1. Introduction

1.1 Motivation

Human blood inventory management is characterized by a string of factors that may prove to be complicated over time (S.M Hesse et al) (2005) [1]. Inventory management related to blood products face several external factors which contribute to its complexity. The blood assignment problem (BAP) relates to an efficient way of assigning whole blood (WB) units to patients when requested. Blood is a vital substance found within living organisms that contain components with unique responsibilities within the human body, combining these components results in a WB unit. On average, WB units usually take around 30 days to expire, unless these units are frozen which can be a costly process (V.De Angelis et al) (2000) [2] Complications related to blood inventory arise when an unexpected demand occurs, this can be linked to sudden onsets of trauma experienced by an individual which is in need of immediate attention. Blood transfusions save thousands of lives on a daily basis through medical treatment (A.O Adewumi) (2010) [3], this makes blood a valuable commodity which should be preserved and used efficiently. The focus of this study will be placed on an efficient blood assignment policy, whilst conforming to external factors that impact the blood assignment process with relation to the South African National Blood Service (SANBS).

There are six problems that must be addressed, these problems embody the BAP. This consists of demand, supply, expiry, importation, compatibility and costs.

Demand: The BAP can be considered as a NP-Hard problem due to its stochastic nature of daily demand (M.O Olusanya et al) (2015) [4]. Demand for blood units can be classified into two categories. The first category relates to patients who have premediated blood related activities planned for the day, this can involve treating blood conditions such as anaemia and/or surgeries, these are some uses of blood products [5]. The second category relates to individuals who experience sudden onsets of trauma which need immediate attention. These forms of trauma especially in South Africa relate to motor vehicle accidents, criminal activity etc. As depicted, it is not possible to predict when these sudden occurrences will happen, therefore a surplus of blood must be kept on hand in order to meet sudden demands.

Supply: Relates to the quantity of WB units on hand at any given moment. The supply of blood must be kept in refrigerated units in order to preserve the WB unit's integrity. Majority of WB units are received from voluntary donations from the population. However, due to the increase in blood related diseases such as Human immunodeficiency virus (HIV) and hepatitis, the need for screening of blood donations is vital, any blood units that test positive for a blood related virus is automatically discarded.

Expiry: WB units have a lifespan of approximately 30 days. After the expiry date, blood cell components start to deteriorate making the WB unit unusable. The disposing of WB units can further increase the expenses incurred by the blood bank, as proper medical waste disposure has to be followed. This is a highlighted aspect of the BAP, as expiry also implies that blood resources are not be utilised efficiently.

Importation: Importation occurs when a daily demand exceeds current supply on hand. All blood demands should be met, therefore blood banks need to import additional units from external sources if the demand level exceeds supply. This further increases the expenses of the blood bank.

Compatibility: A positive aspect of blood assignment relates to the compatibility between certain blood types. Compatibility relates to blood types that are able to utilise other blood types in order to fulfil a demand. Due to this ability among blood types, it is therefore possible to fulfil daily demands by utilising other compatible types, which in turn minimizes blood importation.

Costs: Various steps are involved before a WB unit reaches its specific patient.
Each step has a form of cost associated with it, whether it is transportation or storing whole blood units, these activities sum together to form a final cost. There are 4 main activities which are used to tally a final amount.

- **Production costs**: Relate to costs of running blood campaign collections, also included in this amount will be procedures in separating the BAP from whole blood units.

- **Expiry costs:** As mentioned, BAP have a short lifespan, therefore any expired blood products including BAP, must be incinerated.

- **Inventory costs:** Costs associated with keeping BAP at optimum temperatures and in an adequate environment.

- **Importation costs:** If in the event the supply on hand does not cover the demand for that day, BAP will have to be imported in order to fulfil the remaining demand.

1.2 Problem Statement

Blood banks are responsible for obtaining, pre-processing and transporting the blood products to hospitals. Every day the blood supply must be checked for any units that have exceeded the shelf life, these units are then removed from the current supply and incinerated. New stock must also be processed and added to the supply for usage. Most blood banks follow the "First in- first out" (FIFO) method, this implies that the oldest blood units are used first. The use of the FIFO policy reduces possible expiry. In addition to the checking and adding process, a request for the next day's blood demands must be analysed, and appropriate amounts of blood per blood type must be set aside to fulfil such requests. The problem faced by blood banks is to satisfy the demand for WB units for every patient, whilst trying to minimize expiration and importation of additional blood units, this in turn decreases the costs incurred by the blood bank. It is therefore conclusive that the inventory model to be implemented must address the aspect of a dynamic environment with a stochastic supply or demand at any given moment.

1.3 Aims and Objectives

The primary objective of the BAP is to obtain a more profound understanding of its characteristics and establish dependencies among these aspects. The aim is to implement new forms of metaheuristics based approaches to work the BAP, with the purpose of maximizing blood product delivery and minimizing expiry, importation and costs of the blood bank. The work conducted in this study will attempt to advance the research of the BAP or similar perishable inventory related problems. The following is a list of project objectives that will be accomplished in this study.

- Develop a model for the BPPIP using a mathematical approach, whilst adhering to policies related to the PLT collection and distribution.

- Implement different metaheuristic algorithms (MA) which will work the BAP. These techniques include Genetic Algorithm (GA), Bat Algorithm (BA) and Symbiotic Organism Search (SOS).

