can thus analyse the flow of work through Mr. Biscuit's production in order to create alternative product layouts that will potentially improve work flow and minimise unstructured movements and wasted time. Tompkins suggest that one must take note of the following limitations of a product layout when designing one, or in this case finding alternative improvement layouts (Tompkins et al., 2010).

Limitations and disadvantages of a Product Facility Layout:

- Breakdowns of machines or downtime of workstations causes an interruption in the production and thus the loss of production time.
- Product design changes can cause the current layout to become obsolete.
- Slowest workstation will increase entire production time.
- High investment in equipment.

6.1.2 Approach to Planning a Facility Layout

To provide an improved facilities layout, the following steps must be followed according to Tompkins (Tompkins et al., 2010):

1. Define the Problem

Define the objective of the facility and how the facility best supports the objective of what is being produced. The requirements for the products must thus be defined as well as the primary and support activities needed to be performed to produce product.

2. Analyse the Problem

Determine how production activities interact with each other and support one another within the facility, qualitatively and quantitatively.

3. Determine the Space Requirements

The space requirements for all the activities must be determined, taking into account all equipment, personnel and material requirement.

4. Evaluation of Alternative Layouts

Alternative Layout plans must be ranked and compared according to acceptable and applicable criteria, and subjective factors also need to be taken into account when evaluating alternatives and the effects thereof.

5. Selection of Preferred Layout Design

Determine and select the layout plan that will be the most acceptable in satisfying the objectives of the facility and act as the best possible solution for the problem initially defined.

6. Implement the Design

Planning must be done for the physical implementation of the new facility layout.

7. Maintain and Adapt the Facility Plan

Any new requirements or changes within the facility must be taken into account and the facility plan changed accordingly.

8. Redefine the Objective of the Facility

Once again changes in facility requirements or product design will have to be taken into account and the layout modified accordingly.

Steps one and two have been defined within the project proposal and is once again stated at the beginning of this document. Steps three through five will definitely be applied to the project at hand and is discussed in detail later on in this document, whereas steps six to eight depends on the decision of management whether or not to implement the suggested layout alternative.

6.2 Facility Planning Methods

Various facility planning procedures have been developed for the purpose of designing layout alternatives for production plants. These procedures can be categorised as either being construction layout methods or improvement procedures. Improvement procedures generates alternative layouts that seeks to improve the existing layout and the operations taking place in the facility. The first edition Textbook: Facility Planning and Layout Design by Chandrashekar Hiregoudar and B. Raghavenda, recognises the following facility planning procedures (Hiregoudar and B. Raghavenda, 2007):

- Immer's basic layout planning steps
- Nadler's ideal systems approach
- Apple's plant layout procedure
- Reed's plant layout procedure
- Muther's systematic layout planning

Tompkins, a more modern taker on facilities planning discusses only the last three procedures as they are more focused on facility layout problems only and uses concepts from Immer's and Nadler's approaches that acts as its foundation. This document reviews the procedures set out by Tompkins (Tompkins et al., 2010) as follows:

6.2.1 Apple's Plant Layout Procedure

Apple developed the following 20 steps to be followed when planning to produce or design a plant layout. It is not necessary for the steps to be executed precisely as stated as each facility planning project is unique and has its own requirements at different stages in the project. The steps are given in table 2 on the next page.

Table 2 : Apple's 20 steps

1	Procure the basic data.	11	Determine storage requirements.
2	Analyse the basic data.	12	Plan service and auxiliary activities.
3	Design the productive process.	13	Determine space requirements.
4	Plan the material flow pattern.	14	Allocate activities to total space.
5	Consider the general material handling plan.	15	Consider building types.
6	Calculate equipment requirements.	16	Construct master layout
7	Plan individual workstations.	17	Evaluate, adjust and check the layout with the appropriate persons.
8	Select specific material handling equipment	18	Obtain approvals.
9	Coordinate groups of related operations	19	Install the layout.
10	Design activity interrelationships.	20	Follow up on implementation of the layout.

6.2.2 Reed's Plant Layout Procedure

Reed recommends a "systematic plan of attack" which also consists of steps that needs to be followed for planning and improving a facility layout. These steps are given in table 3.

Table 3: Reed's Plan of Attack steps

1	Analyse the product or products to be produced.	6	Establish minimum aisle widths.
2	Determine the process required to manufacture the product.	7	Establish office requirements.
3	Prepare layout planning charts.	8	Consider personnel facilities and services.
4	Determine workstations.	9	Survey plant services
5	Analyse storage area requirements.	10	Provide for future expansion.

6.2.3 Muther's Systematic Layout Planning (SLP) Procedure

Richard Muther was the first to apply a systematic methodology to the manufacturing systems planning and the facility planning for the system. In 1973 he developed the layout procedure SLP for the designing and improving of facility layouts and the flow of movement between operations within the facility. SLP's framework of layout development is given in Fig. 3. (Tompkins et al., 2010)

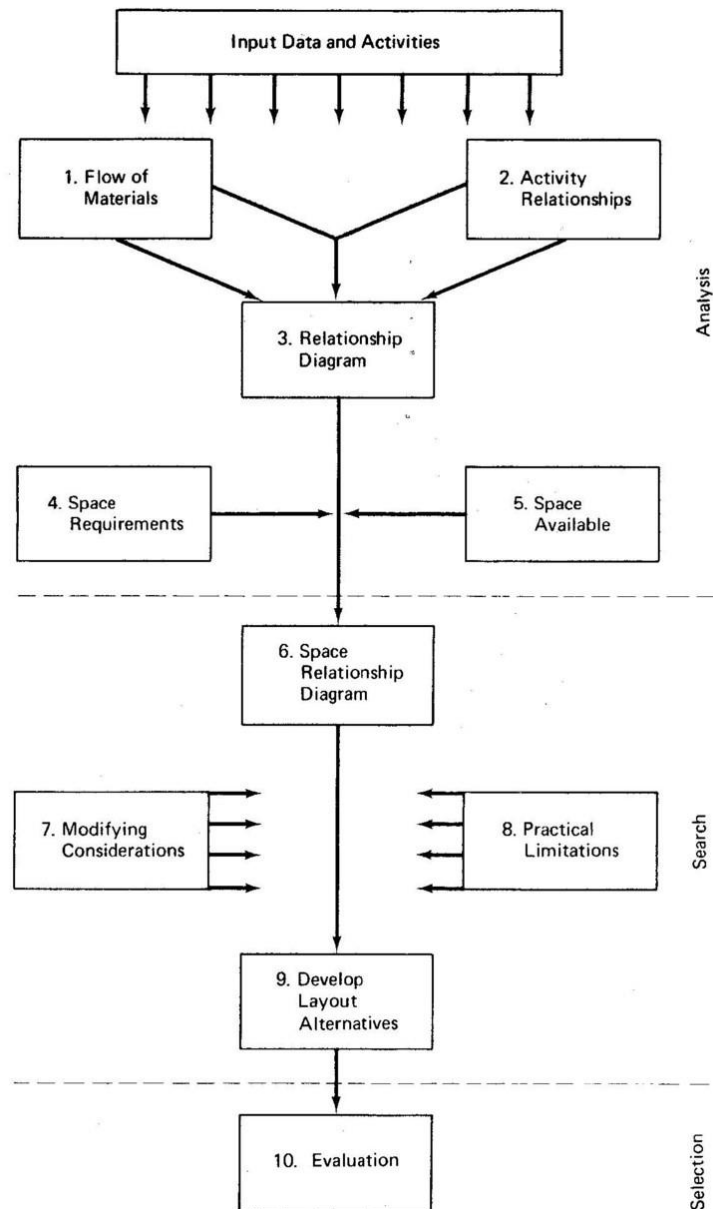


Figure 3: SLP Framework

SLP uses an Activity Relationship Chart as its foundation that will ultimately affect the final improved layout. From this chart a well-rounded understanding is gained of the activities in the facility and the roles and relationships between them and from this a material flow analysis and relationship analysis is done through the use of a From-to Chart and the activity Relationship Chart. From this a relationship diagram is developed. The space requirements for each activity is then taken into account to form a space relationship diagram. This provides one with a better visual understanding of the activities, their requirements and their relationships. After practical limitations of the facility are taken into account, a range of feasible layout alternatives are developed and then evaluated to conclude the most improved layout. The development and evaluation for this procedure can be executed through various evaluation approaches.

SLP is understood as a straightforward approach, but as in all facilities planning applications, difficulties do arise and alternative diagrams can be used to clear any complications. As the primary problem for the project at hand for Mr. Biscuit is flow and unnecessary movement within the facility between different activities, Muther's Systematic Layout Planning procedure is selected as the technique to be applied to the project.

6.3 The Use of Muther's Systematic Layout Planning in Previous Projects

According to a range of recourses, Muther's Systematic Layout Planning (SLP) approach is a frequently used facilities planning technique as the flow of employees, materials, equipment and other resources have a significant impact on the production performance of any facility. Through the use of this method and the application thereof on the physical arrangement of workstations within a plant, it can produce the best positioning and movement relationship of material, labour, equipment and other work activities on the facility floor. Systematic Layout Planning is considered a relatively simple process that works through multiple steps to develop an applicable and feasible plan of action for a facility. It handles a multiple-criteria evaluation process and is preferably used to evaluate alternative layouts and make a decision on the best and most practical layout for the given facility. SLP was found by many companies as an appropriate facilities planning method to use that showed various improvements and promising benefits.

James P. Gilbert, Professor of Operations Management and Quantitative Analysis at Rollins College presented a project at the 2nd World Conference on PON named: Construction Office Design with Systematic Layout Planning (UNINOVE, n.d.) through which SLP was used to develop a new office layout for a mid-sized construction firm operating in the private sector. The company owners were able to develop a significantly improved office layout through which the service quality, process speed and work process understanding was improved. Through this project it was concluded that SLP is proven to be an appropriate tool to be used for small to medium-sized office layouts as well as for re-layout design projects.

Systematic Layout Planning was also used as the chosen technique in a project named: Improving the layout to enhance the process flow in small batches Weight Control Laboratory, that was done by UNINOVE's Claudio Rodrigues Pereira and Milton Vieira Junior. (Gilbert, 2004) One problematic aspect this company was facing is an increase in demand similarly to the project discussed in this document. In the project they found and agreed that the better distribution of work processes through target materials, products, processes, information and people is a key factor to achieving optimum plant performance. This was done through the development of an alternative layout and better physical resource arrangement through the use of SPL. The application of this method resulted in a low cost alternative configuration that incorporates a simple solution to address the problem of growing demand and also partly solved another problem of shortage of capacity. This project also concluded that through the use of SPL and tools such as Excel, improvements was achieved in the arrangement of the physical space and the process flow within the facility which in turn resulted in the reduction of distance travelled by workers and the saving of previously wasted energy.

6.4 Facility Layout Planning using Design Algorithms

Tompkin states that the relative positioning of departments or workstations in the facility, on the basis of distance and material flow intensities can be reduced to an algorithmic process for the purpose of constructing a new layout or to improve an existing layout. The algorithms discussed by Tompkins and below, provide a formal procedure for layout development and also an objective criteria to facilitate the evaluation of alternative layouts. These algorithms can be executed by hand or through the aid of a computer. They are as follows (Tompkins et al., 2010):

6.4.1 The Pairwise Exchange Method:

This method is primarily used to improve an existing facility layout. The objective of this method is usually based on the distance travelled within the facility and aims to reduce or minimise this distances. All possible exchanges between departments are considered and the exchange that results in the travelling cost reduction is selected. In Tompkins it is assumed for simplicity that all departments in the facility is equal in size for this method, where departments of different sizes are incorporated within the Craft method (Tompkins et al., 2010). When deciding on which algorithm approach to use one must consider that this method does not guarantee on providing the optimal layout as the improved layout is directly dependant on the original layout.

6.4.2 The Craft Method:

This method is also used for the purpose of improving an existing facility's layout with a From-to Chart as the input and foundation for this method. As mentioned above it is not required or assumed that all the departments be equal in size or in a rectangular form. This method follows an iterative process where the rectilinear distances between the centroids of the departments are firstly calculated and then stored within a distance matrix. Thereafter possible department exchanges, both two-way and three-way, are considered where the best exchange option that will result in the largest layout cost reduction, is selected. This process is repeated until an optimal layout is gained. Once again, the Craft method is greatly affected by the initial layout due to the fact that the process is very path-dependant. This method also rarely generates a layout with straight line and uninterrupted paths, which in reality is mostly unpractical.

6.4.3 The Graph-Based Method:

The graph based method can be used without requiring an initial layout and can thus be used for the construction of a layout and not only for improvements. The objective used for this method is usually adjacency based. It is recognised as a useful mathematical tool which can be used to obtain a solution for facilities planning problems. It is noted that the distance travelled is not taken into account during the implementation of this method, nor does it account relationships other than the relationships between adjacent departments. The department's dimensional specifications are also not taken into account as this must be determined externally from the method and due to physical requirements or limitations. The best strategy followed for the evaluation of the layout is to iteratively construct an adjacency graph for layout alternatives in order to identify the maximally weighted planar adjacency graph that will represent the best layout from all alternatives.

6.4.4 The Blocplan Method:

This method arranges all departments in bands. Blocplan firstly uses the input data from a Relationship Chart and a From-To Chart to assign each department to a band. The entire layout is then developed through the use of computation of bandwidths where after the departments are arranged optimally within each band.

6.4.5 Mixed Integer Programming:

This also is a mathematical programming tool used for the construction of layout types. Unfortunately, this method can only be used if all the departments are rectangular shaped. A model where the objective is distance based and incorporates material flow intensities, can be developed using mixed integer programming to determine the optimal layout.

For the purpose of this project the Graph-Based Method will be used when evaluating the alternative layouts. Distance travelled and space requirements will be taken into account before and during the development of the alternative layout. The objective of using this evaluation method is for the fact that it will be applied to various designed layouts and provide a standard criteria that will be used to compare the layouts and determine the best suited one for Mr. Biscuits' facility.

6.5 A Kanban System as an Industrial Engineering Supporting Tool

According to Stevenson, a Kanban System can simply be defined as a manual system that is used for the controlling of moving parts and materials that responds to a signal for the demand or delivery of those parts and or materials between workstations within the factory (Stevenson, 2012). A Kanban card is a visual device used to communicate a signal for a need to either produce the next parts or to deliver parts to the next workstation. These are separately known as a Production Kanban and a Conveyance Kanban. In agreement with Stevenson, the Certified Six Sigma Green Belt Handbook (2nd Edition), states that the proper implementation of a Kanban System will improve system control by assuring timely and smooth movement of products and information within the facility in a rational manner. A Kanban creates a synchronised process which eliminates confusion and possible delays and or stoppages (Munro, Ramu and Zrymiak, 2016). A Kanban system can thus possibly also be recommended to the Mr. Biscuit management as this will also contribute to an improved production flow.

The plan that will thus be followed for this project is summarised in the flow diagram in Fig. 4 here below:

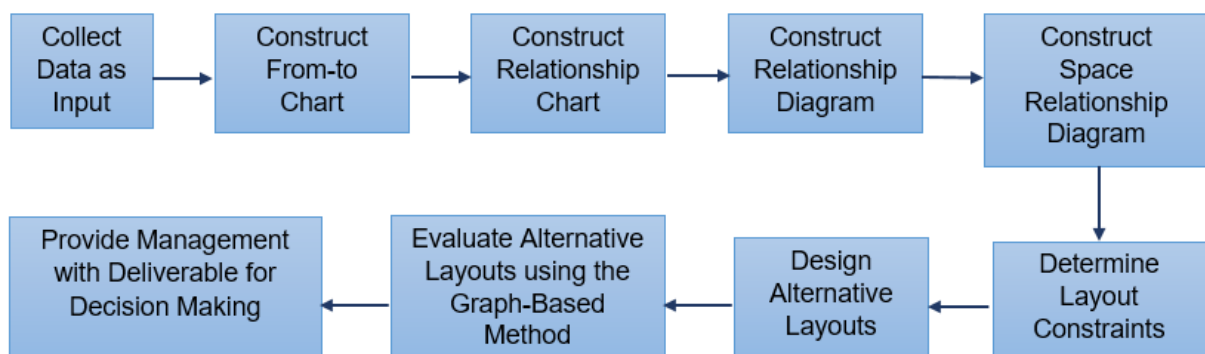


Figure 4: Project Plan

7. Development of Supplementary Industrial Engineering Methods

It is a goal for most companies, including Mr. Biscuit, to reduce and ultimately eliminate wastes and other non-value adding activities. For Mr. Biscuit specifically, wasted time and wasted movements need to be reduced. The 20 Keys workplace improvement initiative identifies 20 critical focus areas within any workplace that is responsible for the success of the company. This approach was developed by Professor Iwao Kobayashi and the implementation of these keys will contribute to continuously improving any company. One of the main aims thereof is lead time improvement through the application of lean processing principles (20keysglobal.com, 2016) A summative image of these 20 keys is given in appendix B (Fig. 24). The two keys that are the most relevant to the current problem at Mr. Biscuit is key number one and thirteen; 1) Cleaning and organising to make work easier, and 13) Eliminating waste.

1) Cleaning and Organising

Dr. Dino Petrarolo (BSc, MSc(Eng), PhD), a Manufacturing Development Consultant, states in his report called Benchmarking Organisational Capability using The 20 Keys, that key one acts as the fundament for all other improvements. Key one's cleaning deviates from common "housekeeping" approaches and motivates workers to perform cleaning and organising tasks through the understanding that through doing so their work will be made easier. (Petrarolo, 2012) This key is mainly composed of the 5S Approach. The 5S approach can be shortly described by the following sentence; A place for everything and everything in its place (Allen, Robinson and Stewart, 2001). The 5S Approach consists of the following steps as seen in table 4 on the next page.

Table 4: The 5S approach

1) Sort	Removing unnecessary objects from the workplace.
2) Set	Allocate a place for applicable equipment, tools or materials and define the responsibilities associated with them clearly.
3) Standardise	Create a working schedule, object allocation chart, document operating procedures and personnel responsibilities to ensure the standardisation of all positions and tasks on the facility floor.
4) Shine	Clean the workplace and equipment thus ridding it from any contamination.
5) Sustain	Training and support operations must be implemented to ensure previous 4S's are sustained in the long term within the facility.

The implementation of the 5S approach is also clearly indicated in their definitions. Firstly, all redundant objects taking up space in the facility must be removed, so that other necessary objects that are out of place can be identified. Predetermined locations can then be established for these objects within the new improved facility layout. It is important that these new permanent positions must be placed at locations within the facility where they will be most beneficial to the production process. Here the concept of visual management can be used to outline or highlight these standard locations.

It is important to maintain a clean working environment, otherwise the well-structured floor space will not be as efficient as it can possibly be and will cause procedures in the facility to fall into its old un-neat ways. Factory workers and other employees must thus be trained to be aware of what to do and how to use the allocated spaces in order to sustain the to-be improved facility.

13) Eliminating Waste

There are seven main wastes of lean manufacturing impacting every working environment that has to be identified and eliminated. Every activity that takes place during production is either a value adding or non-value adding activity. A value adding activity refers to any task or process that changes the nature of the product, in other words its shape or characteristics. The aim of the seven wastes principle is thus to eliminate these non-value adding activities that do not contribute to the formation of the final product.

The elimination of these wastes will contribute to a more productive production process and thus a shortened lead time. (Educational Business Articles Blog: Stay in touch!, 2016) These 7 wastes are listed below.

- 1) Transport
- 2) Inventory
- 3) Motion
- 4) Waiting
- 5) Over-processing
- 6) Over-production
- 7) Defects

This project focusses on the reduction of wasted motion and time wasted on waiting. Waiting time is mostly caused by waiting for a preceding activity to finish, the changeover time for the cutting machine when the cutting dye is being changed, or due to confusion between workers as to which order must be executed next in production and how far the current order is completed. As been discussed wasted motion is caused mainly by an unstructured production layout which causes workers to move around unnecessarily.

These two counter-productive activities can possibly be eliminated through the design and implementation of the improved facility layout, due to a more structured and standardised environment. Where the time wasted due to workers' confusion about the production status, this could possibly be improved through the application of Mini Businesses. A Mini Business refers to a daily meeting between employees that usually work together, to establish a production plan for the day based on demand, and to discuss goals that needs to be achieved each day. This will result in everybody being on track with the production plan, thus eliminating time spent on wondering.

The application of these two keys will not only affect singular improvements within the production process but will also contribution to an improved facility layout design. The alternative layouts should incorporate these two keys for both implementations to be successful and contribute to a significant improvement of the facility.

8. Data Analysis

Data gathering and analysis is an extremely important tool to use for the identification and clarification of problem areas. Proper data analysis will most likely reveal the severity of the problem under investigation. Within this project the excessive movement of workers within the factory facility has been identified as a problem caused by a non-optimal facility layout and the following data that was gathered and analysed supported this statement.

8.1 Quantitative Measurement of Flow

The movements between workstations and primary areas within the facility was analysed. These flows can be measured quantitatively by recording the exact amount of times movement takes place between departments. Most often, and in this case as well, a From-to Chart was used to record and summarise the movements that took place.

The From-to Chart measures the number of back and forth trips that is taken between the indicated production activities for a production shift. This establishes a measure of flow that accurately indicates volumes of flow for the facility. The From-to Chart given in table 5 shows the number of back and forth movements between the listed areas.

Table 5: From-to Chart

From-To-Flow (Number of trips between activities.)	Raw Materials	Mixer	Cutter	Ovens	Cooling Area	Workstation 4 A	Workstation 4 B	Workstation 4 C	Sealing and Final Packaging	Packaging Rack	Finished goods Storage
Raw Materials	0	24	0	0	0	0	0	0	0	0	0
Mixer	24	0	72	0	0	0	0	0	0	0	0
Cutter	0	72	0	135	0	0	0	0	0	0	0
Ovens	0	0	135	0	126	0	0	0	0	0	0
Cooling Area	0	0	0	126	0	41	75	108	0	0	0
Workstation 4 A	0	0	0	0	41	0	0	0	72	27	0
Workstation 4 B	0	0	0	0	75	0	0	0	87	36	0
Workstation 4 C	0	0	0	0	108	0	0	0	189	72	0
Sealing and Final Packaging	0	0	0	0	0	72	87	189	0	0	144
Packaging Rack	0	0	0	0	0	27	36	72	0	0	0
Finished goods Storage	0	0	0	0	0	0	0	0	144	0	0

The From-to Chart gives a visual representation of movements that can easily be used to make decisions regarding the placements of departments or workstations, thus to improve the workflow. In order to make the quantities of movement easily interpretable, trips under the quantity of 50 is highlighted in green, trips between 50 and a 100 in yellow and excessive number of trips above 100 in red. The trips represented within the chart resembles the average movements of workers during a nine-hour working time shift which exclude lunch breaks and cleaning times. The movements captured in this chart is only movements necessary for production and for the purpose of this project, additional unnecessary trips were excluded from the data analysis. These trips may include visits to the bathrooms, offices or for social purposes. Note that trips between the packaging rack and sealing and final packaging is indicated by a zero as these movements were considered internal workstation movements.

8.2 Qualitative Measurement of Flow

Flows within the facility can also be analysed in a qualitative sense, which can be done by using the closeness relationship values that was also developed by Murther. This method makes use of a Relationship Chart, as can be seen in Fig. 5, that combines the closeness relationship values, also known as a closeness rating, combined with a numerical value that represents the reason for the closeness rating and intensity of flow between departments. These ratings are shown in table 6 and 7.

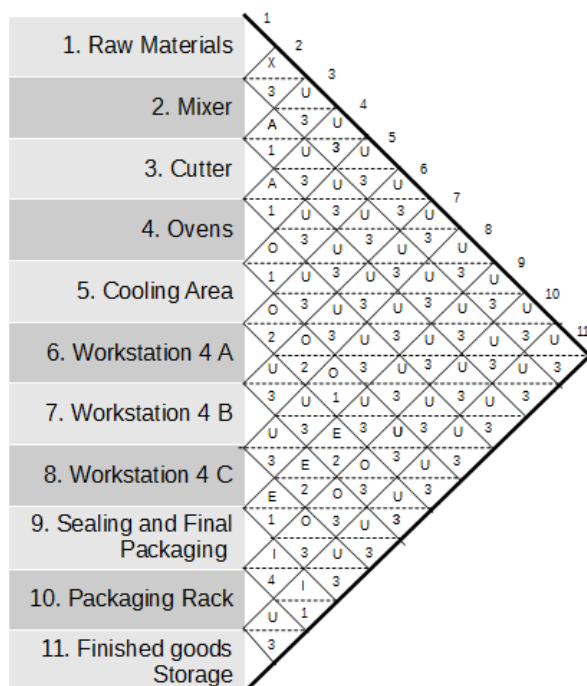


Figure 5: Relationship Chart

This Relationship Chart is linked to the movements observed and displayed in the From-to Chart. The closeness or otherwise the importance of the relationship between departments was concluded through intense observation and study of the production process as well as through discussions with workers and management of the production process. The Relationship Chart in Fig. 5 is thus a result of those qualitative observations.

Table 6: Closeness Rating

Value	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness okay
U	Unimportant
X	Undesirable

Table 7: Reason for Closeness Rating

Code	Reason
1	High frequency of flow
2	Medium frequency of flow
3	Low frequency of flow
4	Convenience flow
5	Difficulty and high cost to move
6	Personnel restrictions

8.3 Conclusion

Firstly, from the From-to Chart, the high volume flow it is clearly visible. There are a lot of movement taking place between the cutting station and the ovens, as there is one cutting station and three ovens in use per shift which causes a lot of back and forth movements in order to get all trollies to ovens that are sometimes spaced quite a distance apart, depending on which ovens are being used. High flow is also due to this movement being especially important to the production process. Strangely enough, despite the high flow, trollies always seem to build up in this space in front of the ovens, limiting moving space for other activities. Once again there is a lot of movement between the ovens and the cooling area for the same reason as with the cutting station.

Within the next step of production there is once again high flow between the cooling stand and workstation 4 C, a lot higher than with workstation 4 A and B. This is primarily due to the fact that only two out of the three workstation 4's is almost fully utilised at a time. Clearly workstation 4 C is utilised the most and workstation 4 A, the least. Ironically enough, workstation 4 C is currently positioned the furthest away from the cooling stand, but it is most probably utilised the most due to the fact that it is positioned almost right next to the final sealing and packaging area. In the From-to Chart it is also clear that the most movement takes place between workstation 4 C and the final sealing and packaging area, confirming that it is the most utilised station of workstation 4. Improvement should definitely take place within this area during the development of the facility improvement plan.

Lastly there is high volume movement between the final sealing and packaging area and the finished goods storage area. The specific movements between final packaging and finished goods were analysed on high production days where packages containing finished goods were collected in intervals from the on-floor storage space allocated for finished packaged goods throughout the shifts. This was done to avoid a large build-up of finished packages on the factory floor. As managers predict high production in the future this data was used as it would assist the planning of an improved facility. Again, these two floor space positions are not positioned closely to each other which makes moving these packages difficult as they have to be moved through other activities taking place on the facility floor.

Areas for improvements were made clear through this data analysis, which will be used and considered during the planning and designing of the new layout alternatives and the evaluation thereof. Other observations regarding internal workstation movements as well as work-in-progress inventory build-ups were made that will also be considered when designing improved layouts.

9. Layout Design Development

9.1 Activity Relationships

Before alternative facility layouts can be designed, all the requirements for the facility must first be established. This acts as the first step in developing a logical design for the layout of the facility. From the data and movement flow analysis that was done, the relationships between all workstations and activities could be established.

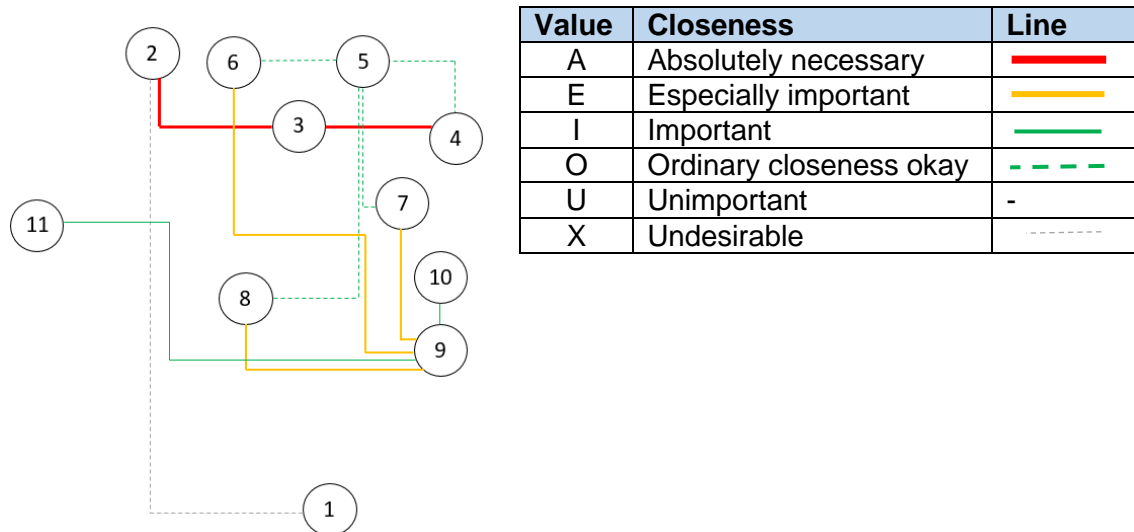


Figure 6: Relationship Diagram

Based on the From-to Chart (Table 5) as well as the Relationship Chart (Fig. 5) a relationship diagram of all the activities was constructed. All activities are relatively positioned according to their current positions within the facility. This diagram, as seen in Fig. 6, visibly shows the frequency of flow between all workstation activities and also depicts the importance of the movements.

Note that all unimportant movements, which are indicated by a **U** in the Relationship Chart, are not shown on this diagram as they take place between all workstations and would be unnecessary and meaningless to show. From this diagram it is clear to see that the most movement and most important movements takes place between the mixer(**2**), the cutter(**3**), and the ovens(**4**), as well as between workstation 4 A(**6**), B(**7**) and C(**8**) and the sealing and final packaging(**9**) activities.

Activity (**2**), (**3**) and (**4**) are spaced relatively well in terms of the flow between them, but the flow of movement between them cuts straight through one half of the facility, and blocks other flows that simultaneously takes place. The especially important flows between the separately placed workstations 4 A(**6**), B(**7**) and C(**8**), takes place over some distance throughout the facility to connect to the sealing and final packaging area. Fortunately, it is known that the highest flow of movement of all three these workstations occurs from workstation 4 C, the closest one to the sealing and final packaging area. Despite this fact, these workstations will definitely have to be positioned more efficiently.

9.2 Space Requirements

The second step is to determine the amount of space that needs to be assigned to each workstation activity. Each workstation includes the equipment used for the activity, materials that are involved in the process and of course the workers working at each workstation. All of these elements requires space in order to perform its required function. Table 8 below shows the areas of all these requirements. This data was also collected during the data gathering phase of this project and the specific measurements therefor can be found in table 19 and 20 in Appendix C.

Table 8 : Space Requirements

Activity Requirements		Area Requirements (m^2)			
Workstation	Number of Workers	Equipment	Material	Workers	Total
Raw Materials Storage	0	155.52	0.25	0	155.77
Mixer	1	11.54	0.59	1.5	13.63
Cutter	2	2.41	0.29	3	5.7
Ovens	1	32.87	1.03	1.5	35.4
Cooling Area	0	6	1.37	0	7.37
Workstation 4 A	2	3.35	1.1	3	7.45
Workstation 4 B	2	3.35	1.1	3	7.45
Workstation 4 C	2	3.35	1.1	3	7.45
Sealing and Final Packaging	5	42	2.29	7.5	51.79
Packaging Rack	1	8.46	0	1.5	9.96
Finished goods Storage	2	105.12	0	3	108.12
Net Area Required					412.69
Aisle Allowance (12%)					49.52
Total Area Required					462.21

The space allocations for activity equipment only includes equipment used within the scope of the production of the various cookies. The assumption was also made that a person takes up approximately $1.5 m^2$ space within their workstation when performing their work in a stationary position, which is the case at most workstations. Also, only two dimensional areas on the factory floor was taken into account as these workstations do not depend on the height of equipment for the required task to be performed, and vertical distances is not a constraint for production within the facility. According to Tompkins, additional space for aisles in-between workstations must also be taken into account, but at this stage can only be approximated. Table 18 (Appendix C) from the Facilities Planning textbook (Tompkins et al., 2010) provides Aisle Allowance percentages based on the largest material handling load, which in this facility is the packaging trolley ($0.83 m^2$ or $8.93 ft^2$). Thus from table 18 an Aisle Allowance of 12% is provided as an estimate for the additional space required. See Appendix C for the relative calculation and reasoning.

The relationships established in the Relationship Chart and diagram was then combined with these space requirements to form the Space Relationship Diagram given in Fig. 7. The total space requirements for each workstation within Fig. 7 comes from table 8 on the previous page. Systematically a better understanding is being developed as to how requirements link in with each other. This then triggers the formation of ideas that will later lead to the development of alternative improved layouts in which these relationship and space requirements will be taken into account.

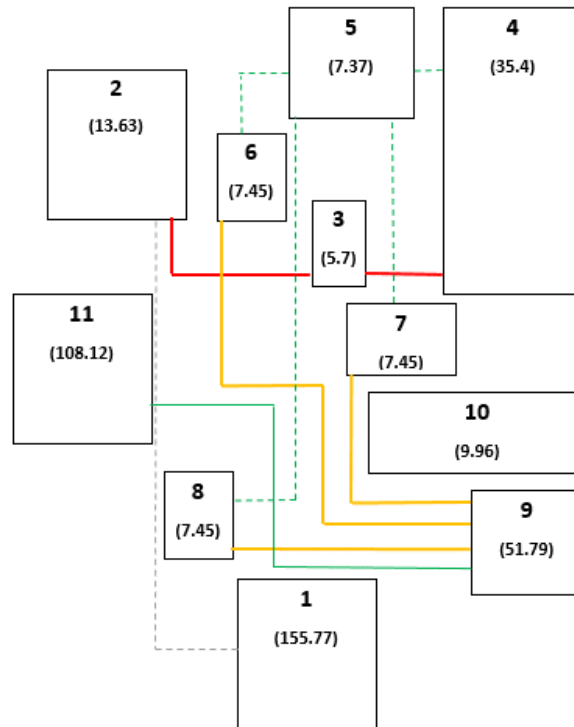


Figure 7: Space Relationship Diagram

9.3 Facility Layout Constraints

In addition to the requirements, there are certain constraints that must also be taken into account when designing alternative improvement layouts. Layout constraints for the facility is listed below.

- The physical structure of the factory building cannot be changed as the costs thereof would be an unwanted expense by management. This includes the shape as well as the total available space of the factory floor.
- There are certain physical elements within the scope of the layout that are fixed in their positions, such as the ovens as well as the raw materials storage room, the mixing room and the finished goods storage room. This will have to be taken into consideration as it will not be possible to relocate or change the size thereof.

It is thus important to take these constraints into consideration together with facility requirements as they affect how the alternative layouts will be designed and possibly later implemented.

10. Layout Solution Alternatives

The designing of alternative layouts for the Mr. Biscuit facility was done with the goal in mind to reduce and or eliminate wasted times caused by excessive movements, un-optimal distances travelled and most commonly, inefficient flow between workstations. Other factors also had to be taken into consideration when planning an improved facilities layout, such as the constraints mentioned earlier in this document as well as the integration of 5S and other lean operating features into the layout.

10.1 Important Flow Considerations

According to Tompkins, (Tompkins et al., 2010) when developing a facility layout with the focus on flow patterns, it is important to separate the traffic patterns of different materials, employees and also that of visitors. When planning the flow patterns of a facility layout one must always consider security, ease of access and the possible integrations of various flows. Tompkins also discusses Material Flow Systems in which The Work Simplification Approach is mentioned. This approach is based on the principle of minimising the total flow of material handling movements and includes some of the following:

- Planning for the delivery of all materials, brought into the factory.
- Minimising multiple flows by reducing flows between to two consecutive points to a single movement if possible.
- Combining flows where possible.
- Minimise distance travelled which will also reduce manual handling.
- Minimising flow density.