- Analyse previous data and statistics collected from other research, and identify common trends which can contribute to the following study.

- Implement a blood assignment policy which maximizes WB unit delivery whilst minimizing expiration and importation.

- Datasets will be randomly generated. An aim in this study is to implement datasets based on social trends in the South African population. This in turn will give more accurate results which could be expected in everyday living.

- Create multiple datasets which will test each MA performance. Each dataset will try and mimic scenarios that may be faced by the blood bank.

- Incorporate blood compatibility which will aid in minimizing the amount of importation and expiry of WB units.

- Incorporate a means of expiry WB units once it has exceeded its shelf life.

- Implement a system which will import additional WB units when demand exceeds supply for the day (after blood compatibility has taken place).

By completing the objectives mentioned above will allow for a more intelligent system to work the BAP.

1.4. Assumptions

When establishing aspects of a mathematical model it is almost impossible to implement every variable of a complex problem. Therefore many models introduce assumptions to try and simplify computation. Assumptions are often deemed as a metaphorical bridge which gaps the real world to the mathematical world. With regards to the BAP and many other blood related problems, it is difficult to obtain data from hospitals and blood banks. Consequently, assumptions are made in order to mimic real world information. The following are aspects that are assumed in the BAP model.

- The model will be devoid of race, gender, age and any other contributing characteristics of an individual.
- The model will ignore blood related diseases. All blood will be deemed as "clean".
- WB units will have a lifespan of 30 days. Therefore expiry will occur every 31 days.
- A year will be considered to have 365 days.
- Fixed cost amounts will be ignored. By minimizing both expiration and importation of blood units, this in turn will decrease the costs incurred by the blood bank.
- Wastage will occur as a result of expiry and not human error (i.e. Accidental spillage)
- Blood banks will have infinite capital.
- External sources used for importation will have an infinite supply of WB units.
- Only social trends from the South African population will be considered, no external countries will be included.
- The focus will be on whole blood units, and not individual blood components such as red blood cells, white blood cells, platelets or plasma.

1.5 Methodology

As mentioned previously, the BAP is comprised of various components. These components will be broken down more concisely in chapter 3. However, in a general sense the following items make up the methodology for the BAP.

- Identify controlled activities conducted by the blood bank. Such events relate to aspects that the blood bank can control at any moment such as blood drives, storage, distribution etc.

- Identify uncontrolled activities that affect the blood bank. Such events relate to aspects such as sudden demand for WB units, excess stockpiling etc.

- Establish social trends related to the South African population for dataset generation.

- Implement MA in conjunction with the created datasets in order to obtain results.

- Record results obtained from each implementation, and convey the data in a meaningful manner.

- Identify the best MA which produced the best results.

1.6. Scope and Limitations

The following study implements 3 metaheuristic algorithms to work the BAP, namely GA, BA and SOS. The aim of each implementation tries to minimize additional WB unit importation, expiration due to exceeding shelf-life which in turn decreases the total expense incurred by the blood bank, whilst trying to fulfil all demand for WB units for that day. Each dataset will resemble a scenario that could be imposed upon the blood bank. A control dataset based on parameters from previous research will be used to establish if this study's results have implemented improved ways to work the BAP. This study will focus mainly on demand, supply, expiration and importation, even though the BAP is comprised of other contributing factors. Similar prior research such as the blood platelet production and inventory problem (BPPIP) conducted by [1], analysed blood bank policies for issuing blood products as well as reviewing these policies on a periodic basis. Due to this study's focus mainly emphasizing demand, supply and dataset generation, only one policy will be implemented. In addition, due to confidentiality issues related to obtaining real-life data, datasets will be randomly generated, however some of the datasets will be created by utilising social statistics obtained from the South African population. This attempts to generate data which correlates more appropriately to the population.

1.7 Research Contributions

The BAP aims at minimizing importations and wastages in relation to WB whilst ensuring that all demands are met. There are aspects of this model that can be implemented in similar inventory related issues as optimization of inventory policies is a common research problem [4]. The model introduced in this study takes expiration as a high priority parameter and introduces a technique for expiring units when necessary. Blood compatibility plays an important part in minimizing importation, this has also been established within the model for the BAP. Another relevant aspect in most inventory problems relates to demand and supply fluctuations, this is largely associated with an ever changing environment. The following study attempts to research the social aspect of the BAP, and how certain influences will act upon the model. Overall, the contribution of this thesis will build upon previous ideas relating to the BAP, and form a newer model which considers both the lifespan of WB units as well as a more appropriate determination of supply and demand based on the South African population statistics.

1.8 Project Outline

The remainder of this thesis will be structured as follows: Chapter 2- Literature review, relates to previous research conducted in the field of metaheuristics and the BAP, as well as similar dynamic perishable stock inventory problems. This chapter will also identify similar properties which could be considered in this study both mathematically and ideologically. Chapter 3- Methodology and algorithms will give a step-by-step description of all equations and algorithms used in the development of the BAP model. Chapter 3 will also convey the policy implemented and how the datasets were created. Chapter 4- Results and discussion, this chapter will focus on the results obtained from each MA approach, and identify which algorithm worked the best for the BAP. Results in this chapter will also be depicted by the use of tables and graphs to illustrate similarities and differences. Finally, Chapter 5- Conclusion will offer a general overview on which of the techniques where successful on the BAP, and give an insight with regards to future work on this problem.

References

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