Thus in order to achieve an effective flow system it is important to combine flow patterns and separate flows of different materials and workers in the production process and also ensure adequate aisles on which these different flows of materials can be moved uninterrupted and with ease.

10.2 Other Considerations

Other additional data was captured during the data gathering phase of the project to provide further guidance for designing alternative layout solutions. This data captures the bulk of work-in-progress materials and or material handling equipment at certain areas on the facility floor over time. The purpose for this was to establish the area size required for these materials at different points within the process. Fig. 8 illustrates a small summary of this data in the form of bar graphs.

The number of the baking trolleys in certain areas, where captured in intervals of five minutes over a fixed time period. Refer to Fig.8 a, b and c on the next page. For trolleys waiting at the cutting station (workstation two), an area for at least three or four trolleys will have to be made available ($1.38 m^2$). There where always about an average of two trolleys waiting to be taken to the ovens and thus that space will also have be made available next to workstation two ($0.68 m^2$). Lastly in terms of trolleys at the cooling area, a space for five trolleys will be made available ($1.7 m^2$).

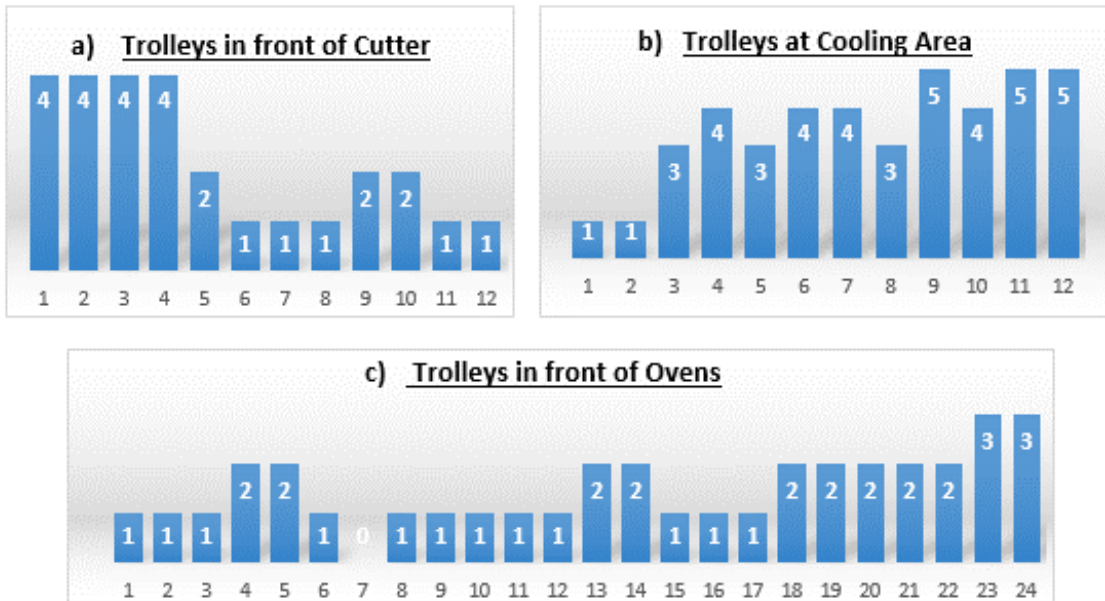


Figure 8: a) The Number of Trolleys at the Cooling Area b) The Number of Trolleys waiting at the Cutting Workstation c) The Number of Trolleys waiting in front of the Ovens

In considering eliminating wasted space the first element that was focussed on was the packaging rack containing packaging material, that is originally positioned next to workstation five. This rack consists of six 1 × 1.4 meter individual racks of which not all shelves were fully utilized. It was thus decided to eliminate one of the six individual racks to make space for possible better movement within the facility. This also forms part of the 5S Sort approach to remove unnecessary objects.

During factory visits it was also observed that crates used by workstation 4 and five were left at random spots on the facility floor when they were not being used. This contributes to an untidy work environment and creates obstacles that disrupts production flows. Thus a space was allocated in each of the layout alternatives where crates must be stacked when not in use. Crates are also used to store underdone cookies that needs to be sent back to the ovens for re-baking.

The path that these crates follow are called backtracking paths. Currently they also do not have a fixed waiting position before being baked, thus a space will have to be made available for them in each of the alternative layout designs. This again contributes to the Set and Shine aspects of the 5S approach by allocating a place for equipment and thus creating a cleaner and more tidy environment.

Lastly it was clear that workstation two could be improved. Currently workstation two consists of two dough cutting machines of which only one is operational and manned by two workers. As the second machine is not needed for production it is currently being used as a platform on which different cutting dies are stored on top of each other. This can cause damage to the dies and also contribute to the workstation being less tidy and less efficient. There is however a simple solution for this. The non-operational machine will be replaced by a table suited for the workstation. On this table there will be a place for each die and any other equipment used by the workstation. This again forms part of the 5S and waste elimination initiative.

10.3 Description of Layout Alternatives

The following part of the document shortly describes each alternative layout that was designed as a solution for the Mr. Biscuit facility where after it will be discussed in detail during evaluation. Each description is accompanied by a figure of the layout within the factory, whereas the full facility plans are provided in Appendix D.

The designs were made using the software program TurboCAD*16 Pro, which is a brilliant and easy to use tool for the fast construction of 2D and 3D designs, making it very suitable to construct the layout designs for the Mr. Biscuit factory. Original plans of the factory could be imported into the program with ease, providing the perfect sectioned plane on which the new improved designs could be developed. Also any designs with this TurboCAD program can be easily converted into a professional document format. (TurboCAD via IMSI Design, 2016)

10.3.1 Layout One

The first aspect considered when the first design was being created, was to move workstation two away from the middle of the working area and closer to workstation one. The idea is to create a circular flow between workstations two, three and four as this is the path that the backing trolleys constantly follow. Also workstation four tables are grouped together in this design and will also be grouped in the other layout alternatives in order to combine original flows. See the plan for layout one in Fig. 9 below.

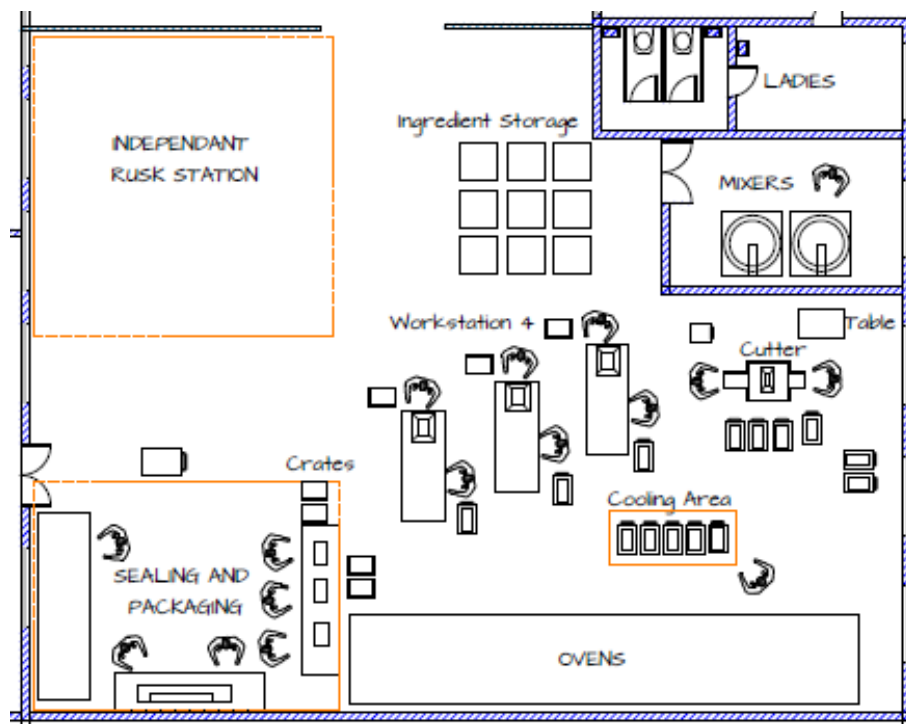


Figure 9: Layout 1 Design Alternative

10.3.2 Layout Two

In this design it was decided to divide workstation five into three separate sections namely: 5a) The weighing of the cookie packages 5b) The sealing of plastic bags and packaging them into boxes and lastly 5c) The temporary placement of packaged boxes before they are taken to the finished goods storage area. This was done as to move the workstation four tables from the centre of the facility floor and create a larger area in which backing trolleys can be moved around. This creates a path with less obstacles on which these trolleys can be moved with more ease.

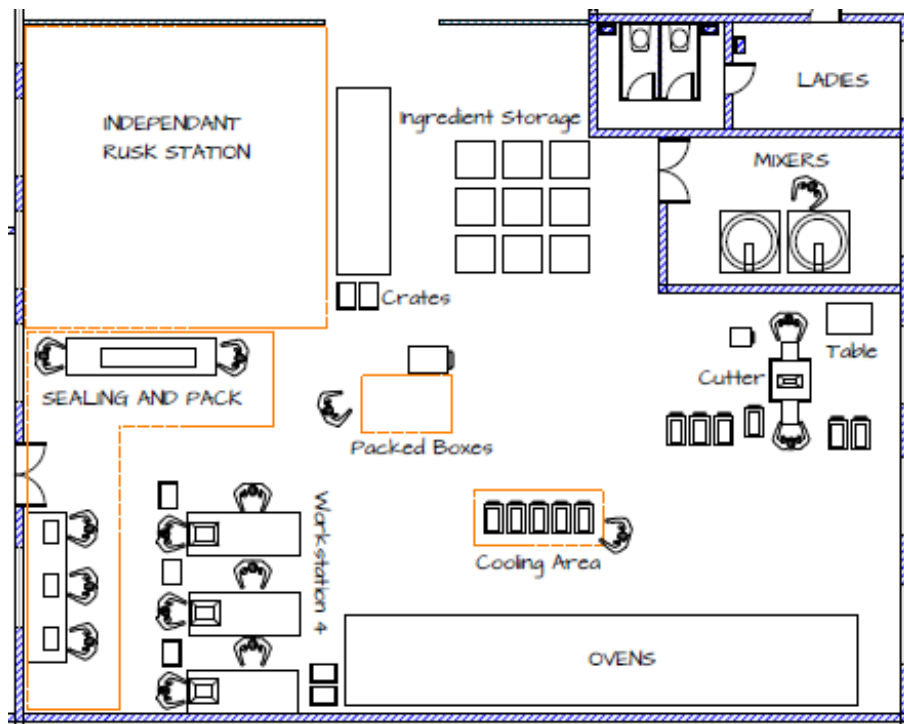


Figure 10: Layout 2 Design Alternative

10.3.3 Layout Three

The third design has an almost similar feel to design one, where in this design workstation four tables are rotated 90° to the left such that the output point of workstation four is closest to the input point of workstation five, thus minimising the distance travelled between the two workstations. The cooling area is left in its original position as in the current layout of the facility in order to create moving space for baking trolleys as workstation four now takes up a bit of that space. Layout three is provided on the next page.

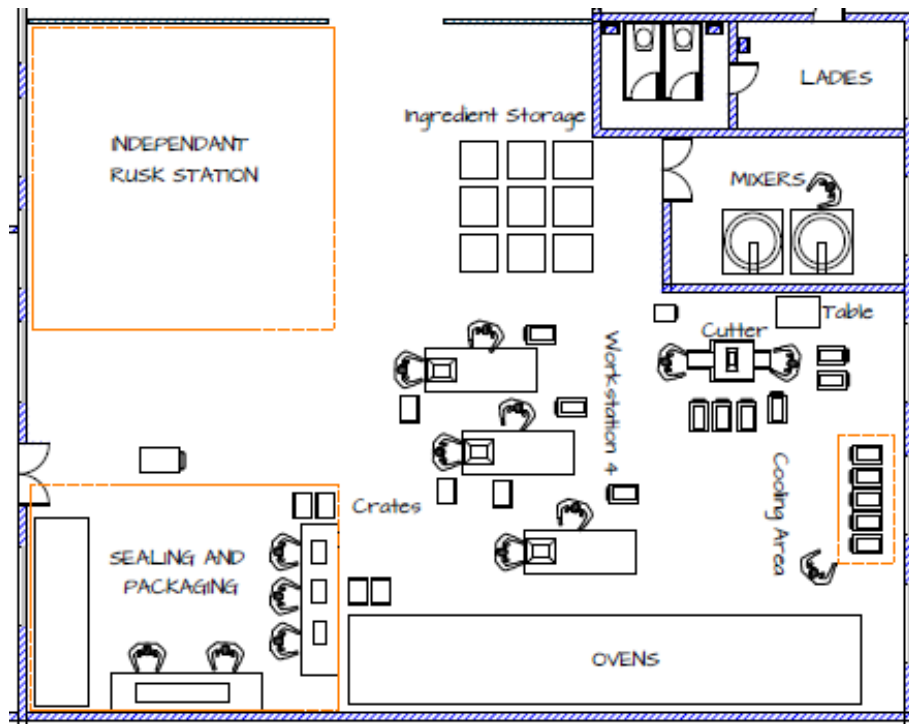


Figure 11: Layout 3 Design Alternative

10.3.4 Layout Four

Design four is the only design where the temporary ingredient storage space on the facility floor was moved deeper into the facility. The reason for not making this decision within the other designs was because it would create a longer distance for the forklift to travel. Workstation two now occupies its original position. Also workstation five switched positions with the independent rusk station. This was done to bring the final stage in the production process closer to the finished goods storage area.

Workstation four is now also placed directly next to workstation five with the idea to completely eliminate the manual movement requirement between the two. The concept here is that crates that are filled with packaged bags will simply be pushed underneath the table behind workstation five directly into workstation five. The plan for layout four is provided in Fig. 12 on the next page.

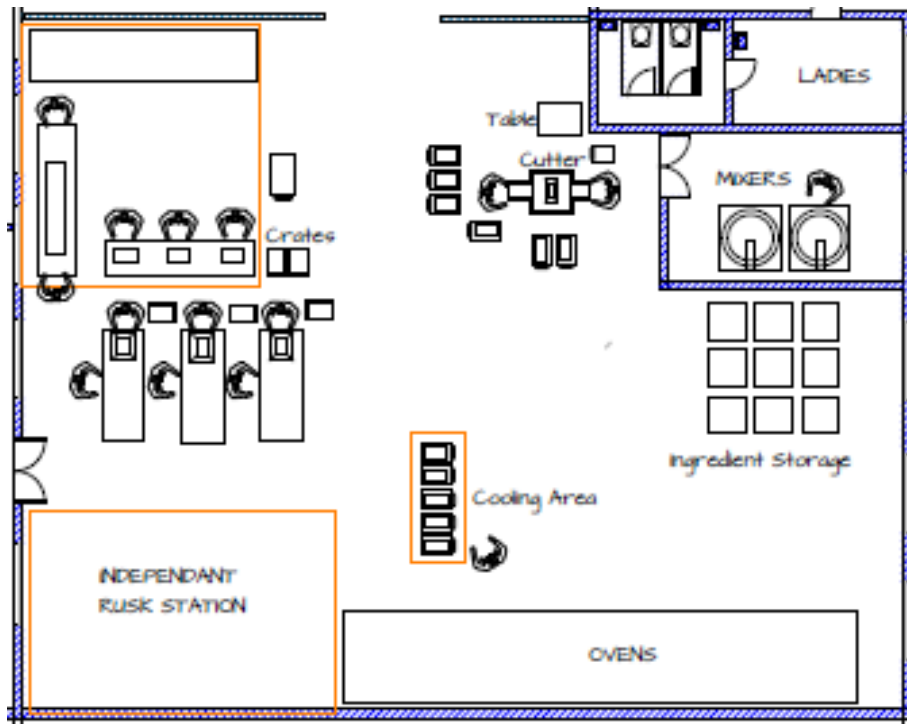






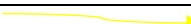


Figure 12: Layout 4 Design Alternative

11. Evaluation of Alternative Layouts

The alternative layouts that have been designed will now be evaluated and compared to the current layout of the Mr. Biscuit facility and also to each other. Through this process a proposed layout solution will be identified. Each layout design will be evaluated in terms of physical changes made to the current layout and the effects thereof. The flow patterns produced by each layout will also be analysed and lastly each layout design will be evaluated against the criteria set out by The Graph-Based Method heuristic.

Table 9: Material Flow Path Colours

Arrow Colour	Material Handling Paths
	Raw Material Trolley
	Dough Trolley
	Biscuit Trolley
	Crates
	Packaging Trolley
	Forklift
	Backtracking Crates

During the discussions of the flow diagrams, it will be required to refer to table 9, which provides a description of the different material flows within the facility. The figures of each flow diagram and adjacency graph within the following evaluations are also provided in Appendix E in a larger size for closer observation.

Due to the fact that most of the equipment within the facility remains the same for each layout alternatives and the fact that no extreme changes such as the structure of the factory building can be altered, as discussed in constraints, the financial aspect to implement each layout will be more or less the same, eliminating it as a determining factor within the evaluation stage.

11.1 Application of the Graph-Based Method as Evaluation Criteria

The Graph-Based method was applied to the designed layouts as an evaluation tool or criteria in order to evaluate the layouts in a quantitative manner. It was used to iteratively construct an adjacency graph for each layout alternative and identify the graph that represents the best layout. An adjacency graph consists of nodes that represents each workstation. An arc links two nodes and represents that those workstations share a common boundary. Each arc carries a weight that is derived from the following modified Relationship Chart provided in Fig. 13.

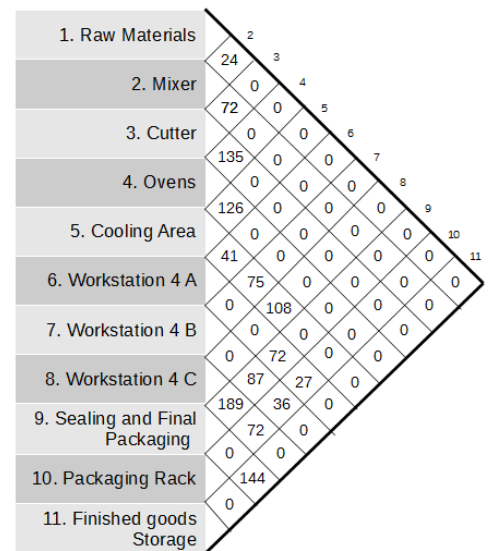


Figure 13: Relationship Chart

This Relationship Chart is based on the From-to Chart (Table 5) containing the number of trips that were taken between workstations. The Relationship Chart is altered for the Graph-Based Method as it only uses the numerical weights rather than the closeness rating provided in the original Activity Relationship Chart (Fig. 5). Note that the numerical representation of workstations in the graphs are equivalent to the numbering in the new Relationship Chart.

These graphs have a property called planarity, meaning that arcs must not and cannot intersect. This property must thus be taken into account when constructing the graphs. These planar graphs will thus be composed of many triangular shapes that are created by arcs between the nodes. The adjacency-based objective for these alternative layouts is to find a maximally weighted adjacency graph, in other words the graph with the maximum sum of arc weights. Stated otherwise, workstation represented by nodes share a flow density between each other, and if two shares a boundary with each other, they are either located next to each other or closer to one another. If more high density flow boundaries are formed by a design it means that those high density flows will be reduced and or eliminated with a new design. This will also give the graph of the design a higher arc score, concluding that it represents a better design.

11.2 Layout One

11.2.1 Physical Evaluation

One of the prominent changes made in the design of layout one and also within the other layouts, was the grouping of all the tables that makes up workstation four. This was done to eliminate unnecessary distances travelled between them by the two workers currently working between these three tables. Also this simplifies the path of the baking trolley operator to these three tables as he would only have to travel to one location. Adding to the simplification of his path, the cooling area is now located halfway between the ovens and workstation four, intercepting the path between them. This cuts the trolley operator's path in half, reducing his trip between these three points in the process. Workstation two, now including and equipment table, was also moved to one corner in the facility for the purpose of creating an improved flow within the process.

The isle requirements for the different material handling equipment have been taken into consideration, the only constraint regarding the path that the forklift must follow is it might have some difficulty turning around between workstation four and the temporary ingredient storage, thus requiring it to reverse on its path back out again.

11.2.2 Flow Evaluation

Design one was structured to create a line flow pattern of the type S-flow, which is commonly used in various types of production lines. The goal is to separate different material handling flows and shortening the paths of some material flows depending on how much the path is used. The only material flow path that crosses other paths within this layout is that of the raw material trolley that occasionally moves perishables ingredients from the raw material storage to the temporary on-floor ingredient storage. Fortunately, this happens too seldom to cause any disruption. The flow diagram for this layout is provided in Fig. 14.

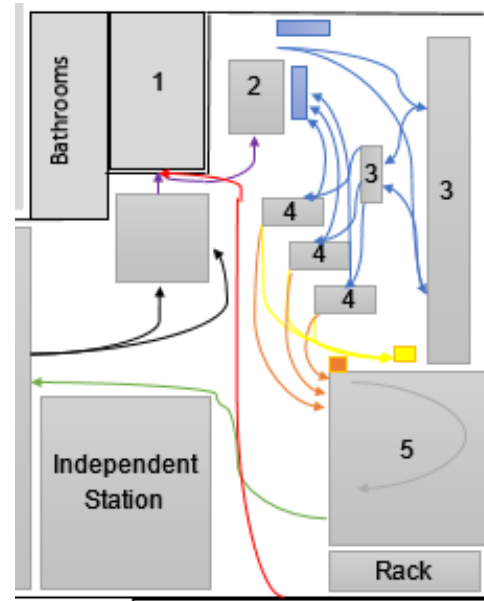


Figure 14: Layout 1 Flow Diagram

11.2.3 Graph Evaluation

There are 23 arcs connecting all workstation nodes in the most logical manner for this layout. The graph is displayed in Fig. 15. The arc weight was calculated and all the non-zero arc weights is summarised in table 10. Thus, layout one obtained an 890 arc score.

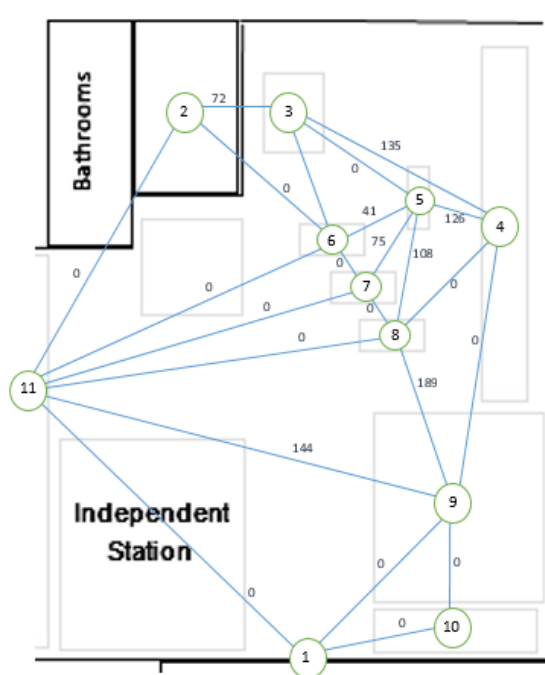


Figure 15: Adjacency Graph of Layout 1

Table 10: Arc Score of Layout 1

Arc	Weight
2-3	72
3-4	135
4-5	126
5-6	41
5-7	75
5-8	108
8-9	189
9-11	144
Total	890

11.3 Layout Two

11.3.1 Physical Evaluation

As mentioned in the short description of layout two, the main initiative with the designing of this layout was to separate workstation five into its individual internal operations, namely the weighing of semi-packaged bags, sealing of those plastic bags and finally packaging these completed bags into boxes for further transportation purposes. The purpose for this decision was to possibly create more space on the facility floor for movements to take place with more ease. In doing so workstation four could also be relocated to the space located next to the ovens. This made a wider circular path possible on which the trolley operator can manoeuvre the trolleys between workstation two, the ovens, the cooling area and workstation four.

Another improvement made possible by relocating workstation four is that the distance that crates have to travel between workstation four and the first part of workstation five been reduced to an almost minimum distance, almost eliminating the requirement for workers at workstation four to walk and move the crate to workstation five. On the other hand, this relocation will cause the trolley operator to travel over a longer distance than originally required, but with less obstructions in its path.

Concerns regarding this layout is firstly the packaging rack which is now located next to the independent rusk station, narrowing the isle space in which the packaging trolley and the forklift must travel. Even though there is enough isle space in the design for their movements, if this design is implemented that isle could possibly become cluttered with boxes and or other packaging materials if a neat work environment is not sustained during operation.

This can be the result of another possible problem resulting from this layout due to the location of the third part of workstation five. This area is provided for the temporary storage of boxes before they are taken to the finished goods storage. It can become the source of an untidy work environment, if these boxes are carelessly placed anywhere on the facility floor instead of being packed neatly with in the situated area. Lastly the implementation of this layout might take a bit more effort than layout one and three due to the separation of workstation five.

11.3.2 Flow Evaluation

The structure of this layout created an almost U-type line flow between workstations two, three, four, and five or more prominently between workstations two, three, four, and two again. It was structured this way in an effort to once again separate different material flow paths as much as possible. The flow diagram in Fig. 16 on the next page, shows the long flow paths of the trolley operator as well as the shortened flow path of crates between workstation four and five. It is also indicated on the diagram that crates will now have to be moved between workstation five's three parts, creating extra flow paths rather than combining them. Again the raw material trolley's path crosses multiple other paths but in this layout the backtracking path of crates filled with unbaked cookies back to the ovens crosses with the baking trolleys flow path. Fortunately, this also only happens about once per shift.

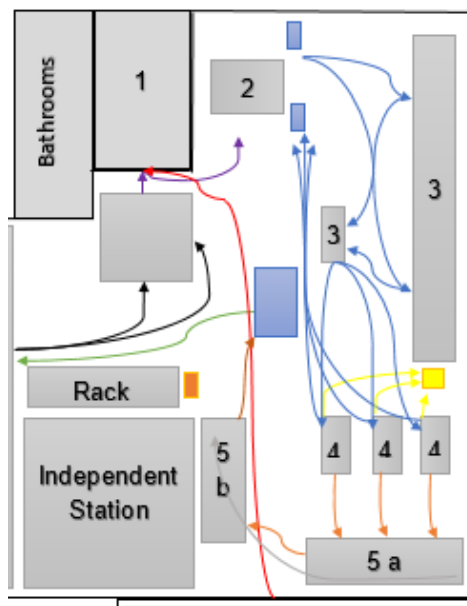


Figure 16 : Layout 2 Flow Diagram

11.3.3 Graph Evaluation

Layout three consist of 29 arcs connecting all workstation nodes in the most logical manner for this layout. The graph is displayed in Fig. 17. The arc weight was calculated and all the non-zero arc weights is summarised in table 11. Thus, layout two obtained a 905 arc score. This is already a higher score than layout one.

Table 11: Arc Score of Layout 2

Arc	Weight
2-3	72
3-4	135
4-5	126
5-6	41
5-7	75
5-8	108
6-9	72
7-9	87
8-9	189
Total	905

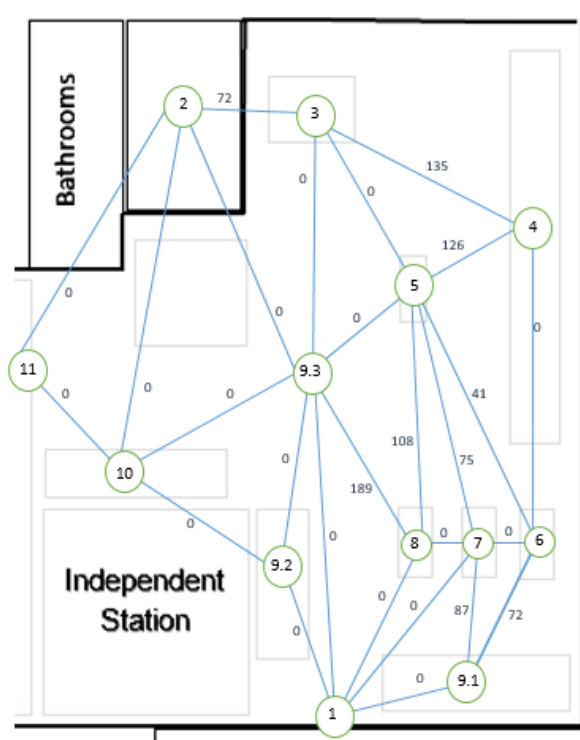


Figure 17: Adjacency Graph of Layout 2

11.4 Layout Three

11.4.1 Physical Evaluation

The design of layout three is in many ways similar to that of layout one, due to the fact that in layout one workstation four was originally grouped in such a way that the tables stood next to each other in a parallel and rectangular manner, where after they were moved to stand parallel to each other in a diagonal line like in the design of layout three. This was done because the original structure of layout one's workstation four, would have made it difficult for workers at workstation four to move their crates past each other. In this layout however workstation four is rotated 90° to the left such that the output point of workstation four is closest to the input point of workstation five, making it an improvement on the design for layout one.

Because workstation four is once again located almost in the middle of the facility floor, the cooling area was moved to its original location to create space for the baking trolley's movements. Also workstation four's location separates the different material paths completely isolating the space in which the baking trolley travels.

Where the manoeuvring of the forklift in layout one would have intercepted some difficulties as discussed, in layout three this constraint has been avoided. This is because of the direction of the diagonal line in which the workstation four tables are placed, making it possible for the forklift to reverse, turn around and move forward to the outside of the building in the case that it has to transport ingredients to the deeper side of the ingredient storage space. The only blockage that can result from this layout is at workstation two where trolleys wait in front of and behind the workstation. Because workstation two is located in the corner and the cooling area almost blocking it in from its output point, this can cause difficulties retrieving the trolleys from workstation two, thus slowing down the process.

11.4.2 Flow Evaluation

As a result of workstation four splitting the main production operations, it created a clear separation of different material flows, with only the trolley having to be move around on the one side and crates being moved on the other. Also the location of workstation four forms a straight line flow of work-in-progress products as it is one of the middle operations in the production process. In other words, and this can be clearly seen in the flow diagram in Fig. 18, work-in-progress products basically flows straight from the cooling area through workstation four to workstation five, thus almost combining different flows into a singular path.

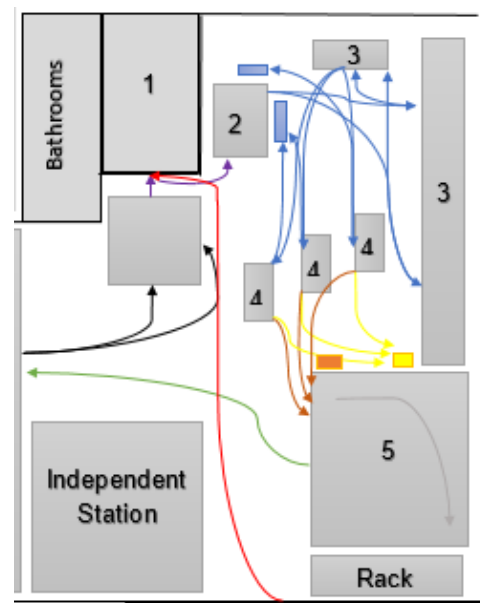


Figure 18: Layout 3 Flow Diagram

11.4.3 Graph Evaluation

There are 22 arcs connecting all workstation nodes in the most logical manner considered for this layout. The graph is displayed in Fig. 19, where in table 12 the arc weight was calculated and all the non-zero arc weights are summarised. Thus, layout three obtained an 825 arc score, the lowest score thus far, despite its improvements on layout one. This is probably due to the cooling area being located in its original position, prohibiting barriers to be formed between number 3 and 4, and also number 5 with 6,7, and 8 as in layout one.

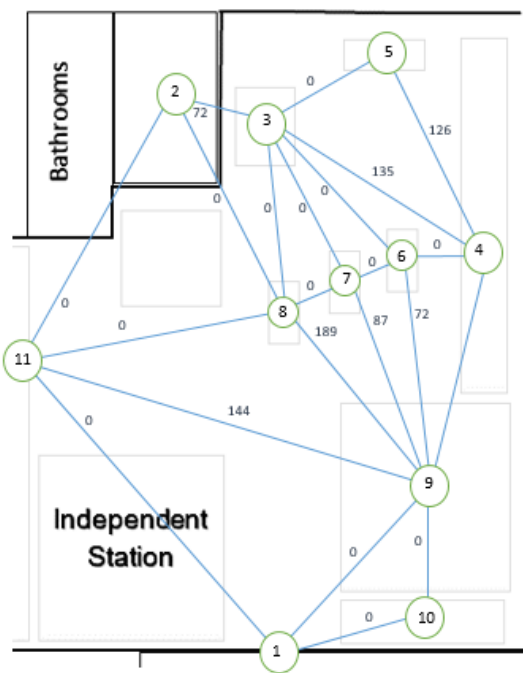


Table 12: Arc Score of Layout 3

Arc	Weight
2-3	72
3-4	135
4-5	126
6-9	72
7-9	87
8-9	189
9-11	144
Total	825

Figure 19: Adjacency Graph of Layout 3

11.5 Layout Four

11.5.1 Physical Evaluation

The design for layout four was done last and incorporated the most changes from the original layout in comparison to the other layout alternatives. One of the most prominent changes was the relocation of the independent rusk station, which is not a part of the normal production process. It switched positions with the original location of workstation five in an attempt to shorten the distance between the last operation in the production process and the finished good storage area.

With this design, management must consider decreasing the amount of floor space the independent rusk station occupies as it will be necessary to fit more or less into the space of workstation five. It is possible that with this implementation the rusk station will not be able to produce as much rusks as it has in the past, within a certain time frame. The station is less frequently used for production and the reduction in size thereof may not have a negative effect on the overall supply of demand.

Also in this design the temporary ingredient storage was moved deeper into the facility taking the position of workstation two in all the other layout designs. Thus, workstation two was moved to the original location of the ingredient storage. This was done as to bring workstation two and four closer to each other in an attempt to minimize the total distance travelled by the baking trolley operator. Workstation four is now also placed directly next to workstation five. The relocation of these three functional positions creates sufficient space for the baking trolley operator to manoeuvre the trolleys with absolute minimal obstacles in his path.

The position and direction of the workstation four tables is structured in such a way that it completely alters the way material is moved between workstation four and five. The table on which workers weigh the plastic packaging with scales, will be open and empty underneath, thus making it possible for crates to be pushed or slid underneath the table from workstation four to workstation five. By implementing this alternative route, it completely eliminates the distance normally travelled by workers between these two stations. Lastly the cooling area is once again positioned diagonally between the ovens and workstation four, thus shorting the path in this part of the process. The entire floor space used for the flow of production has been made smaller due to the specific positioning of the workstations.

The only potential for clutter to accumulate within this layout is with the trolleys waiting at workstation two. Baking trolleys are brought to the output end of workstation two, where it is used by the worker working there, whom can possibly cause an obstruction in the isle behind her by carelessly placing the trolley in the isle once she is finished with it. This can then disrupt movements that has a flow path through that isle.

11.5.2 Flow Evaluation

The flow diagram for this layout design in Fig. 20, clearly shows that the paths travelled by the trolley operator has been reduced as well as those for the crates moved between workstation four and five and lastly the path that the packaging trolley follows. The backtracking paths for crates with underdone cookies have been lengthened somewhat with the reduction of the other crate paths. Once again this will not cause a real problem as this path is followed very seldomly.

It can also be observed from the flow diagram of this layout that the path of flow of the raw materials trolley crosses more of the other flow paths than in any of the other layout alternatives. Despite that fact, it follows a simple straight line flow making it easy to avoid other material movements on other paths if necessary by simply stopping.

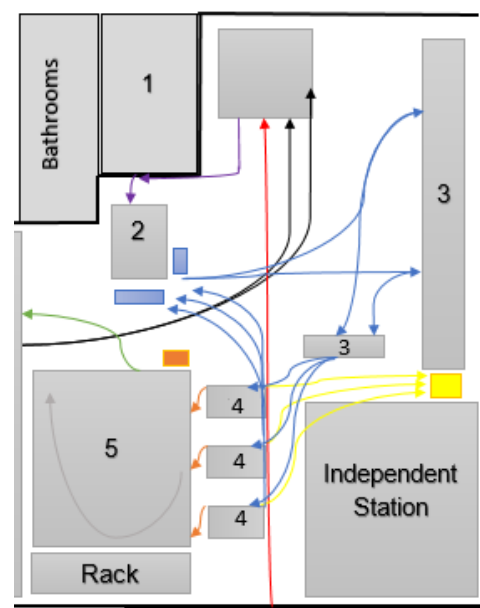


Figure 20: Layout 4 Flow Diagram

11.5.3 Graph Evaluation

There are 20 arcs connecting all workstation nodes in the most logical manner for this layout. The graph is displayed in Fig. 21. The arc weight was calculated and all the non-zero arc weights are summarised in table 13. Layout four, which incorporated the most changes from the original layout, obtained an arc weight score of 986, giving it the highest score amongst all the alternatives.

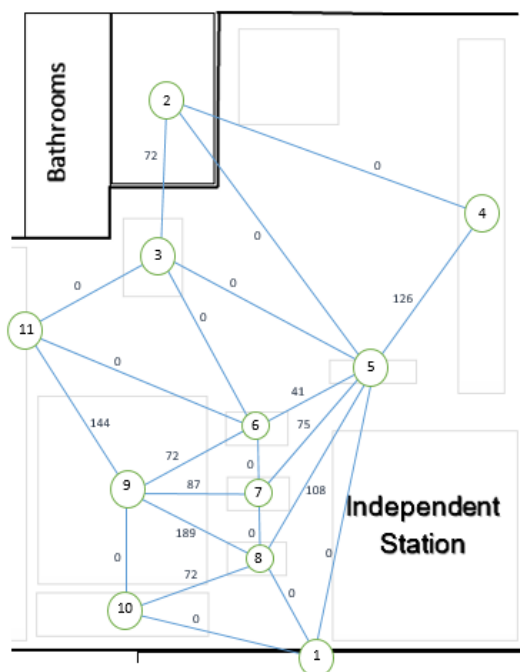


Table 13: Arc Score of Layout 4

Arc	Weight
2-3	72
4-5	126
5-6	41
5-7	75
5-8	108
6-9	72
7-9	87
8-9	189
8-10	72
9-11	144
Total	986

Figure 21: Adjacency Graph of Layout 4

11.6 Solution Selection: Layout Alternative Four

Based on the evaluation results discussed above, a decision had to be made on which layout alternative represents the best solution for this project. Taking into consideration all the aspects discussed, it was concluded that layout four would represent the best solution for the problem at hand. There are multiple reasons for selecting the layout that included the most drastic changes which turned out to be a very good thing.

First of all, the area over which the main production steps takes place has been reduced, resulting in reduced distances travelled and simplified flows for the different material paths. Even though the space used by the most important production movements have been reduced in size, space was not wasted as the remaining space was used for the temporary ingredient storage. Also despite the fact that the temporary storage location causes a longer distance for the forklift and raw materials trolley to travel, their paths have sufficient space in which they can easily manoeuvre without any obstacles or causing major disruptions to the process. A last physical determining factor for deciding on layout four is the fact that the movement between workstation four and five has almost been completely eliminated through the innovative manner of moving materials between these two stations.

All of these physical improvements on layout four is lastly, strongly supported by the Graph-Based Method that was used as evaluation criteria. Layout four's planar-adjacency graph and its arc weight score of 986 clearly shows that it has a path reduction advantage over all the other alternatives. This made it clear that layout four represents the most improved layout from all the alternative layouts.

12. Solution Validation

In the problem statement of this document it was made clear that if the company wishes to be able to increase their supply to meet the expected higher demand from an expanding client base which is to increase over the next year or so, they would have to increase their throughput rate. The identified way to do so was to improve the facility layout of the Mr. Biscuit factory for their cookie production process. The aim is to design an alternative layout that will reduce or eliminate unnecessary movements, improve the flow of the facility through better positioning of workstations and thus to eliminate other wastes such as wasted time.

Fig. 22 below shows the two flow analysis diagrams of firstly the current flow within the Mr. Biscuit facility and then the flow that will be produced if layout four is implemented. These two diagrams make it visually clear that layout four produces a better flow within the factory. Positioning of workstations in the current layout causes a clutter of flows between different material movement paths with multiple crossovers between flow paths causing obstacles for every step in the production line. Whereas the flows in layout four are structured to simplify movements by combining flow paths and reducing the distance materials have to be moved through the facility.

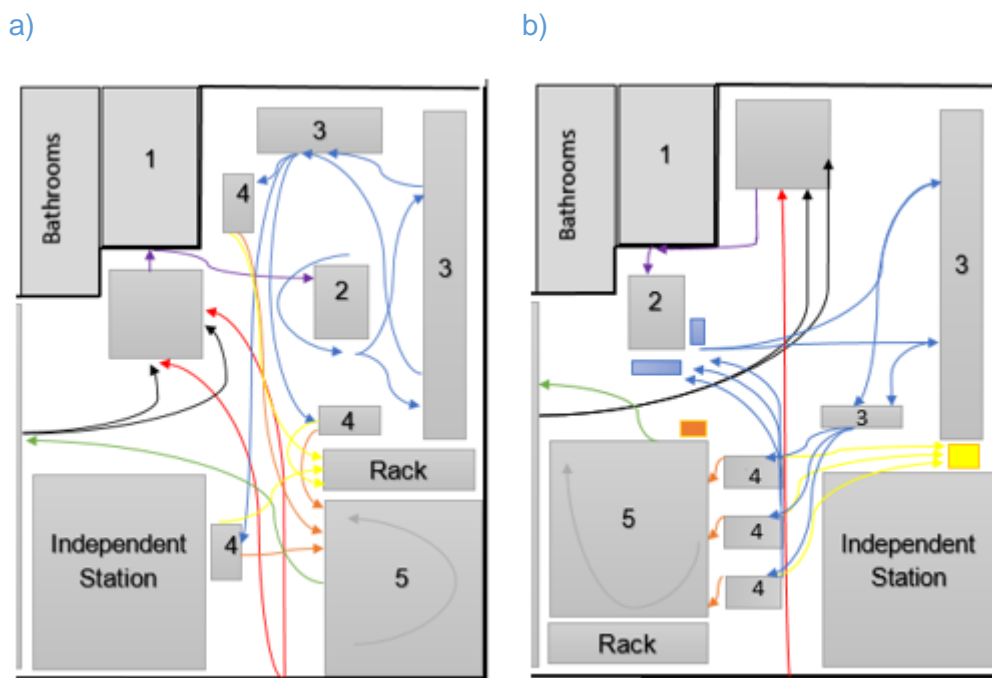


Figure 22: a) Flow Diagram of Current Layout b) Flow Diagram of Improved Layout

Another means to validate that the design of layout four is an improvement on the current facility layout is to evaluate the current facility layout through the Graph-Based Method used as criteria to evaluate the alternative layout options. The results of this evaluation is shown in Fig. 23 and table 14. The current layout of the facility scored an arc weight score of only 758, making it the layout with the lowest score amongst all the layout alternatives, especially in comparison to layout four's score of 986. This does mean that any of the layout alternatives would have been an improvement to the current layout, but according to the Graph-Based Method, layout four would result in the best improvement.

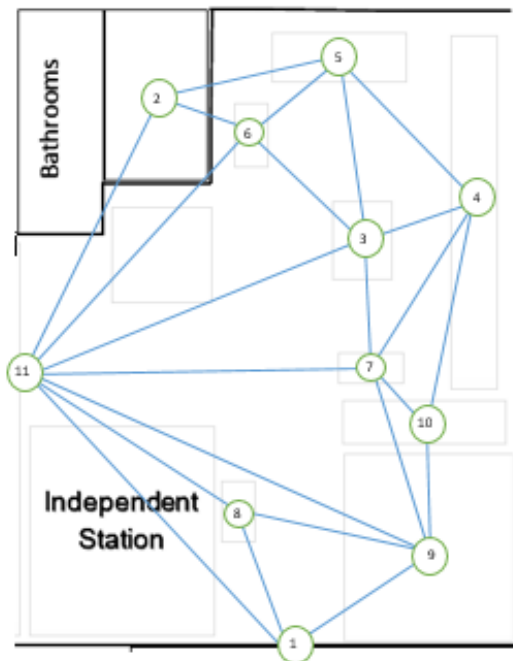


Table 14: Arc Score of Current Layout

Arc	Weight
3-4	135
4-5	126
5-6	41
7-9	87
7-10	36
8-9	189
9-11	144
Total	758

Figure 23: Adjacency Graph of Current Layout

It must be noted that if this layout four is accepted as a solution by the Mr. Biscuit management, they would have to reduce the area on which the independent rusk station is currently operating on. The decision to reduce this area during the design of layout four was validated by the fact that during one of the meetings it was discussed that demand for rusks fluctuates during the year and recently production of rusks have been reduced due to reduction in demand thereof. Not only was this discussed but during numerous visits to the factory it was clear that the rusk station was idle most of the time. It would thus not have a significant negative impact on the factory if this space was reduced by eliminating one or two of the special ovens used for the rusks for example.

Another possible concern that need not be one, is the fact that space might seem limited for movement for workers at workstation four, because workstation four is so close to workstation five. During the design of layout four enough space was provided for these workers to perform activities. According to the space requirements in table 8 in this document a person requires at least $1.5 m^2$ area of space where they stand or sit, whereas the space available for workers between workstation four and five about $2 m^2$, providing them with sufficient space to do their job comfortably.

This layout will be proposed to the management team of the Mr. Biscuit factory as it seems to have fulfilled the aims set out in the requirement to design an improved layout for the facility. The design of layout alternative four has proven to be an improvement on the current facility layout in terms of the structuring of workstations, the flow of material paths and the potential reduction of resulting wastes. It is an innovative design that poses a valid solution which will result in a more efficient production process as required in the future.

13. Proposed Implementation

The implementation of layout four can be accomplished with the labour and equipment already available to the factory and is estimated to take about the time of one daytime working shift, which is ten hours long. The long daytime shift occurs from Monday until Thursday, where Friday is sometimes used for cleaning and the packaging of finished products that were not finished on the Thursday. It will thus be suggested that a Friday is used as a day for the implementation of this layout, as this will not interrupt production, as production does not currently take place on Fridays. Also if in the case that all the relocating of workstations cannot be done during this ten-hour shift, workers will have to come in on the following Saturday to complete the process.

The steps that need to be followed to implement layout four in a constructive and orderly manner are set out in table 15 below. It is estimated that six employees, will be required to perform the implementation. Not all workers have to be involved in the implementation as they might not be required to perform activities making them equivalent to wasted labour and lost costs. If the employees involved in the implementation process, follow the steps set out efficiently, under senior supervision, the process can be completed within one daytime shift.

Table 15: Implementation Steps

Steps	Description
1	All trolleys, crates and any other material handling equipment has to be taken out of the facility.
2	The operational cutter for workstation two must be moved to be temporarily located in the aisle between the independent rusk station and workstation five. Whereas the non-operational cutter can be moved out of the facility through the finished goods storage area.
3	This also has to be done for the workstation four table that is originally placed next to the dough mixing room.
4	The forklift can now be used to systematically pick up and transport each pallet or container and place them in a straight line parallel next to the ovens, neatly as not to create obstructions.
5	The steel frame on which these pellets and containers were kept must now be moved to its new location in layout four. This will require at least five to six physically capable employees in order to carry the structure with care and stability.

6	Now once again the forklift can be used to repack the structure with the pallets and containers.
7	During step six, the operational cutter can now be placed in its new position opposite the mixing room.
8	All workstation four tables must now be moved to the back of the facility, positioned aside and just in front of the ingredient storage structure. This is done such that the switching process of workstation five and the independent rusk station can begin. This next part will take the most manual effort.
9	Orderly unplug and move all the rusk ovens into the finished goods storage area where a space for them had to be made available earlier. Do the same for the rusk drying containers and cutting tables.
10	The packaging rack next to workstation five has to be the first item to be moved into its new position so that it does not cause any disruptions while other workstation five equipment is being moved. Also one of the six individual racks that makes up this storage space will be taken out of the facility during this move.
11	Next the table with the plastic bag sealing machine will be moved to its new location.
12	The last table containing the scales will be moved into its new position, thus completing the move of workstation five.
13	Equipment from the independent rusk station can now be relocated to its new area of operation, excluding for example two ovens in order to reduce the space used by this workstation.
14	Lastly all the workstation four tables can now be positioned next to each other in their new location beside workstation five.
15	Finally, all crates can be brought in and positioned in their new fixed locations. As well as the baking trolleys that will make up the cooling area and be positioned in their new waiting spaces. Also the new table for workstation two can now be brought in and placed in its position, on which the cutting dies and other equipment used by workstation two can be placed.

The only prominent costs involved in this implementation process is the probability of an increased labour cost. According to the Basic Conditions of Employment Act for the Republic of South Africa (Labour.gov.za, 2016), any employees can work up to 45 hours a week excluding overtime, in which they are paid at their normal labour rate. It is also prohibited that any employee may work up to more than ten hours overtime a week. Thus in the Mr. Biscuit employee's case they work 40 hours a week up until Thursday where they can still work five hours on a Friday without overtime payment. This means that the six employees helping with the implementation of the new layout will have to be paid at an overtime rate of 1.5 times their normal salary for the overtime hours worked. The factory workers at Mr. Biscuit is paid an average salary of R5000 a month, this comes down to a labour rate of about R25 rand an hour. Thus for the five hours they will have to work overtime on Friday and the possibility of having to work up to five hours on the next Saturday will total to an additional R2250 labour cost for the implementation.

It is important that all the steps set for the movement and implementation process must be done with extreme care as to not cause damage to equipment that will result in extra unnecessary costs for management. After all the physical work included in the implementation is completed, the new flow system must be implemented with the facility workers. It is important for them to understand the new design and how to operate within this new process flow. Also it has to be made clear how to use the new fixed allocated spaces for crates and trolleys as to sustain a clean and tidy facility. Thus some production time will have to be put aside to explain and demonstrate the new system to all Mr. Biscuit employees. Once they understand the system, why it was implemented and how it will make their own lives and working conditions easier, they will be more positive and open to adapting to the changes implemented.

14. Recommendations

All of the recommendations for this project is interlinked with the 5S approach and waste eliminations as discusses as supplementary methods of improvement in this document. The implementation of these approaches are for the purpose to sustain a productive and efficient production process within Mr. Biscuits new improved facility layout. Recommendations directly linked to the 5S approach are discussed below.

1. Sort

The removal of unnecessary equipment and other facility objects have been realized with the implementation of the improved facility layout. If any object becomes redundant or non-operational, it must be removed to avoid the accumulation of clutter.

2. Set

The table provided at workstation four needs to be visually outlined and labelled on its surface of each of the cutting dies and any other equipment such that these utilities be placed back where they belong. Also the packaging rack next to workstation five must be clearly labelled on each rack to indicate each packaging item's position. This will reduce searching time for products of which the placement is currently unknown. Lastly and most importantly, all large production equipment must be set in their new locations. To prevent workers from possibly moving objects around and placing items such as tables and baking trolleys to or on incorrect locations, areas for workstations can be outlined on the facility floor by painting the area or at least outlining it. This approach forms part of visual management tactics.

3. Shine

Cleanliness is extremely important to a factory such as Mr. Biscuit's, as it is a factory that produces food. It is thus recommended that a small dustbin be placed at each workstation such that workers can immediately through any wastes such as fallen dough or broken cookies into these dustbins. Also a cleaning schedule can be drawn up to keep the factory as clean and tidy as possible. This is discussed in the next step.

4. Standardise and Sustain

These two aspects almost work together and integrates all the other S-aspects in order to keep the facility organized and free from wastes. The cleaning schedule is a method to make cleaning habits a standard activity in order to sustain it. A cleaning schedule can have a basic structure as provided in table 16 on the next page.

Table 16: Cleaning Schedule Example

Cleaning Activities	After Activity	Before Lunch	End of Shift	End of Week
Clean dies		X	X	
Empty dustbins			X	X
Throw out crumbs within workstation four table			X	X
Stack crates		X	X	
Pick up wastes from floor	X			
Put away unused packaging boxes				X
Wash floors				X
Etc.				

Other means to keep all operations functioning effectively and efficiently is by implementing waste elimination initiatives. Two means of eliminating wastes further are discussed below.

1. Kanban Implementation

A Kanban is a method used for managing the production of products that focusses specific attention to continuous delivery and thus not overburdening workers in the production process. The means in which a Kanban System is recommended for this project is in relation with the movement of crates in the factory. Currently empty crates are taken from a stack of crates in the factory and then used at workstation four to fill them with semi-packaged cookie bags which are then sent to workstation five. During this process, workers from workstation four waste their time by searching for the product specific packaging bags on the packaging racks without sometimes being sure which to take as they don't always know what type of cookies are waiting for them next.

A way in which to eliminate this wasted time is through the use of a Production Kanban, a physical visual card that will inform workstation four which packaging material to use next. Or an even better approach to this problem is that if one of the workers of workstation five takes the empty crates after the sealers are done with them and insert the next required packaging material for workstation four into the empty crates. The packaging bags will then act as the Kanban itself and completely eliminate the need for a workstation four operator to look for the packaging in any case after retrieving the empty crates from workstation five. For this to be realized, the next waste elimination initiative will also have to be implemented.

2. Mini Businesses

As mentioned in the development of supplementary methods for improvement, a Mini Business is a daily meeting, in the morning, between employees that usually work together, to establish a production plan for the day based on demand, and to discuss goals that needs to be achieved each day. Within this meeting, a schedule for what needs to be produced for the day will be drawn up. This schedule will also show the order in which the different types of cookies will be produced and how much of each kind. Everyone can write this schedule down and check off every batch throughout the day once they have completed their operation regarding that batch. By doing so workers will not have to waste time by asking every other worker during production what happens next and also how a worker at workstation five will know which packaging bags to put in the crates for workstation four. An example of such a schedule is provided in table 17. A template for such a schedule can also be provided to workers beforehand to make it easier for them.

Table 17: Production Schedule Example

Production schedule			
Type of Cookie	Number of Batches	Batch number	Batches Completed
Ginger	4	1	✓
		2	✓
		3	✓
		4	✓
Shortbread	2	1	✓
		2	✓
Chocolate	3	1	
		2	
		3	
Coconut	3	1	
		2	
		3	

By implementing all these simplistic operations that where now discussed and recommended, production operations will run a lot smoother and without complications or unnecessary stoppages. By eliminating these stoppages, a lot less time will be wasted and a much more productive process will be achieved.

15. Conclusion

A complete production process was initially required to determine any constraints within Mr. Biscuit's production facility and it became clear that a lot of unnecessary movement is currently taking place within the facility due to the unstructured layout of the facility. Each time unwanted movements take place, precious time and energy is wasted that could have been spent on the completion of production activities.

Facilities planning is an advanced industrial engineering tool to use for the improvement of any facility. From the literature study done in this document, Muther's Systematic Layout Planning (SLP) approach along with the Graph-Based Method was chosen to be applied in this project to formulate the necessary requirements for the layouts to be designed as well as the evaluation thereof. Additionally, the supplementary industrial improvement tools, namely the 5S approach along with waste elimination, is discussed to be applied in combination with facilities planning to improve the structure and working conditions of the facility.

After appropriate data was collected from the facility, the movement relationships and level of importance of those movements between workstations was formulated along with the space requirements for each workstation. Lastly the constraints regarding the facility and its implication on the project were explored.

The knowledge that was gathered within the first stages of the project was used together with some additional information, including additional space requirements and research regarding flows within facilities, specifically in connection with the Work Simplification Approach, was then applied to develop and design layout alternatives.

Four alternative layouts for the Mr. Biscuit facility were thus designed and then drawn up with the software program TurboCAD*16 Pro. Drawing these layouts on the program again provided insight into how the space was used and how it affected the flow patterns and aisle requirements around it. If a layout did not seem completely feasible, it was continually changed as necessary, thus making the designing process an iterative one.

These four alternative layouts were then described and evaluated in detail in terms of the flow patterns they created and also against the Graph-Based Method as criteria chosen for this project. At the end of the evaluation process, layout four was identified to be the best suited solution for the problem, even though all alternatives displayed different measures of improvements. Layout four meets all the objectives for this project, namely the reduction or elimination of unnecessary movements and an improved and simplified flow throughout the facility, realized through the better and logical placement and positioning of workstations.

A proposed implementation process is also provided as a means to implement the new chosen layout for the facility, with as much ease as possible and in as short a time as feasible. This project has the potential to implement even further improvements for the Mr. Biscuit facility with the incorporation of the 5S approach and waste elimination methods which is proposed under recommendations.

In conclusion to this facilities planning project, the final goal is to provide, as a deliverable to the Mr. Biscuit management, the best layout suited for this facility. Layout alternative four will be handed over to management with all its improvement aspects in the hopes that they will decide to accept and implement this improved layout into their facility for the purpose of obtaining a more productive and capable production system in the future.

16. References

1. Allen, J., Robinson, C. and Stewart, D. (2001). *Lean Manufacturing - A Plant Floor Guide*. Society of Manufacturing Engineers (SME), pp.262-264.
2. Educational Business Articles Blog: Stay in touch!. (2016). *7 wastes: the 7 deadly wastes to any business*. [online] Available at: <http://www.educational-business-articles.com/7-wastes/> [Accessed 30 Apr. 2016].
3. Gilbert, J. (2004). *Construction Office Design with Systematic Layout Planning*. [online] Winter Park, Florida: Crummer Graduate School of Business. Available at: https://www.pomsmeetings.org/confproceedings/002/poms_cd/browse%20this%20cd/papers/002-0563.pdf [Accessed 11 Apr. 2016].
4. Hiba, J. (1998). *Improving working conditions and productivity in the garment industry*. Geneva: International Labour Office
5. Hiregoudar, C. and B. Raghavenda, B. (2007). *Facility Planning and Layout Design : an Industrial Perspective*. Technical Publications Pune, pp.79-86.
6. Labour.gov.za. (2016). *Basic Guide to Overtime — Department of Labour*. [online] Available at: <http://www.labour.gov.za/DOL/legislation/acts/basic-guides/basic-guide-to-overtime> [Accessed 24 Aug. 2016].
7. Munro, R., Ramu, G. and Zrymiak, D. (2016). *Certified Six Sigma Green Belt Handbook*. 2nd ed. American Society for Quality (ASQ), p.355.
8. Petrarolo, D. (2012). Benchmarking Organisational Capability using The 20 Keys. *The South African Journal of Industrial Engineering*, 8(2).
9. Proera, (2015). *20 Keys management system*. [online] Available at: http://proera.md/consulting/consulting_services/20keys/index.html [Accessed 30 Apr. 2016]
10. Rufe,, P. (2016). *Fundamentals of Manufacturing*. 3rd ed. Society of Manufacturing Engineers (SME), pp.369,370.
11. Stevenson, William J. *Operations Management*. New York, N.Y.: McGraw-Hill/Irwin, 2012. Print
12. Time Sampling: Definition & Examples. (2003). [video] Available at: <http://study.com/academy/lesson/time-sampling-definition-examples.html> [Accessed 13 Mar. 2016]
13. Tompkin, J., White, J., Bozer, Y. and Tanchoco, J. (2010). *Facilities Planning*. 4th ed. United States of America: John Wiley & Sons, Inc, pp.297-302.
14. TurboCAD via IMSI Design. (2016). *TurboCAD Pro 2016*. [online] Available at: <https://www.turbocad.com/turbocad-windows/turbocad-pro-2016.html> [Accessed 27 Aug. 2016].
15. UNINOVE, (n.d.). *Improving the layout to enhance the process flow in small batches Weight Control Laboratory*. [online] UNINOVE. Available at: <https://www.pomsmeetings.org/confpapers/051/051-0148.pdf> [Accessed 11 Apr. 2016].
16. Zheng, L., Zhu, L., and Bai, L. (2013). A Simulation Analysis of Facility Layout Problems in Reconfigurable Manufacturing Systems. *Proceedings from the 2013 International Conference on Computer Sciences and Applications, China*
17. 20keysglobal.com (2016). *20keysofficial site*. [online] Available at: <http://www.20keysglobal.com/> [Accessed 30 Apr. 2016].

Appendix A

Department of Industrial & Systems Engineering Final Year Projects Identification and Responsibility of Project Sponsors


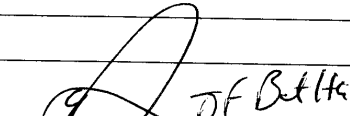
Final Year Projects may be published by the University of Pretoria on *UPSpace* and may thus be freely available on the Internet. These publications portray the quality of education at the University, but they have the potential of exposing sensitive company information. It is important that both students and company representatives or sponsors are aware of such implications.

Key responsibilities of Project Sponsors:

A project sponsor is the key contact person within the company. This person should thus be able to provide guidance to the student throughout the project. The sponsor is also very likely to gain from the success of the project. The project sponsor has the following important responsibilities:

1. Confirm his/her role as project sponsor, duly authorised by the company. Multiple sponsors can be appointed, but this is not advised. The duly completed form will be considered as acceptance of sponsor role.
2. Review and approve the Project Proposal, ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable from the company's perspective.
3. Review the Final Project Report (delivered during the second semester), ensuring that information is accurate and that the solution addresses the problems and/or design requirements of the defined project.
4. Acknowledges the intended publication of the Project Report on UP Space.
5. Ensures that any sensitive, confidential information or intellectual property of the company is not disclosed in the Final Project Report.

Project Sponsor Details:

Company:	MJ Biscuit t/a MC Biscuit
Project Description:	The Analysis and Productivity Improvement of Mr Biscuit's Production Process
Student Name:	Shani van Wyk
Student number:	13047371
Student Signature:	
Sponsor Name:	Jaco Botha
Designation:	Owner
E-mail:	Info @ mc Biscuit . cc . za
Tel No:	012 8031618
Cell No:	0843160114
Fax No:	086 726 8580
Sponsor Signature:	

Appendix B

Utilization Calculations

A day shift consists of nine working hours excluding break times. Thus the total number of minutes work time is:

9 hours x 60 minutes =540 Minutes

Workstation1:

$$\frac{\text{Task time} \times \text{number of batches}}{\text{shift time}} \times 100 = \frac{25 \text{ minutes} \times 16 \text{ batches}}{540 \text{ minutes}} = 74.07\%$$

Workstation 2:

$$\frac{\text{Task time} \times \text{number of batches}}{\text{shift time}} \times 100 = \frac{20 \text{ minutes} \times 16 \text{ batches}}{540 \text{ minutes}} = 59.26\%$$

Workstation 3 (ovens):

$$\frac{\text{Task time} \times \text{number of trolleys}}{\text{shift time}} \times 100 = \frac{20 \text{ minutes} \times 17 \text{ trolleys}}{540 \text{ minutes}} = 62.96\%$$

1 batch extra for the unbaked cookies separated at inspection.

Workstation 4 (one of them):

$$\frac{\text{Task time} \times \text{number of crates}}{\text{shift time}} \times 100 = \frac{10 \text{ minutes} \times 16 \text{ crates}}{540 \text{ minutes}} = 29.63\%$$

Workstation 5:

$$\frac{\text{Task time} \times \text{number of batches} \times \text{number of crates}}{\text{shift time}} \times 100 = \frac{20 \text{ minutes} \times 16 \text{ batches} \times 3 \text{ crates}}{540 \text{ minutes}} = 62.22\%$$

20 Keys

1. Cleaning and Organizing to make work easy
2. Rationalizing the System / Goal Alignment
3. Small Group Activities
4. Reducing Work-in-Process
5. Quick Changeover Technology
6. Kaizen of Operations (process value analysis and improvement)
7. Zero Monitor Manufacturing
8. Coupled Manufacturing
9. Maintaining Machines and Equipment
10. Time Control and Commitment
11. Quality Assurance
12. Developing Suppliers
13. Eliminating Wasteful Human Activities
14. Empowering Employees to make Improvements
15. Skill Versatility and Cross Training
16. Production Scheduling
17. Efficiency Control
18. Using Information Systems
19. Conserving Energy and Materials
20. Leading Technology / Site Technology



Figure 24: Diagram of the 20 Keys depicting the relations between the keys and the three main objectives thereof (Proera, 2015)

Appendix C

Space Requirements

Table 18: Aisle Allowance Estimates

If the Largest Load/Area is:	Aisle Allowance Percentage is:
Less than 6 ft^2	5-10
Between 6 and 12 ft^2	10-20
Between 12 and 18 ft^2	20-30
Greater than 18 ft^2	30-40

$$1 m^2 = 10.76 ft^2$$

Largest Material Handling Load: Packaging Trolley = 0.83 m^2 (Table 20)

$$\therefore 0.83 m^2 = 8.93 ft^2$$

\therefore Between 6 and 12 ft^2 giving a percentage of between 10% and 20%

\therefore For a more accurate percentage x :

$$\frac{x-10}{8.93-6} = \frac{20-10}{12-6}$$

$$\frac{x-10}{2.93} = 0.6$$

$$x = 11.79\%$$

$$x \cong 12\%$$

Table 19: Area calculations for Workstation Equipment

Workstation Equipment	Length	Width	Area (m^2)
Raw Materials Storage	14.4	10.8	155.52
Mixer (2 Dough Mixer)	-	-	14.14
Cutter	2.19	1.1	2.41
Ovens	13.64	2.41	32.87
Cooling Area	4.23	1.42	6
Workstation 4 A	2.96	1.14	3.35
Workstation 4 B	2.96	1.14	3.35
Workstation 4 C	2.96	1.14	3.35
Sealing and Final Packaging	7	6	42
Packaging Rack	6	1.41	8.46
Finished goods Storage	14.6	7.2	105.12

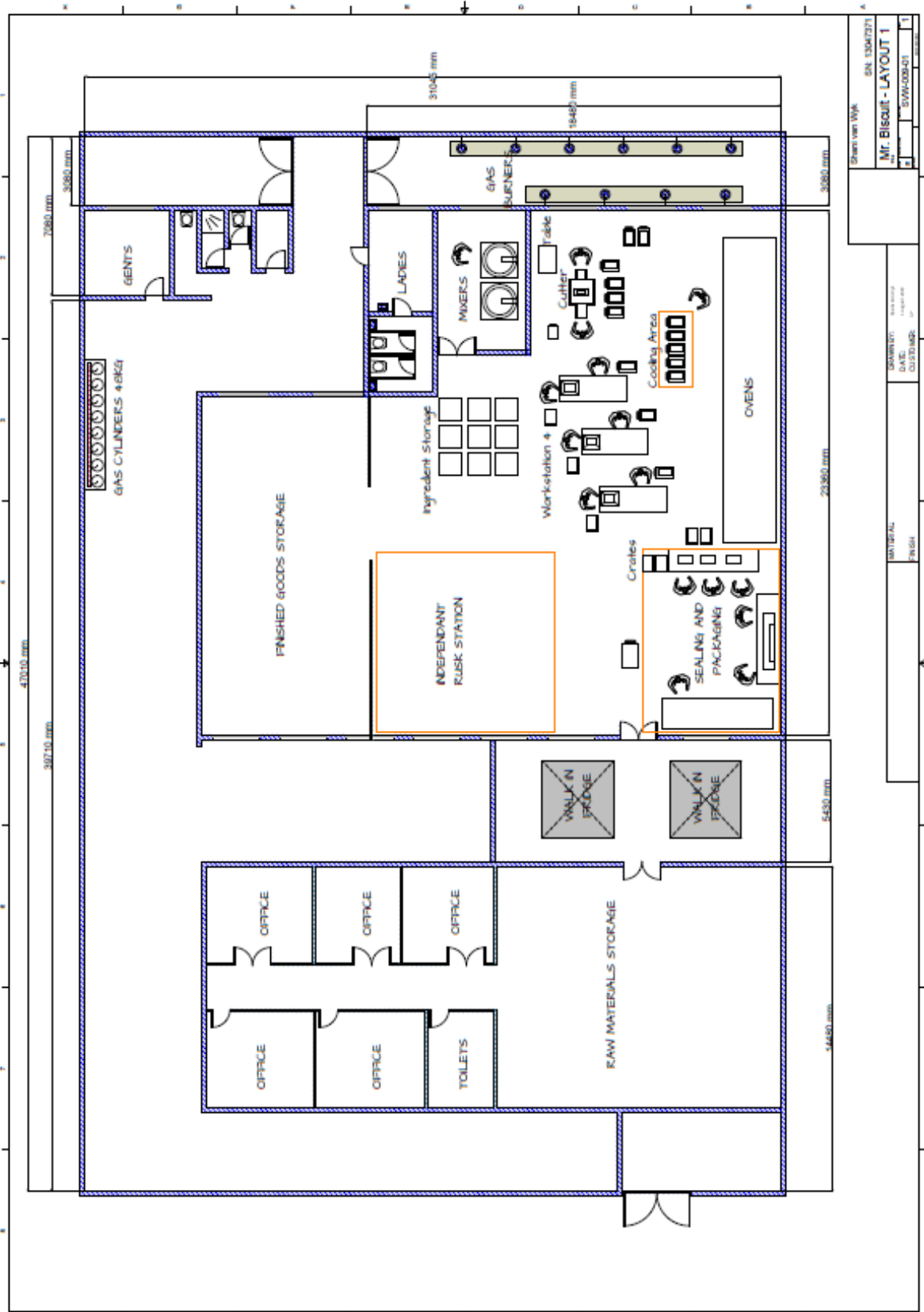
Table 20: Area Calculation of Workstation Materials

Workstation Materials	Length	Width	Area (m^2)
Raw Material Trolley	0.55	0.45	0.25
Dough Trolley	0.64	0.46	0.29
Biscuit Trolley	0.76	0.45	0.34
Crate	0.73	0.5	0.37
Packaging trolley	1.22	0.68	0.83

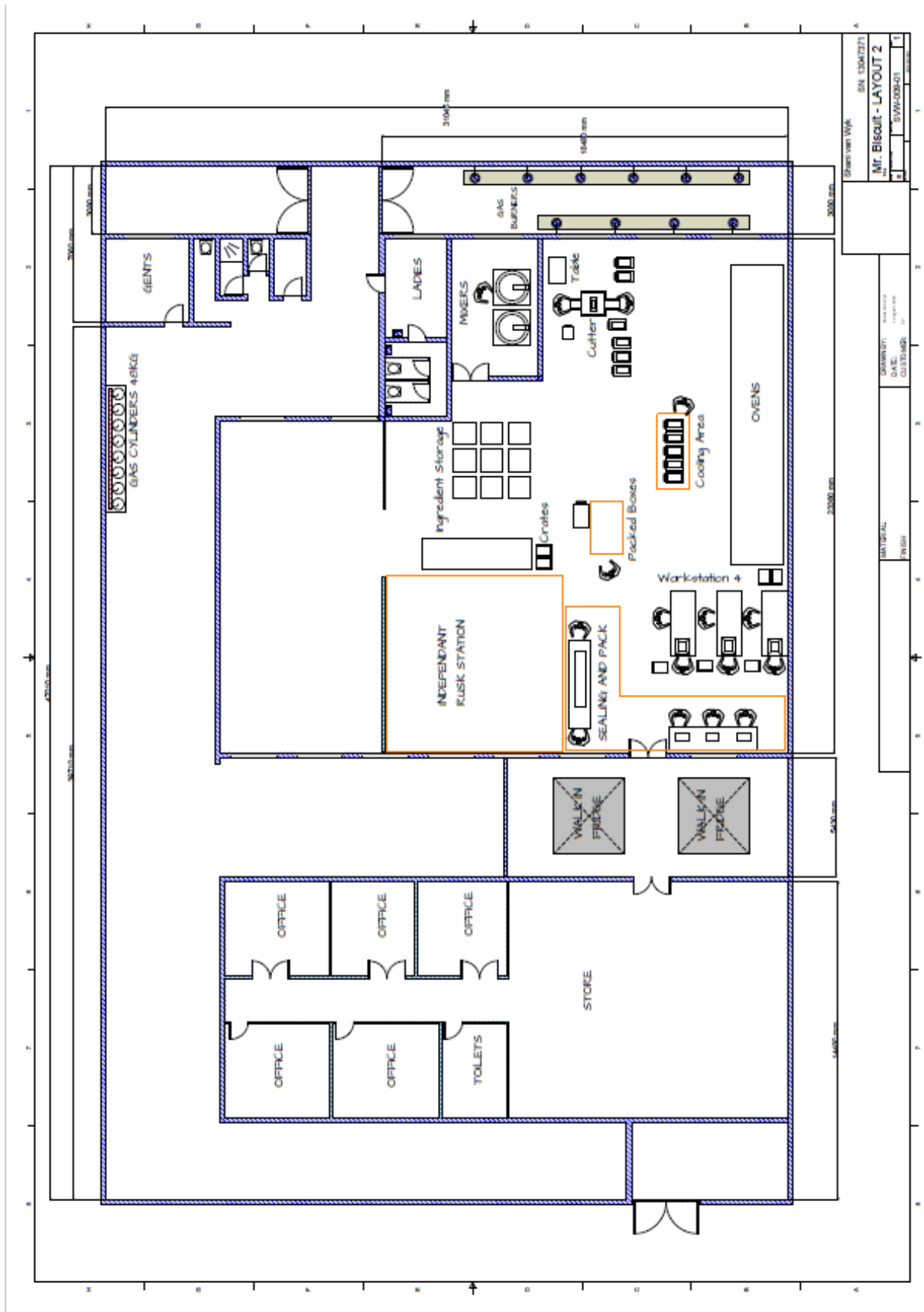
Appendix D

Layout Alternatives

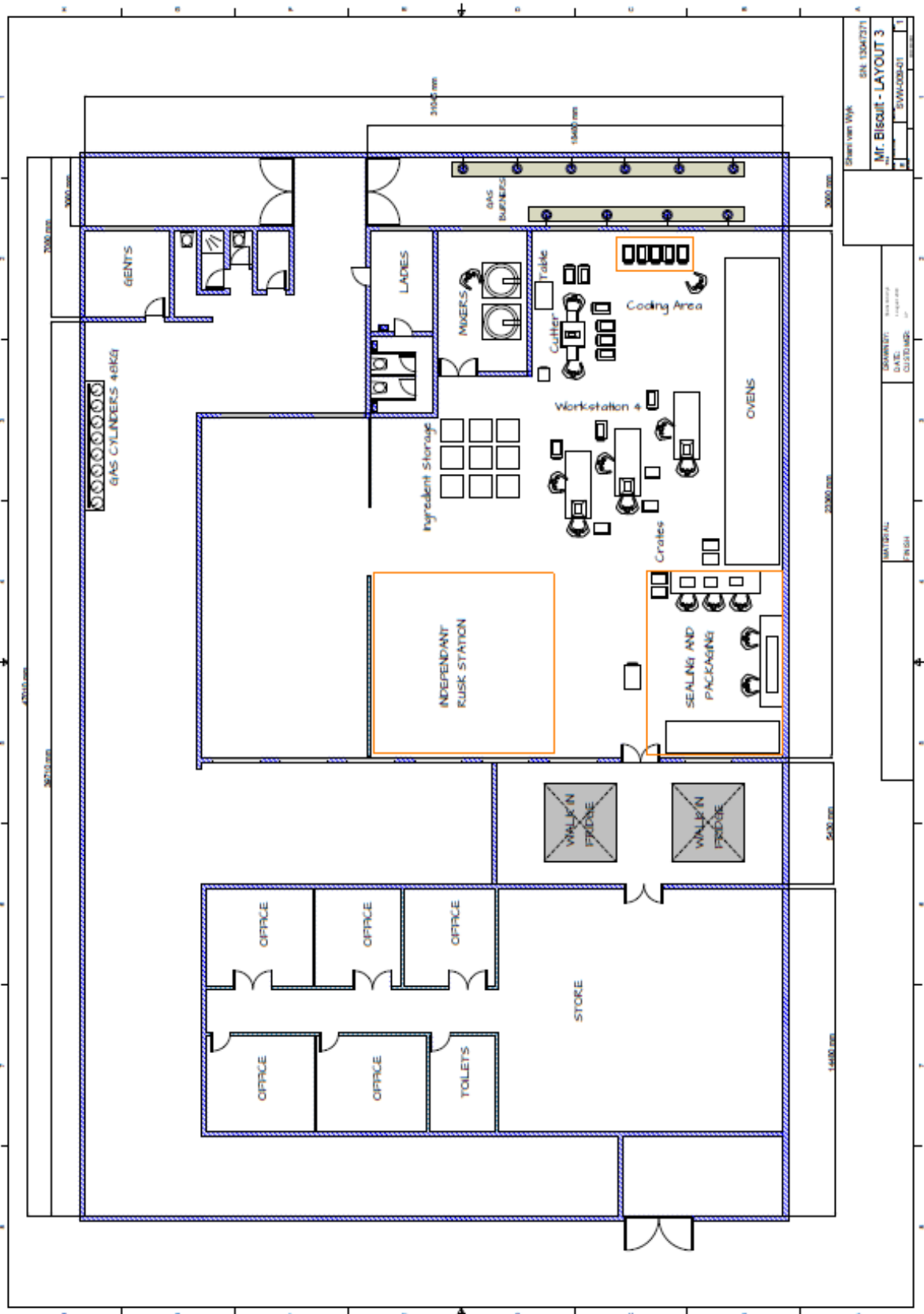
Layout One



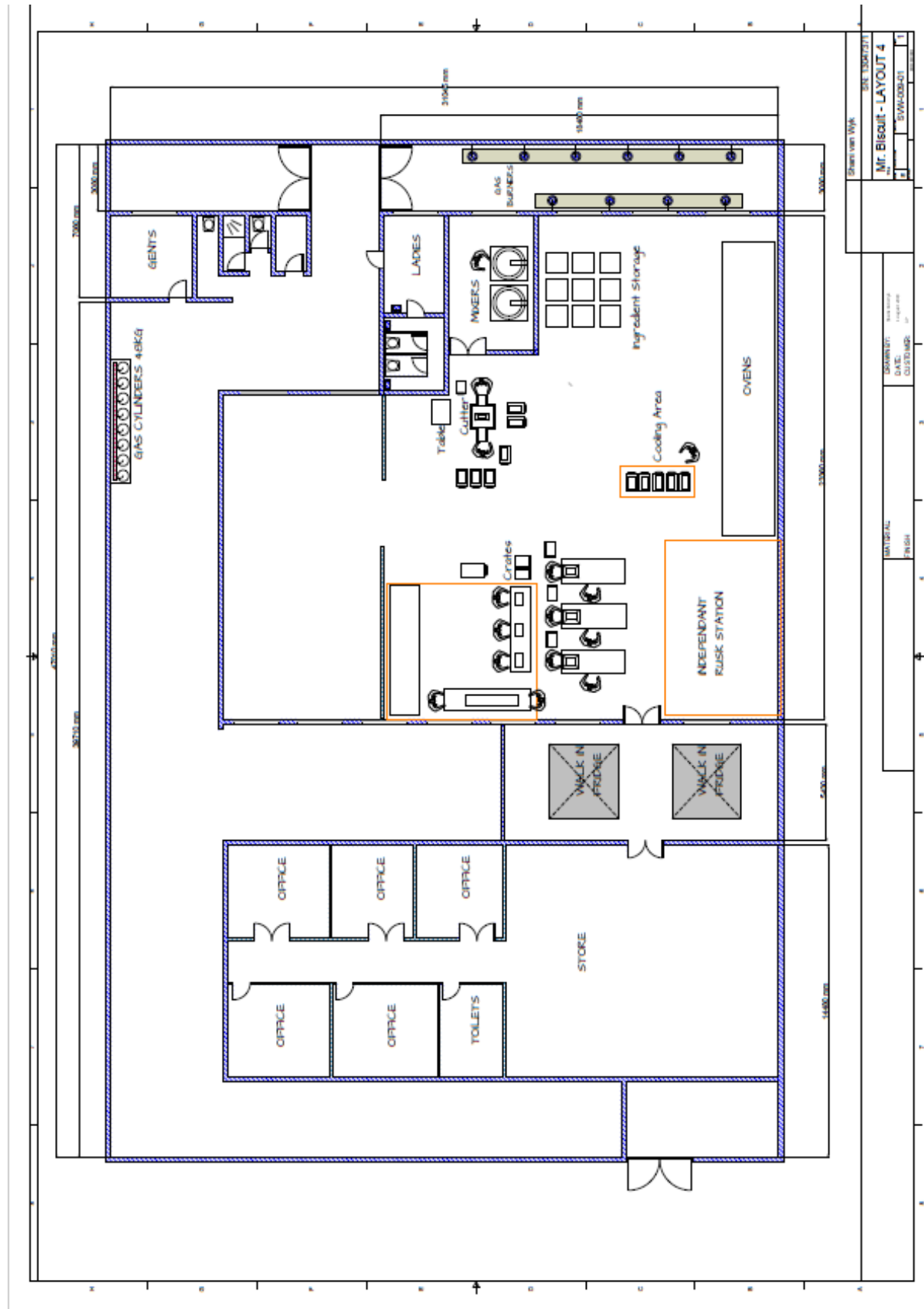
Layout Two



Layout Three



Layout Four

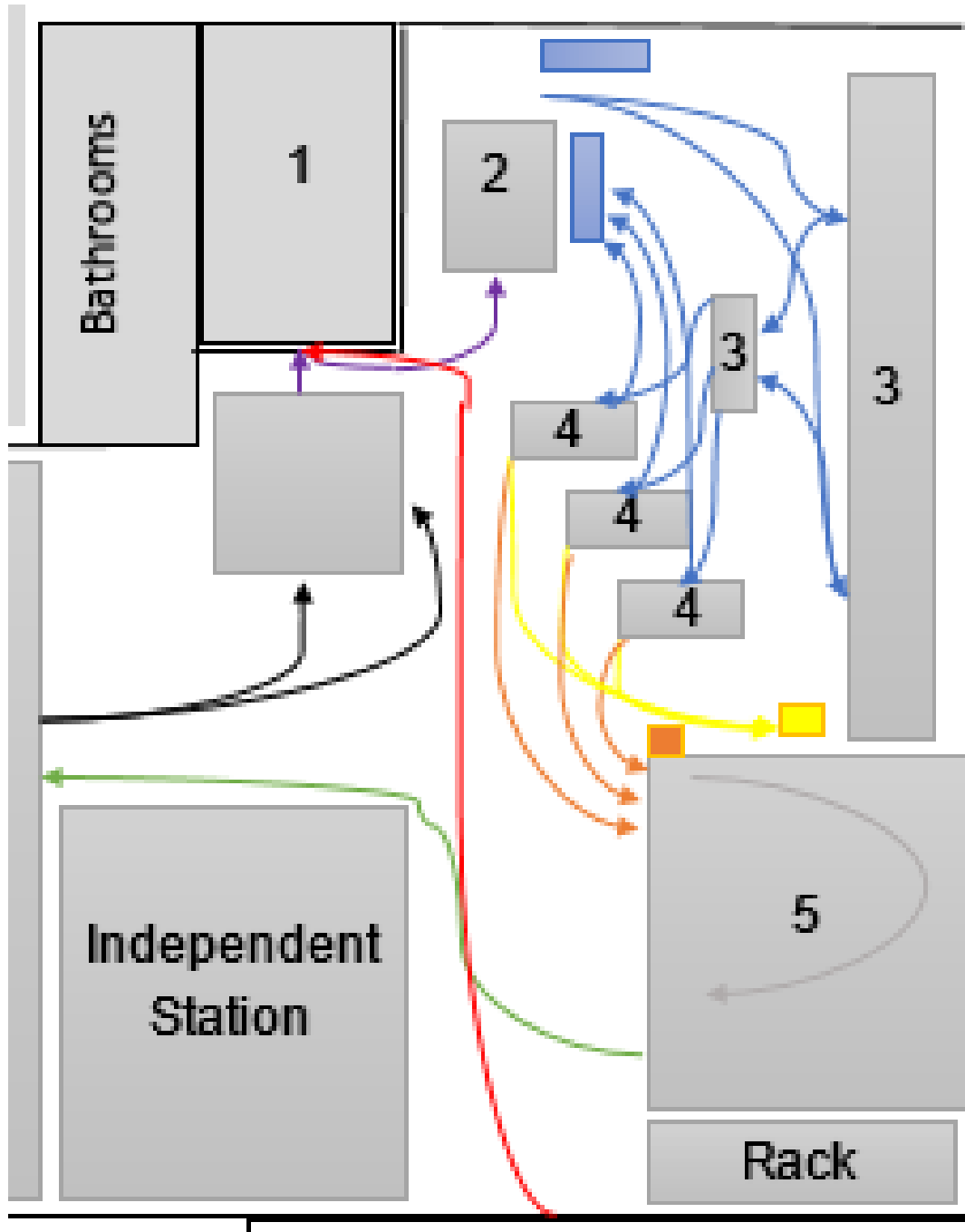


Appendix E

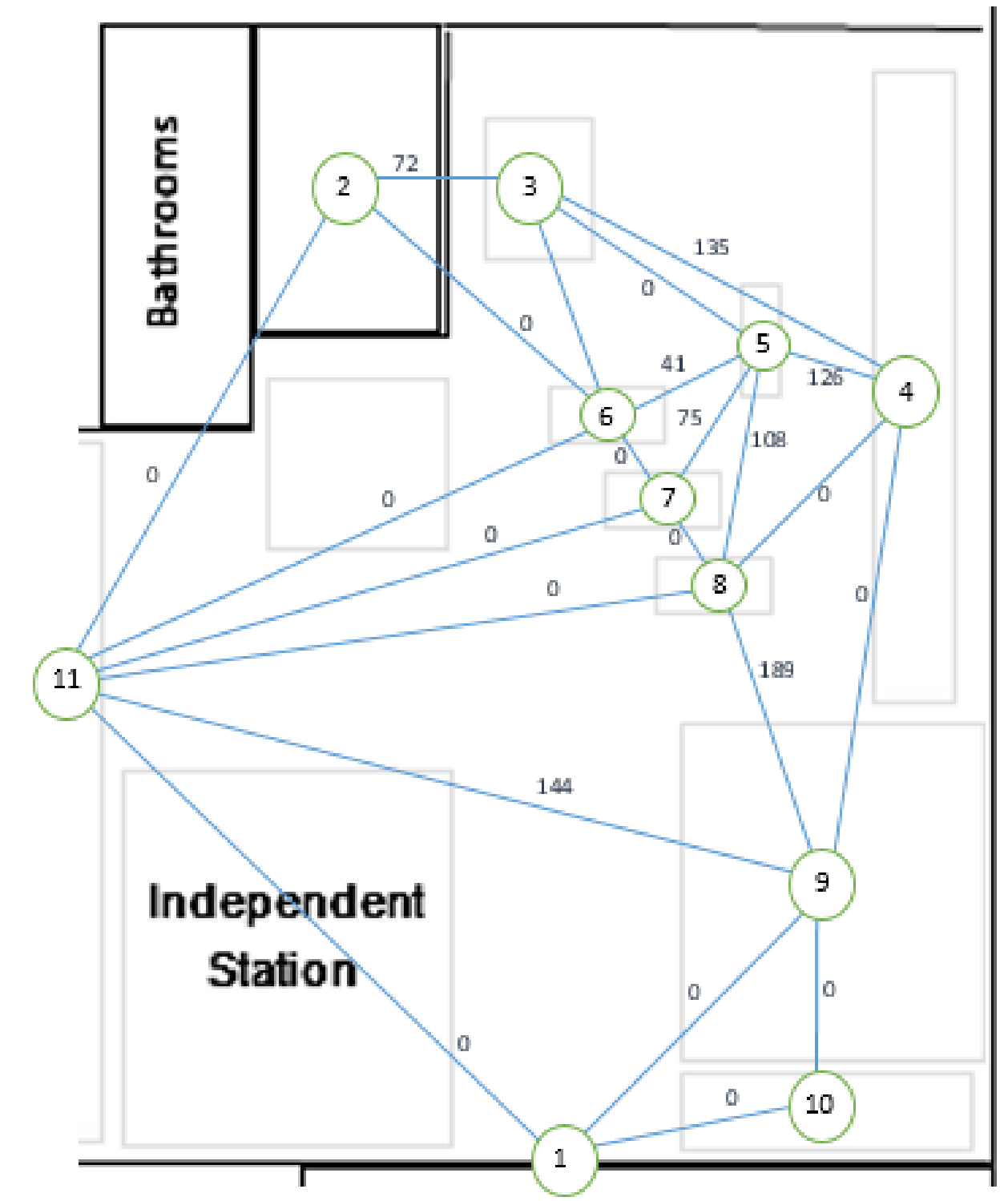
Flow Diagrams and Adjacency Graphs

Layout One

Flow Diagram:

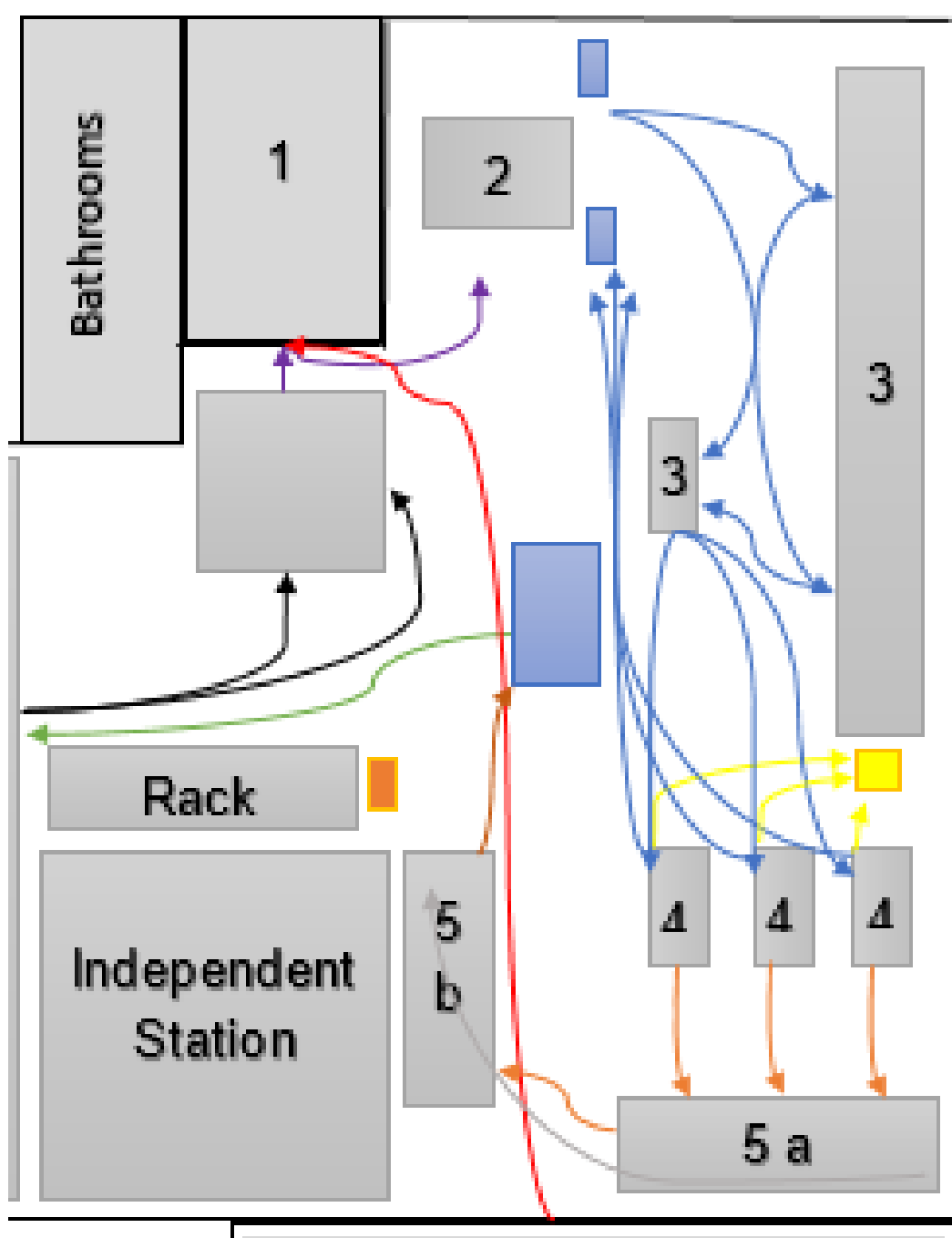


Adjacency Graph:

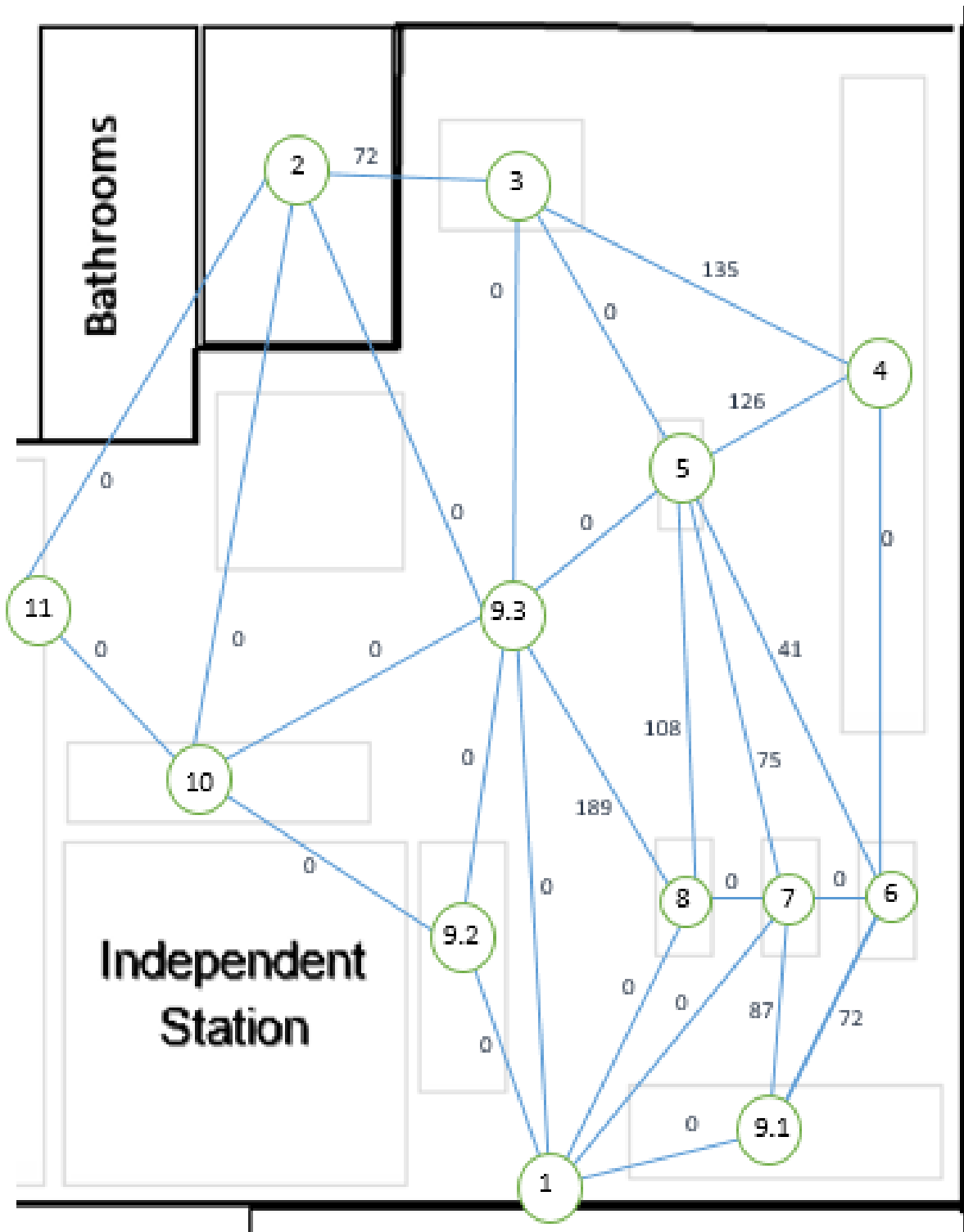


Layout Two

Flow Diagram:

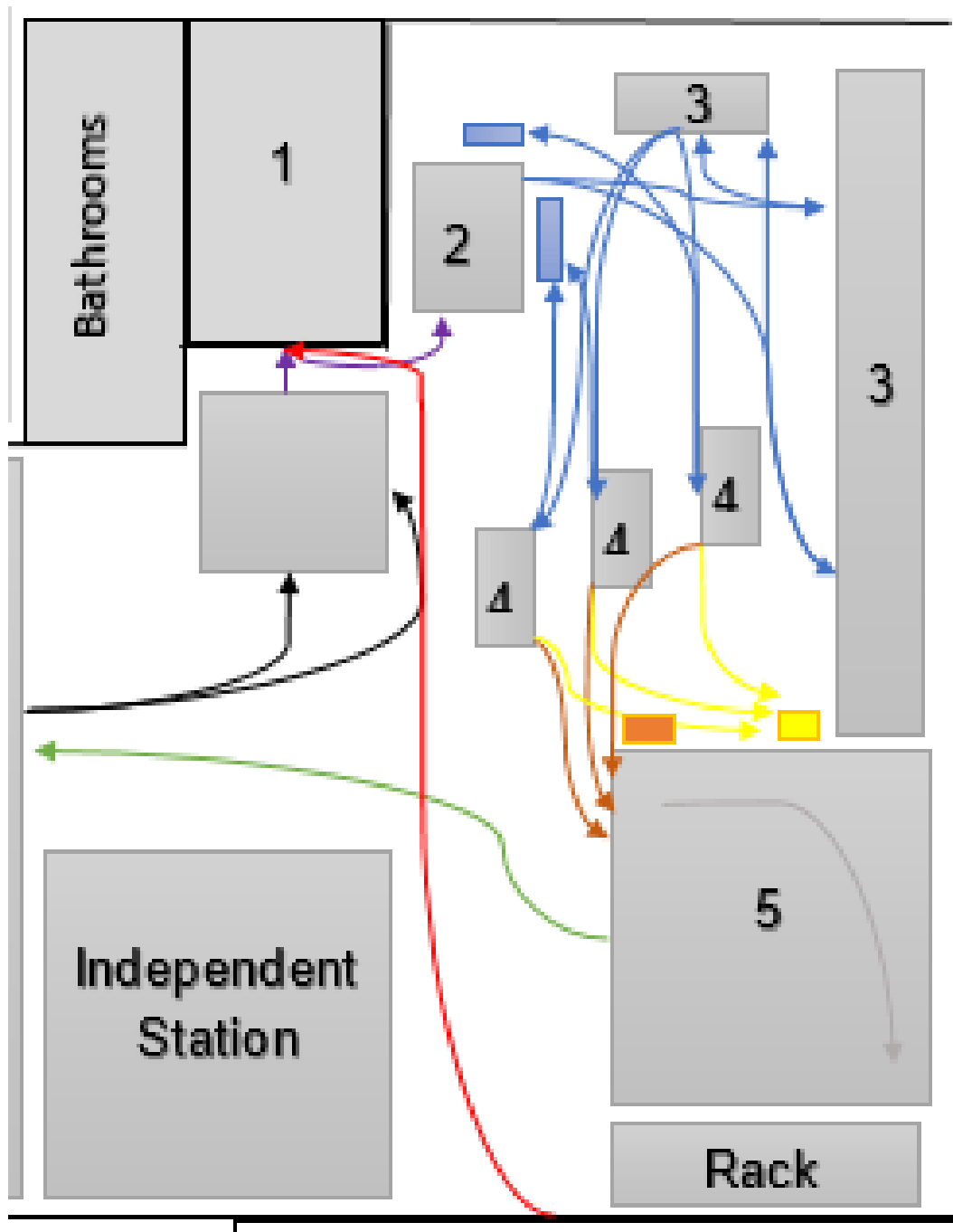


Adjacency Graph:

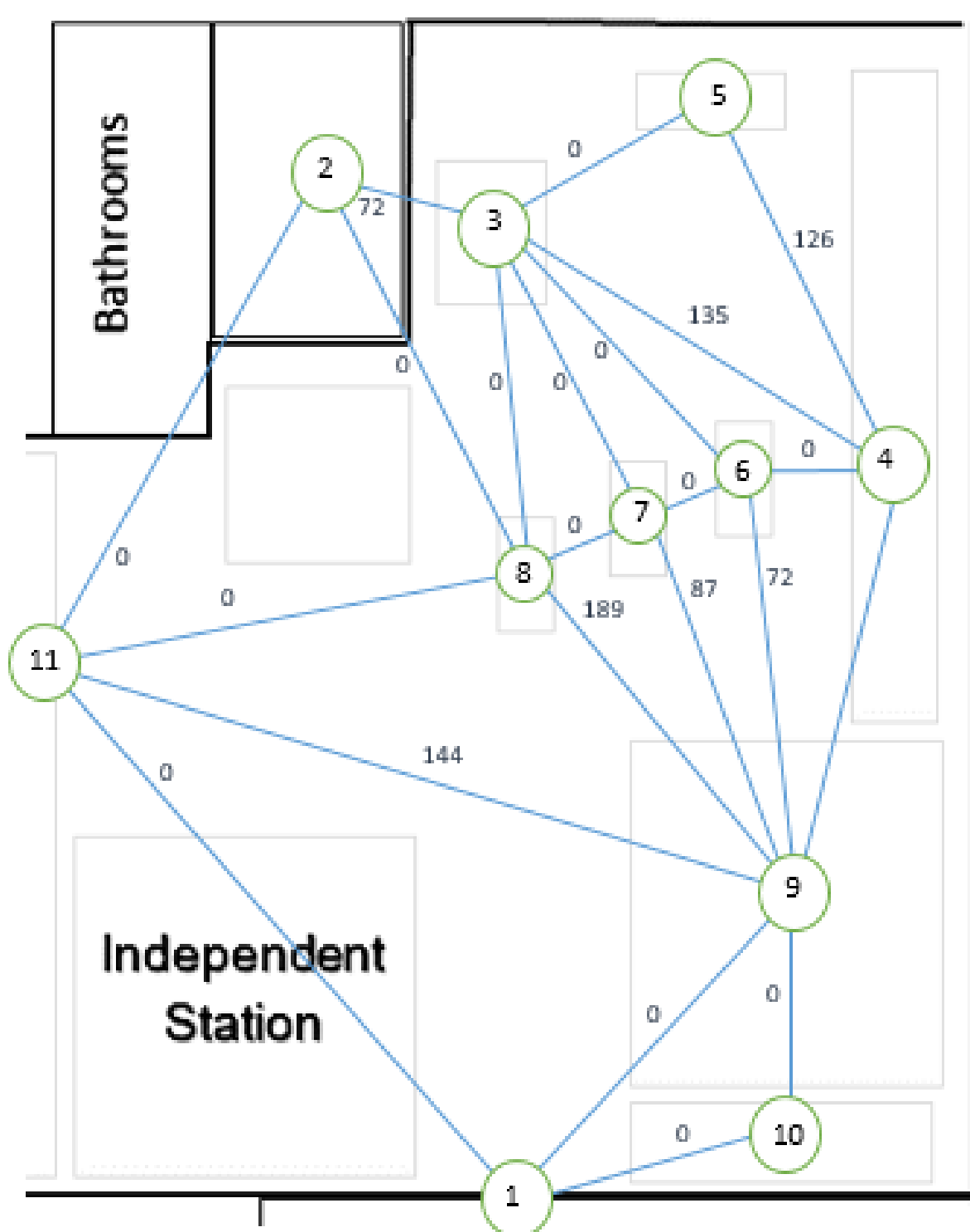


Layout Three

Flow Diagram:

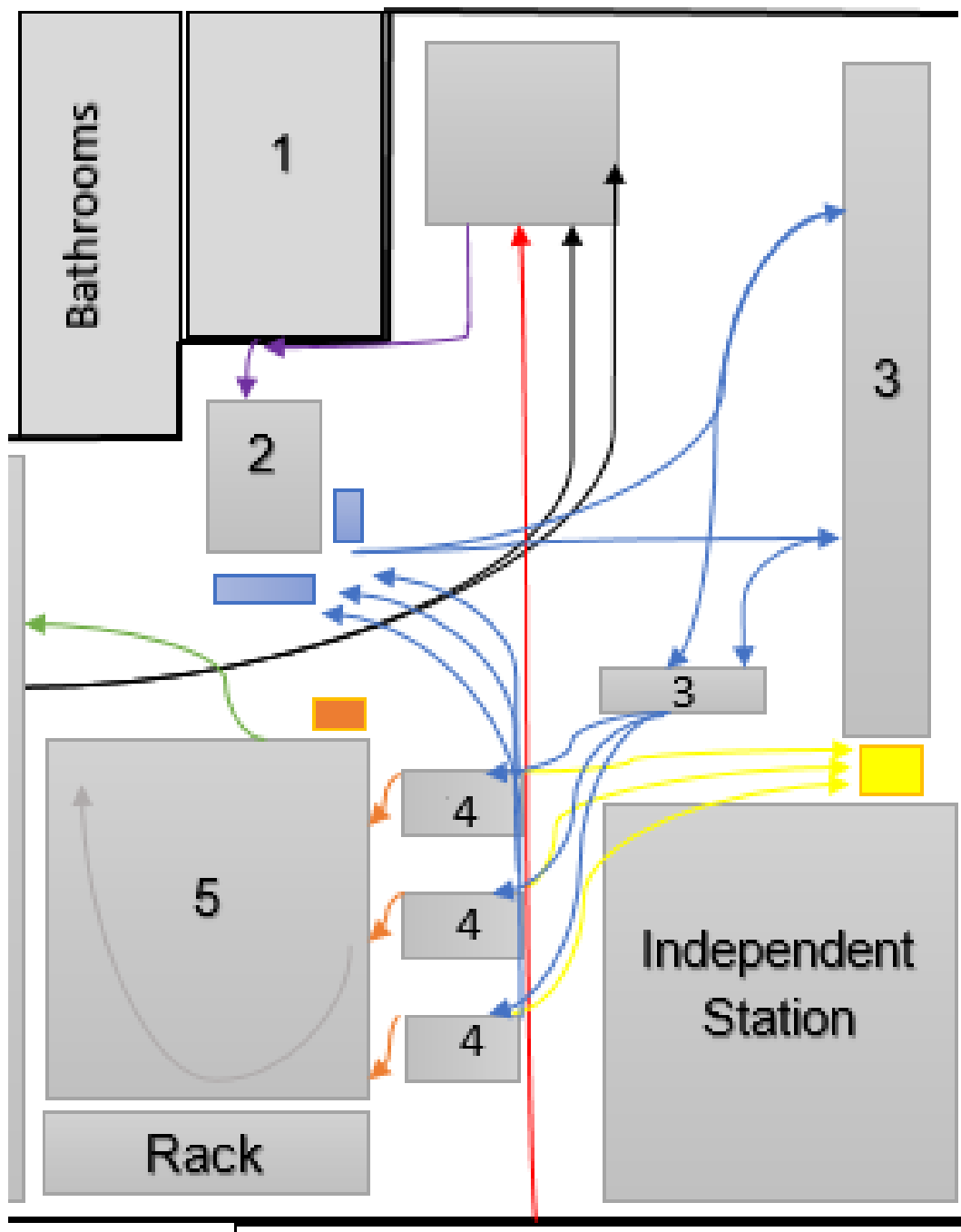


Adjacency Graph:



Layout Four

Flow Diagram:



Adjacency Graph:

