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A mathematical programming approach to a labour sizing and scheduling problem

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Executive Summary

Spring Valley Foods is a supplier of fresh whole and produced fruit. It is a constant battle to ensure just enough workers for the day's work. Labour cost can be one of the highest costs a company can incur, and has a direct impact on the company's profit. The goal of this project is to develop a complete labour plan in terms of sizing and scheduling.

The labour planning will be focussed on the pack-house area. The pack-house is where fruit is sorted in terms of ripeness (mangos, avo's and papayas) or weight (melons). Standard working rates for each process have to be determined.

After a literature study has been conducted it has been determined that the scheduling approach followed will be days-off scheduling, and the solution approach followed is mathematical programming.

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List of Abbreviations

SVF:	Spring Valley Foods
Kg/mhr:	Kilogram per man hour
VBA:	Visual basic application
SA:	Simulated annealing
GA:	Genetic algorithm
TS:	Tabu search

Chapter 1: Introduction and Background

1.1 Company background: Spring Valley Foods

Bakkavor is a leading international producer of fresh prepared fruits and produce. The Bakkavor food group has operations in 10 different countries and supply over 6000 products in 18 prepared food categories (see table 1). Spring Valley Foods (SVF) is part of the Bakkavor food group. Spring Valley Foods opened in 1995 and is situated in Bapsfontein, South Africa. Spring Valley Foods' core business is to supply fresh whole fruits as well as fresh prepared fruits to Marks and Spenser in the United Kingdom and Woolworths in South Africa.

Table 1: Bakkavors' core categories

	United Kingdom	Continental Europe	Rest of world
Ready meals	*	*	*
Ready to cook meals	*	*	*
Pizza	*	*	*
Soups	*	*	*
Sauces	*	*	*
Stir fries	*		
Bakery products	*	*	*
Pasta			*
Prepared vegetables	*	*	*
Ethnic snacks	*		*
Leafy salads	*	*	*
Convenience salads	*	*	*
Dips	*	*	*
Dressings	*	*	*
Sandwiches & wraps	*		*
Prepared fruit	*	*	*
Dessert & pastries	*	*	*
Smoothies			*

Depending on the season there are between 600 and 1000 staff members – thus the need for a comprehensive labour plan.

The weight of fruit Spring Valley Foods will process on average in a week is 130000 tons of mangos, 17000 tons of melon (red, orange and green melon) and 45000 tons of pineapple. Other fruits include: strawberries, raspberries, blueberries, pomegranates, coconuts, kiwis, oranges, papayas, passion fruit, apples, and grapes. In the winter they process avocados to use by other Bakkavor businesses as dressings and dips.

1.2 Examination of the problem

Spring Valley Foods' objective is to have the optimal number of workers for the amount of work in a particular shift. They do not have a formal labour plan implemented and their current practise of labour planning is to estimate how many workers are needed. This estimation is not an accurate method of labour planning as they sometimes have a shortage of workers and cannot complete the days' work, and sometimes they have too many workers resulting in paying for labour that is not utilized. The consequence of not completing the days' work is a penalty from the customer and for that reason it should be prevented. Therefore the labour planning has a direct impact on the company's profit.

In the summer months the workers work in shifts from 7:00 to 19:00 with two breaks, and then the night shift starts at 19:00 to 7:00 with two breaks. The workers working on this schedule works for four days and then gets four days off. In the winter months there is only one day shift from 07:00 to 19:00.

1.3 Research Design and Methodology

This project aims to have a complete labour plan developed that can be used to determine the optimal number of workers for the type and amount of work that must be completed daily.

The scope of the labour planning will primarily be the labour needed for the pack-house area.   The standard working rate for each process in the pack-house has to be calculated, for example: a person can sort mangos at a rate of x kilograms per man hour (kg/mhr). The data analysis chapter describes how the standard working rate is calculated. Note that this standard working rate is just for the purpose of illustration and detailed work studies should be conducted to determine a more accurate standard working rate.

Spring Valley Foods uses different type of workers to achieve their daily demand targets. Permanent workers are employed permanently throughout the year, not depending on the season. Permanent-temporary workers are only employed for a specific season, but when the volumes are low they are removed from the roster. Temporary workers are employed on a day-to-day basis when the volumes are very high but will always work for 4 days when they are needed. A section leader is a worker who is in charge of a specific section, while a line leader is in charge of a specific area in a section.

The wages of a permanent, permanent-temporary and temporary worker is equal; therefore the amount of workers needed will be minimized in the model. The model will not distinguish between these types of workers as Spring Valley Foods will always give preference to their available permanent workers, then the permanent-temporary workers and the shortage of workers will be covered by the temporary workers. There will always be one section leader per section, and one line leader for each area in a section. Thus the scope of the labour demand model will only focus on the permanent, permanent-temporary and temporary workers required for the operations in the pack-house.

1.4 Document Structure

Chapter two presents a review about scheduling approaches and solution methods for the labour sizing and scheduling problem. The scheduling approached discussed include shift, days-off and tour scheduling. The solution approaches discussed are artificial intelligence, constraint programming, metaheuristics and mathematical programming. Chapter three contains the data analysis which explains how the standard working rate is determined for the fruit types. The labour demand model formulation is described in chapter four as well as the functional requirements. A real life scenario is presented in chapter 5. Chapter 6 concludes the report with recommendations for future improvements.

Chapter 2: Literature Review

2.1 Problem identification

Personnel scheduling as defined by Ernest, Jiang, Krishnamoorthy & Sier (2004) is the process of developing schedules for workers so that a company can fulfil its demand for its goods and services. Employees' pay, quality of life, structure of work, family and leisure activities are affected by the work schedule followed (Alfares, 2003). Labour cost of organizations as well as the capability to meet demand is also affected by the employee schedules. The initial part of labour planning is to determine the amount of workers needed daily for the amount of work. The second part of the process is to allocate the workers to a particular day.

Labour planning as defined by Bodo (2012) *is* "the art of getting the right people into the right positions at the right time."

Appropriate scheduling approaches and solution methods must be reviewed in order to select the scheduling approach that will be followed and the solution method to solve the labour sizing and scheduling problem in order to meet the customer demand in a profitable manner.

2.2 Variants of scheduling approaches

The importance of employee scheduling is not only limited to the reduction in labour cost but also includes helping employees to manage their time more efficiently ,complying with employment regulations, managing the workload of a company, dealing with the wages of employees, minimizing absentees and monitoring productivity (Scott).

Staff schedules that are optimized can deliver many advantages as discussed above, but require decision support systems that are implemented in a cautious manner if customer demand is to be met in a profitable way.

Labour scheduling problems can be classified into three different types (Alfares, 2002):

2.2.1 Shift Scheduling:

Shift scheduling focuses on each employee's working hours and break hours per day. Shift scheduling is defined by Ernest et al. (2004) as: "the problem of selecting from a potentially large

pool of candidates what shifts are to be worked, together with an assignment of the number of employees to each shift, in order to meet demand.”
Shift scheduling is used in organisations where a large number of alternative work shifts are considered. These alternatives are the result of variations in starting times, finishing times and the placement of breaks. Although the complexity is increased through the number of alternatives, labour utilization can be improved.

2.2.2 Days-off scheduling:

Days-off scheduling is the process of determining a schedule of work days and rest days per week or work cycle. When dealing with days off scheduling the appropriate labour laws should be taken into account as well as the company regulations.
Days-off scheduling is used in organisations where a seven-day workweek is used. The problem is to satisfy the continuous work requirements with employees who cannot work continuously (Alfares, 2002). All daily labour demands must be satisfied using the minimum number of cost of employees, therefore a pattern must be determined to assign employees to off days (Alfares, 2002).

Alfares (2003) describes a (14,21) days-off scheduling problem. Employees work 14 consecutive days and then get 7 consecutive days off. The main advantage of this working schedule is the minimized transport cost to distant work locations. This schedule was implemented by a major oil company to schedule employees living in distant regions. The objective of (14,21) days-off scheduling approach is to minimize the labour cost or the amount of labour required.

Alfares (2001) describes a (5,7) days-off scheduling problem. Employees work 5 consecutive days and then get 2 consecutive days off. The (5,7) days-off scheduling problem is the most common scheduling problem used. The objective of (5,7) days-off scheduling approach is to minimize the labour cost or the amount of labour required.

A compressed workweek arrangement is described by Alfares (2003). The workweek consists of 4 consecutive work days and 3 off days of which two must be consecutive.

Only three of the many days-off scheduling approaches are discussed above, but days-off scheduling is not limited to only these approaches.

2.2.3 Tour scheduling:

Tour scheduling is a combination of shift scheduling and days off scheduling. Each employee's daily work hours and weekly work days are determined. This approach is used in organisations where a seven-day work week is used, as well as various alternative shifts per day, which may have different starting times and finishing times.

2.3 Chosen scheduling method

Spring Valley Foods are operating on a continuous 7-day workweek and has 1 standard shift in the winter season and two standard shifts in the summer season. Spring Valley Foods have to fulfil a continuous demand with workers who can't work continuously therefore they will have to assign off days for workers. After carefully considering the three different scheduling approaches, the approach selected is the days-off scheduling approach. A suitable working schedule must be determined that takes into account the labour laws and company regulations.

2.4 Variants of solution methods for the labour sizing and scheduling problem

The various scheduling approached has been reviewed in section 2.2. Recall that the days-off scheduling approach has been selected. A solution approach should be selected that will be appropriate for solving the days-off scheduling approach.

Ernst (2004) discussed various solution methods for labour sizing and scheduling. A Brief description of the solution techniques will follow below.

2.4.1 The artificial intelligence approaches include fuzzy set theory, and search and expert systems. Fuzzy set theory has commonly been used to solve air crew scheduling problems. Artificial intelligence approaches is useful when there are a large number of human factors that cannot be coded in software and the individual responsible for the rostering need to make various decisions regarding the rostering.

2.4.2 Constraint programming is used to find feasible solutions for scheduling problems. This technique is used when there is a huge number of constraints to a particular problem and when any feasible solution will be adequate even though it is not optimal. The reason why this technique is being used even when it does not always give the best solution is because constraints that are complex can be expressed without too much trouble. This technique should not be used when the main challenge is to find an optimal solution out of a many possibilities of feasible solutions for a problem.

2.4.3 Metaheuristics is commonly used to solve rather difficult and usually combinational or discrete optimization problems. A heuristic is an experienced-based technique for problem solving that can speed up the process to find a satisfactory solution where an exhaustive search is impractical. Thus this method is thus used for problems that are not suitable for solution through exact methods. As stated by Ernst (2004) "Metaheuristics are typically hybrids of heuristic algorithms. The algorithms combine different base methods under one framework." Metaheuristics therefore consist of different solution methods which include classical heuristics, artificial intelligence, biological evolution, neural engineering, and statistical mechanics. Examples of modern metaheuristics are simulated annealing (SA), Genetic algorithm (GA), tabu search (TS), problem space search, greedy random adaptive search procedure (GRASP), machine learning and reinforcement learning.

An SA framework have been used before to solve staff scheduling problems. The whole rostering problem of days-off, shift and tour scheduling has been solved within the SA framework for airport staff. Train crew rostering and airline crew scheduling have been solved using a SA approach. A SA algorithm have been used to solve a large set covering integer programming formulation for developing a schedule for a mix of permanent and temporary health workers. Personnel scheduling problems like nurse rostering and bus driver schedules have also been solved using GA's. A combination of SA and GA metaheuristic methods has been used to successfully solving staff scheduling and manpower allocation problems.

Metaheuristics are also the method of choice when designing rostering software to deal with messy real world problems that do not solve easily with a mathematical programming formulation.

2.4.4 Mathematical programming methods entail the use of linear programming or linear integer programming to solve scheduling problems. The first person to model the scheduling of labour in mathematical programming form was Dantzig. The most commonly used model is the Dantzig set covering model or a variation thereof. Dantzig's model is formulated as a set covering problem with known staffing requirements. The objective function of this model is to find the minimum cost covering from a set of available schedules. For every period the staffing levels are calculated and are defined as hard constraints that must be satisfied in any feasible schedule (Robbins & Harrison, 2010). Mathematical programming is a low cost solution but there are a few problems that restrict this method to be used universally, such as:

- Mathematical programming approaches are generally applied to simplified versions of the real world problem or only to a selection of complications in the original problem. Hence these approaches are more limiting in what constraints can be expressed easily.
- To implement a good integer programming method for a particular crew scheduling and rostering problem it is quite difficult and rather time consuming. This is only justified when the additional advantages of the reduced cost of solutions obtained is significant and when the scheduling rules and regulations do not change much over time.

When the above mentioned problems will not affect the model being optimized mathematical programming techniques can be used with relatively no trouble.

The set covering model is so general that many problems in the staff scheduling and rostering can be described in this unified format. Examples are days-off, shift, tour scheduling, and crew scheduling and rostering.

2.5. Chosen solution method

After considering the various solution techniques described in the literature it is clear that there are several solution methods to solve staff scheduling problems. The norm to solve messy real world problems of staff scheduling is based on metaheuristic approaches. Mathematical programming has commonly been used to solve scheduling problems. The problems with a mathematical programming approach described poses not to be a problematic for this specific model that will be optimized. It is also the most appropriate as it is commonly used to solve problems based on the scheduling approaches of days-off, shift and tour scheduling. Therefore mathematical programming seems to be an appropriate and the best solution method to solve the labour sizing and scheduling problem. The chosen solution method will specifically be integer linear programming, because the number of workers must be an integer amount. Linear programming techniques can be used to deliver moderately simple and realistic solutions.

Chapter 3: Data Analysis

This chapter describes the method followed to gather the data that will be used in the labour demand model to determine the amount of labour needed. The data analysis was only done for the purpose of illustration, and detailed work studies should be done by Spring Valley Foods in order to determine an accurate standard working rate for each process. Documentation used by the planning department used to review the standard working rate will also be included.

The standard working rate of the avocado, mango, melon and papaya sorting process must be determined in terms of kilogram per man hour (kg/mhr).

This was done by doing work studies, over different days and different times during the day. See Appendix A for all the data that was collected and used to determine the rates. The time intervals chosen were 5 minutes, and the frequency is the number of lugs that is sorted. It is calculated that one lug of avocados weigh approximately 18.4 kg, one lug of mangos weigh approximately 19.8 kg and one lug of papayas weigh approximately 18 kg.

Example to calculate the standard working rate:

The avocado data for 25May have been used to illustrate the calculation.

$$Total\ lugs = 136$$
$$Total\ time = 45\ min$$

$$Total\ sorted = total\ lugs\ \times weight\ of\ lug$$
$$Total\ sorted = 136 lugs\ \times 18.4\ kg/\text{lug}$$
$$Total\ sorted = 2502.4\ kg$$

$$Standard\ working\ rate$$
$$= (Total\ sorted\ \div (Amount\ of\ workers\ \times Total\ time)\ \times 60)$$
$$Standard\ working\ rate = (2502.4\ \div (14\ \times 45) \times 60)$$
$$Standard\ working\ rate = 238.32\ kg/mhr$$

See the summary in table 2 of the standard working rates determined.

Table 2: Summary of standard working rates for mango, avocado and papaya

Fruit	Standard working rate
Mangos	258 kg/mhr
Avocados	175 kg/mhr
Papaya	270 kg/mhr

The standard working rate of the melons will be determined when the summer season starts again. Spring Valley Foods has implemented a new melon sorting table to sort red, green and orange melons which will be fully operating this coming summer season.

The documentation developed by the planning department must be completed by the line leaders daily. The documentation will then be submitted to the planning department and they will calculate the standard working rate for each process, and they will decide when the standard working rate should be adjusted. It is recommended that the standard working rate will be revised monthly as the rate should be slower at the start of the summer season and faster at the end of a season. See figure 1 below for the document, and see figure 2 for an example of how the document will be used.

Date:..
Shift:.......................................
Line leader:...............................
Process......................................
Conveyor:...................................
No of workers:...........................

	Time started	Time finished	Total time	Weight sorted
Total				
			A	B

Efficiency = B / (A * no of workers)
Efficiency =

Figure 1: Documentation to calculate the standard working rate

SPRING VALLEY FOODS BAKKAVÖR

Date:...2 Jul 2012........................
Shift:..Dayshift...........................
Line leader: Maggie..................
Process...Mango sorting..........
Conveyor:1...............................
No of workers:...13.................

	Time started	Time finished	Total time	Weight sorted
	07:10	08:51	1.68	3997
	08:56	10:35	1.65	5299
	10:38	12:30	1.37	2129
	12:35	13:10	0.58	1438
	13:12	13:42	0.50	1126
	13:45	15:55	2.17	4103
	16:30	17:00	0.50	1404
	17:05	17:30	0.42	922
	17:32	17:54	0.37	1003
	17:55	18:10	0.25	1860
Total			9.48	23281
			A	B

Efficiency = B / (A * no of workers)
Efficiency = 23281 / (9.48 * 13)
188.84

Figure 2: Example of how documentation is used to calculate the standard working rate

The total time is measured in hours, and the weight sorted is measured in kg. The efficiency is thus measured in kg/mhr.

The efficiency of the avo sorting process on the 7th July 2012 was calculated as 188.84 kg/mhr. The present standard rate is determined as 175 kg/mhr. The planning department will review these sheets weekly, and the decision is up to them to decide when to adjust the standard working rate values.

Chapter 4: Model Formulation

The labour demand and scheduling model was developed in Microsoft Excel 2010 using Visual Basic Application to make the model a bit more user friendly by eliminating a tedious task of performing the same calculation more than once.

Please see Appendix B for full VBA programming code

4.1. Labour demand

The labour demand model is where the labour required is calculated.

The user will select the shift and date; the type of fruit to be sorted using a drop down list, enters the weight to be sorted in kg, and the hours available to sort the fruit. The model will then use the inputs to calculate the labour needed. Recall that the standard working rate is determined through work studies and is a constant linked to a specific type of fruit.

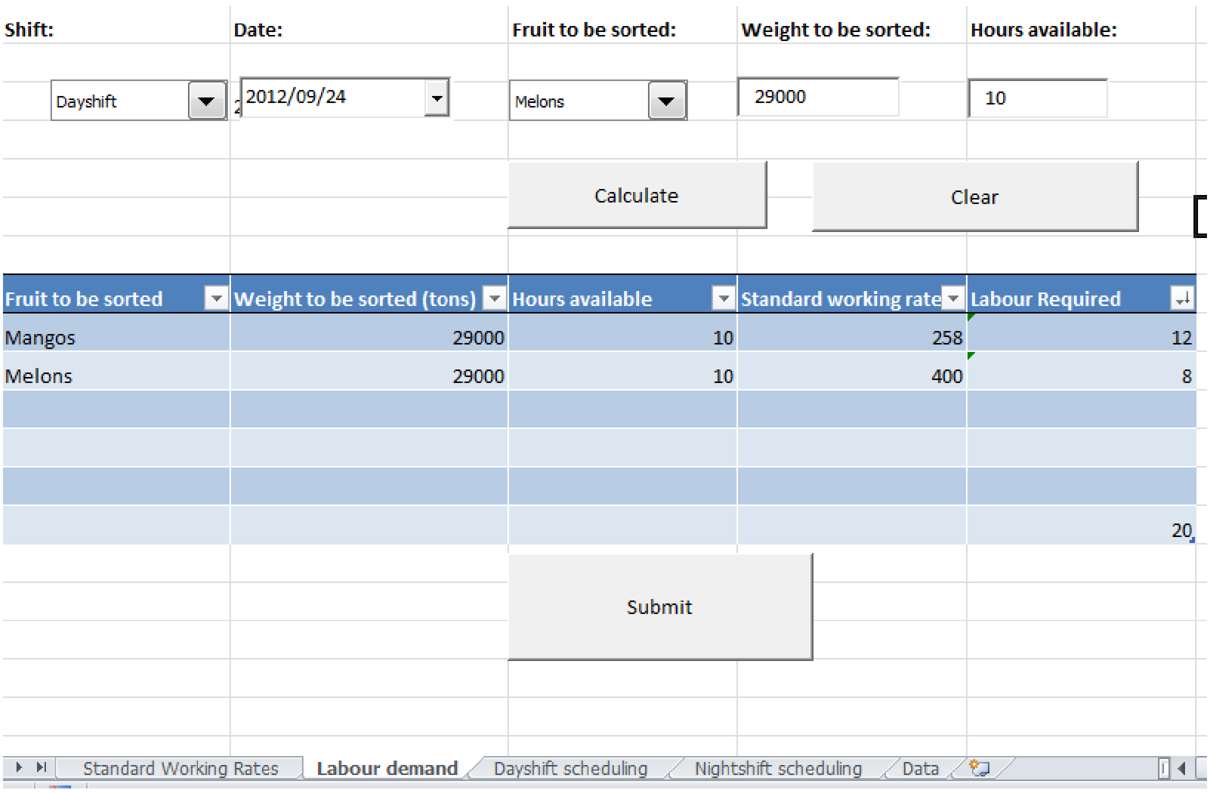

Figure 3: Labour demand interface

When all the inputs have been selected and entered the macro should be activated by the calculate button. The labour required will be calculated using equation 1 and all relevant information will be put into the table. This must be repeated for all the fruit types that must be sorted in that particular shift. The model will prevent a fruit type from being added more than once. Figure 4 shows the error message that will display when a fruit type is attempted to be added, after it has already been added. This is to ensure that duplicates are not added for the same day. The range for the time available will be between 1 and 11 hours. The maximum hours available are 11 hours because a full shift is 12 hours but it includes two half hour breaks, therefore the maximum effective time is only 11 hours. The minimum hours available are 1 hour. This is due to ensure that the user did enter a number in the hours available field. Figure 5 shows the error message displayed if the hours entered are not in range. If a mistake is made the clear button will clear the table, and also reset the “fruit count” in the VBA programming so that fruit may be added again. After all the information is added for the particular shift and date the data should be submitted to the appropriate scheduling sheet, the VBA code will ensure that the correct information will be transferred to the correct scheduling sheet.

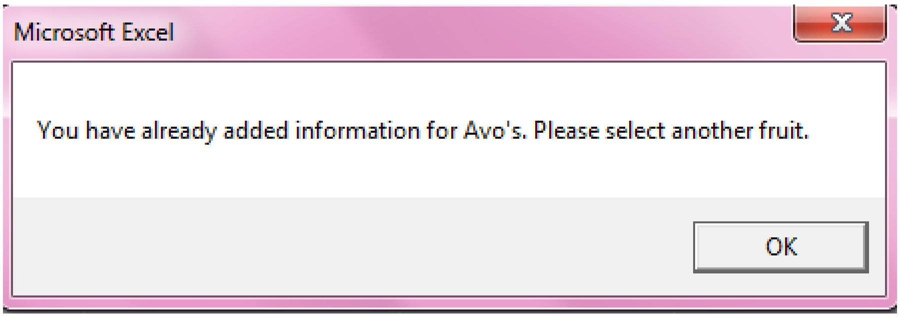

Figure 4: Message displayed when fruit type is already added

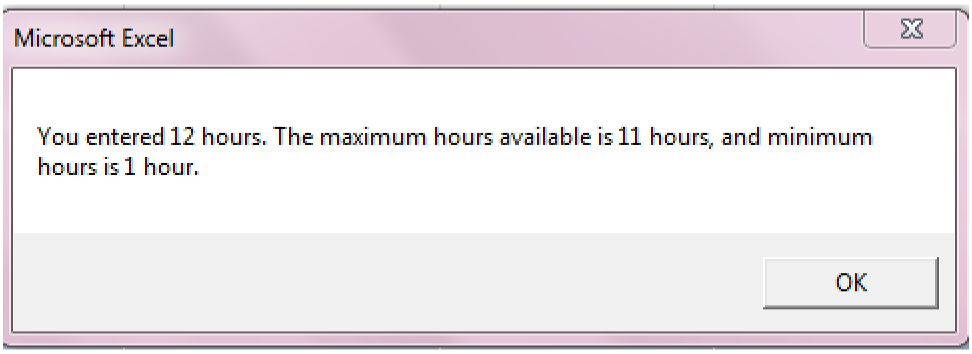

Figure 5: Message displayed when hours are out of range

$$Labour\ required = \frac{Amount\ to\ be\ sorted\ (kg)}{Standard\ working\ rate\ \left(\frac{kg}{mhr}\right) \times Hours\ available\ (hours)}$$

Equation 1: Formula to calculate labour required

The data sheet is a table which contains the information added in the labour demand sheet. This is so that there is a record of the information added in the labour demand sheet.

Table 3: Data table

	A	B	C	D	E
1	Shift	Date	Fruit sorted	Weight sorted	Labour Required
2	Dayshift	2012/09/24	Papaya	29000	11
3	Dayshift	2012/09/24	Avo's	29000	17
4	Dayshift	2012/09/24	Melons	29000	8
5	Dayshift	2012/09/24	Mangos	29000	12
6	Dayshift	2012/09/24	Melons	29000	8
7	Dayshift	2012/09/24	Avo's	29000	17
8	Dayshift	2012/09/24	Papaya	29000	11
9	Dayshift	2012/09/24	Coconut	29000	20
10	Dayshift	2012/09/24	Papaya	29000	11
11	Dayshift	2012/09/24	Avo's	29000	17
12	Dayshift	2012/09/24	Melons	29000	8
13	Dayshift	2012/09/24	Mangos	29000	12
14	Dayshift	2012/09/24	Melons	29000	8
15	Dayshift	2012/09/24	Avo's	29000	17
16	Dayshift	2012/09/24	Papaya	29000	11
17	Dayshift	2012/09/24	Coconut	29000	20
18	Nightshift	2012/09/24	Papaya	29000	11
19	Nightshift	2012/09/24	Avo's	29000	17
20	Nightshift	2012/09/24	Melons	29000	8
21	Nightshift	2012/09/24	Mangos	29000	12
22	Nightshift	2012/09/24	Melons	29000	8
23	Nightshift	2012/09/24	Avo's	29000	17
24	Nightshift	2012/09/24	Papaya	29000	11
25	Nightshift	2012/09/24	Coconut	29000	20

4.2 Labour Scheduling

After the demand has been calculated for each day, an appropriate schedule should be determined to minimize the amount of workers. Recall from section 2.3 in the literature review that days-off scheduling is the chosen scheduling approach and from section 2.5 that mathematical programming, more specifically linear-integer programming, is the chosen solution method.

The model will not distinguish between permanent and temporary workers because they are paid the same wage. The models' objective function is thus to minimize the amount of workers starting on a specific day.

4.2.1 The mathematical programming model:

$x_i = number\ of\ employees\ beginning\ work\ on\ day\ i, \quad i = 1,2, \dots ,7$

$y_i = number\ of\ employees\ that\ began\ work\ on\ day\ i, \qquad i = 8,9,10$

$d_i = labour\ required\ for\ day\ i, \quad i = 1,2, \dots ,7$

$Where\ i$:

$1 = Sunday\ of\ present\ week$

$2 = Monday\ of\ present\ week$

$3 = Tuesday\ of\ present\ weel$

$4 = Wednesday\ of\ present\ week$

$5 = Thursday\ of\ present\ week$

$6 = Friday\ of\ present\ week$

$7 = Saturday\ of\ present\ week$

$8 = Thursday\ of\ previous\ week$

$9 = Friday\ of\ previous\ week$

$10 = Saturday\ of\ previous\ week$

$$\min z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$$

s.t

$x_1 + y_8 + y_9 + y_{10} \geq d_1$ (Sunday constraint)

$x_1 + x_2 + y_9 + y_{10} \geq d_2$ (Monday constraint)

$x_1 + x_2 + x_3 + y_{10} \geq d_3$ (Tuesday constraint)

$x_1 + x_2 + x_3 + x_4 \geq d_4$ (Wednesday constraint)

$x_2 + x_3 + x_4 + x_5 \geq d_5$ (Thursday constraint)

$x_3 + x_4 + x_5 + x_6 \geq d_6$ (Friday constraint)

$x_4 + x_5 + x_6 + x_7 \geq d_7$ (Saturday constraint)

$x_i \geq 0 \quad i = 1,2, \ldots ,7$ (Sign restrictions)

$x_i\ integer \quad i = 1,2, \ldots ,7$

4.2.2. *Interface*

Recall that the labour required for a specific day (d_i) is calculated and transferred from the labour demand sheet. The staff size is the total amount of staff that will be present on that specific day, the number starting this day column is the solution of the linear programming model, and states the amount of employees that should start working on that specific day. Figure 6 and 7 respectively shows the interface of the labour scheduling for the dayshift and nightshift.

LABOUR SCHEDULING: DAYSHIFT

Present week

DATE	DAY	STAFF SIZE		LABOUR REQUIRED	NUMBER STARTING THIS DAY
2012/09/23	Sun	18.0	>=	18	18.0
2012/09/24	Mon	18.0	>=	12	0.0
2012/09/25	Tue	21.0	>=	21	3.0
2012/09/26	Wed	48.0	>=	23	27.0
2012/09/27	Thu	30.0	>=	15	0.0
2012/09/28	Fri	30.0	>=	30	0.0
2012/09/29	Sat	27.0	>=	16	0.0
			Total Employees		48.0

Solve

Copy

Previous week

DATE	DAY	NUMBER STARTING THIS DAY
2012/09/23	Sun	18.0
2012/09/24	Mon	6.0
2012/09/25	Tue	0.0
2012/09/26	Wed	30.0
2012/09/27	Thu	0.0
2012/09/28	Fri	0.0
2012/09/29	Sat	0.0

Figure 6: Labour scheduling interface

LABOUR SCHEDULING: NIGHTSHIFT

Present week

DATE	DAY	STAFF SIZE		LABOUR REQUIRED	NUMBER STARTING THIS DAY
2012/09/23	Sun	18.0	>=	18	1.0
2012/09/24	Mon	26.0	>=	26	9.0
2012/09/25	Tue	21.0	>=	21	11.0
2012/09/26	Wed	23.0	>=	23	2.0
2012/09/27	Thu	23.0	>=	15	1.0
2012/09/28	Fri	30.0	>=	30	16.0
2012/09/29	Sat	19.0	>=	16	0.0
			Total Employees		40.0

Solve

Copy

Previous week

DATE	DAY	NUMBER STARTING THIS DAY
2012/09/23	Sun	12.0
2012/09/24	Mon	6.0
2012/09/25	Tue	6.0
2012/09/26	Wed	0.0
2012/09/27	Thu	15.0
2012/09/28	Fri	0.0
2012/09/29	Sat	6.0

The totals transferred from the labour demand model are in the labour required column. The solve button will activate a macro to solve the mathematical programming model using the Excel solver add-in. The macro will not open the solve parameters window (figure 7), this is just to prevent a user from accidently changing the constraints or objective function.

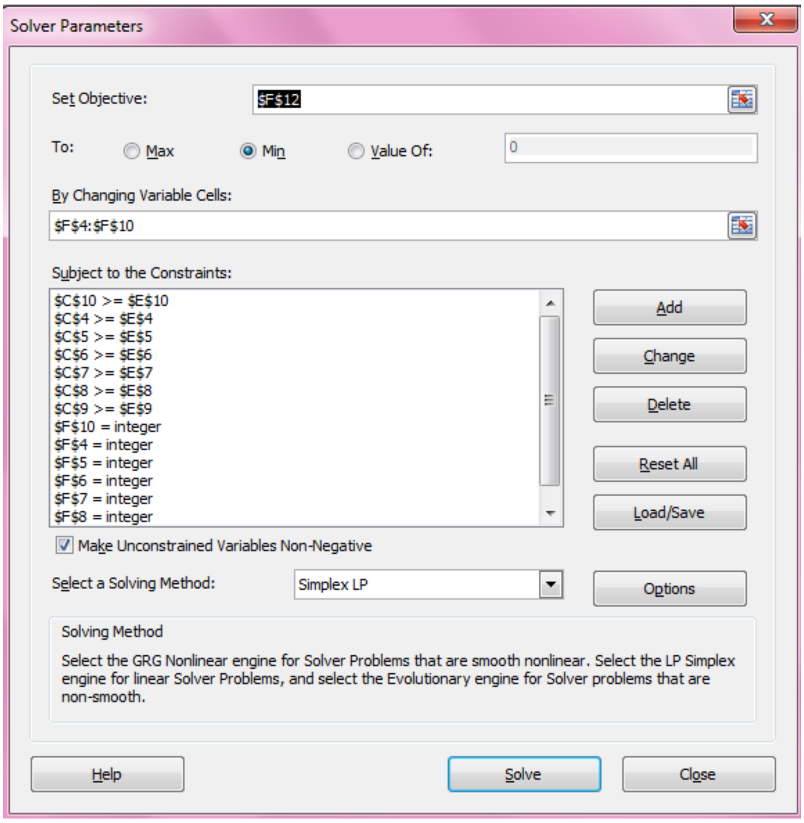

Figure 7: solver parameters window

The user will only see this solver results window (figure 8) when clicking on the solve button. The user may now select if they want to keep solver solution (recommended for this model). The user can now decide if they want to save the scenario, or generate a report.

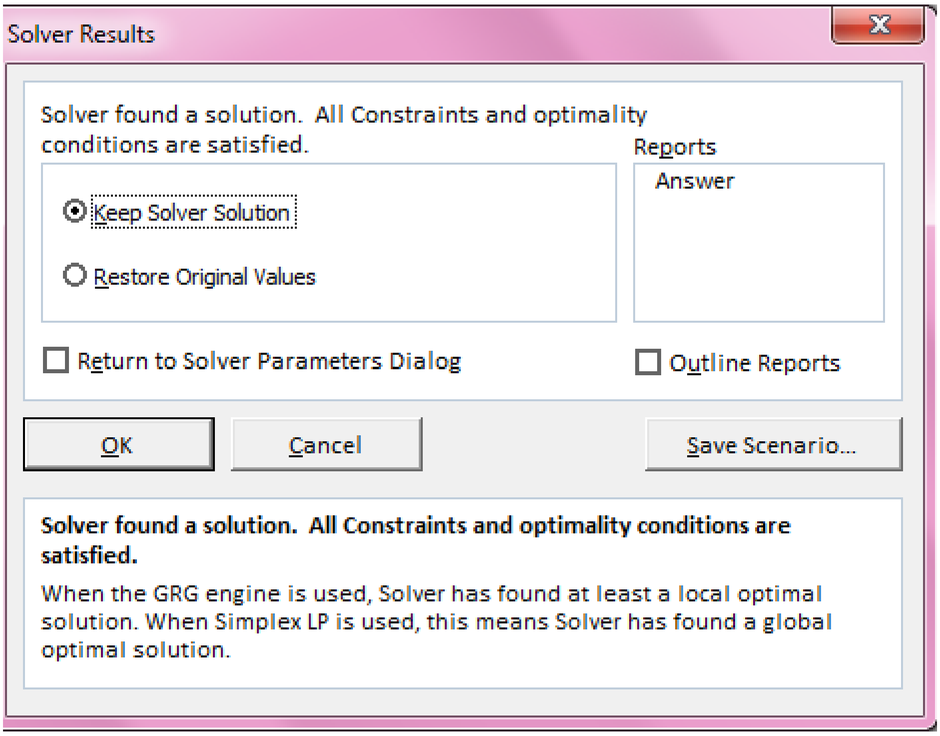

Figure 8: Solver results window

In order for this model to function correctly the user must always copy the present week data to the previous week data before closing the worksheet. The previous week data will thus be ready to use when the model is opened again.

Chapter 5: Test Scenarios

The data used to test the model is from the period 26August – 1 September 2012. The actual data is compared to the results obtained in the labour demand model

			Actual data	***Labour demand model***	***Difference***
Date	***Fruit***	***Demand***	***No of workers***	***No of workers***	
1 September	Avo	50034	20	27	7
31 August	Avo	18733	21	15	6
30 August	Avo	29308	23	16	6
29 August	Avo	25003	21	15	6
28 August	Avo	34999	21	20	1
27 August	Avo	29476	20	17	3
26 August	Avo	25691	19	18	1

Table 4: Test Scenarios: Actual vs Projected

The differences marked in green are a difference in favour of the labour demand model because it means that less workers would have been used to meet the demand and the difference marked in red is a difference in favour of the current practise as the model calculated more workers to be used to meet the demand. Out of the above example it seems that the labour demand model performed better in this period, meaning that if SVF used the amount of workers that the labour demand model calculated they would have saved labour cost equal to 16 workers for the week. Observe that the actual no of workers that was used remains relatively constant with an average of 21 workers per day. This may mean that SVF is not taking the daily demand into account when planning their workforce. The labour demand model calculated the number of workers required based on the daily demand. The number of workers is then scheduled according to the constraints of the mathematical programming model to ensure that an optimal workforce size is calculated. However it is important to realize that this saving will only be possible if the workers have achieved a standard working rate of 175 kg / mhr. More testing of this model is definitely recommended to ensure that savings can be obtained in the long run.

Chapter 6: Conclusions and Recommendations

The aim of this project was to develop a labour plan which will determine how many workers are needed and how many workers should start working on a specific day. Labour costs in one of the highest costs a company can incur and therefore it is essential to always have the optimal amount of workers to complete the days' work. The scheduling approaches considered for this problem was days-off, shift and tour scheduling. The scheduling approach selected was days-off scheduling as SVF works with two standard shifts per day in the summer season, and one shift per day in the winter season. The solution approach followed was mathematical programming because the problems described for mathematical programming poses not to be a problematic for this specific model that will be optimized. It is also the most appropriate as it is commonly used to solve problems based on the scheduling approaches of days-off, shift and tour scheduling. The labour demand model was developed in MS Excel 2010 using VBA programming to make the model more user friendly. The labour demand sheet determines the amount of workers required based on the type of fruit sorted, the weight of that fruit sorted, and the time available to sort the fruit. The scheduling sheets determine how many workers should start working on a specific day. If the optimal amount of workers is always available, and they complete their targets for the day, labour costs can be reduced and therefore profit will increase.

It is highly recommended that SVF will continue to revise the standard working rates for the processes. The reason why the standard working rate should be adjusted is because in the start of the summer season there will be permanent workers, permanent temporary workers, and temporary workers. The permanent temporary workers usually have done the work in a previous period that may be anything between 1-11 months ago and must first get used to the working rate again, and the temporary workers will also have to get used to the working rate. At the end of the season, most of the workers will be used to the working rate, and may therefore achieve a faster standard working rate.

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Appendices

Appendix A: Standard working rate calculation data

Avocado Standard working rate data

<u>25 May 10:00</u>

Interval	Frequency (no of lugs)
10:10 – 10:14	18
10:15 – 10:19	13
10:20 – 10:24	17
10:25 – 10:29	22
10:30 – 10:34	12
10:35 – 10:39	15
10:40 – 10:44	19
10:45 – 10:49	10
10:50 – 10:54	10
Total	**136**

Table 5: Avo standard working rate data 25May morning session

Total time: 45 min

Total sorted: 2507.34 kg

Standard working rate: 238.79 kg/mhr

<u>25 May 12:30</u>

Interval	Frequency (No of lugs)
12:30 – 12:34	14
12:35 – 12:39	12
12:40 – 12:44	11
12:45 – 12:49	14
12:50 – 12:54	8
12:55 – 12:59	16
13:00 – 13:04	17
13:05 – 13:09	16
13:10 – 13:14	14
13:15 – 13:19	12
13:20 – 13:24	Power Failure
13:25 – 13:29	10

13:30 – 13:34	13
13:35 – 13:39	11
13:40 – 13:44	12
Total	**180**

Table 6: Avo standard working rate data 25May noon session

Total time: 70 min

Total sorted: 3318.54 kg

Standard working rate: 177.78 kg/mhr

29 May 09:45

Interval	Frequency (No of lugs)
09:45 – 09:49	17
09:50 – 09:54	17
09:55 – 09:59	24
10:00 – 10:04	24
10:05 – 10:09	21
10:10 – 10:14	21
10:15 – 10:19	20
10:20 – 10:24	24
10:25 – 10:29	19
10:30 – 10:34	26
10:35 – 10:39	26
10:40 – 10:44	30
Total	**269**

Table 7:Avo standard working rate data 29May

Total time: 60 min

Total sorted: 4959.38 kg

Standard working rate: 165.31 kg/mhr

31 May 08:50

Interval	Frequency (No of lugs)
08:50 – 08:54	18
08:55 – 08:59	19
09:00 – 09:04	21
09:05 – 09:09	16

09:10 – 09:14	15
09:15 – 09:19	11
09:20 – 09:24	0
09:25 – 09:29	0
09:30 – 09:34	0
09:35 – 09:39	19
09:40 – 09:44	14
09:45 – 09:49	19
09:50 -09:54	19
09:55 – 09:59	23
10:00 – 10:04	28
10:05 – 10:09	21
10:10 – 10:14	26
10:15 – 10:19	30
10:20 – 10:24	23
10:25 – 10:29	27
10:30 – 10:34	31
Total	**380**

Table 8: Avo standard working rate data 31May

Total time: 95 min

Total sorted: 7005.81 kg

Standard working rate: 147.49 kg/mhr

6 June 08:50

Interval	Frequency (No of lugs)
08:50 – 08:54	12
08:55 – 08:59	14
09:00 – 09:04	12
09:05 – 09:09	4
09:10 – 09:14	11
09:15 – 09:19	9
09:20 – 09:24	8
09:25 – 09:29	12
09:30 – 09:34	11
09:35 – 09:39	8
09:40 – 09:44	12
09:45 – 09:49	9
09:50 – 09:54	11

09:55 – 09:59	9
10:00 – 10:04	13
10:05 – 10:09	12
10:10 – 10:14	12
10:15 – 10:19	18
10:20 – 10:24	14
10:25 – 10:29	15
10:30 – 10:34	22
Total	**248**

Table 9: Avo standard working rate data 6June

Total time: 105 min

Total sorted: 4572.22 kg

Standard working rate: 145.15 kg/mhr

Summary of Standard working rate

Date	Standard working rate (kg/mhr)
06 June	145
25 May	238
25 May	177
29 May	165
31 May	147
Average	**174.4**

Table 10: Summary of Avo standard working rate

Mango standard working rate data

31 January 11:35

Interval	Frequency (No of lugs)
11:35 – 11:39	15
11:40 – 11:44	19
11:45 – 11:49	18
11:50 – 11:54	20
11:55 – 11:59	20
12:00 – 12:04	13
12:05 – 12:09	15
12:10 – 12:14	20
12:15 – 12:19	15

12:20 – 12:24	8
12:25 – 12:29	22
12:30 – 12:34	12
12:35 – 12:39	21
12:40 – 12:44	20
12:45 – 12:49	6
12:50 – 12:54	20
12:55 – 12:59	9
13:00 – 13:04	23
13:05 – 13:09	5
13:10 – 13:14	21
Total	**322**

Table 11: Mango standard working rate data 31Jan

Total time: 100 min

Total sorted: 6363.33 kg

Standard working rate: 272.71 kg/mhr

02 February 08:20

Interval	Frequency (No of lugs)
08:20 – 08:24	21
08:25 – 08:29	9
08:30 – 08:34	8
08:35 – 08:39	19
08:40 – 08:44	15
08:45 – 08:49	23
08:50 – 08:54	16
08:55 – 08:59	20
09:00 – 09:04	8
09:05 – 09:09	0
09:10 – 09:14	0
09:15 – 09:19	0
09:20 – 09:24	14
09:25 – 09:29	11
09:30 – 09:34	18
09:35 – 09:39	20
09:40 – 09:44	15
09:45 – 09:49	9
09:50 – 09:54	13

09:55 – 09:59	1
10:00 – 10:04	0
10:05 – 10:09	20
10:10 – 10:14	26
10:15 – 10:19	24
10:20 – 10:24	22
10:25 – 10:29	25
10:30 – 10:34	27
10:35 – 10:39	8
10:40 – 10:44	27
Total	**419**

Table 12: Mango standard working rate data 2Feb

Total time: 145 min

Total sorted: 8280.24 kg

Standard working rate: 244.74 kg/mhr

Summary of Standard working rate

Date	Standard working rate (kg/mhr)
31 January	272.71
2 February	244.74
Average	**258.73**

Table 13: Summary of mango standard working rate

More extensive work studies will be done in October when the mango lines are fully operating to obtain a more accurate efficiency reading.

Papaya standard working rate data

Interval	Frequency (No of lugs)
08:40-08:44	22
08:45-08:49	30
08:50-08:54	26
08:55-08:59	30
09:00-09:04	36
09:05-09:09	29
09:10-09:14	20
09:15-09:19	23

09:20-09:24	22
09:25-09:29	13
Total	**251**

Table 14: Papaya standard working rate data 29May

Total time:	50 min
Total sorted:	4518 kg
Standard working rate:	271.08 kg/mhr

AppendixB: Visual Basic Code

```
Public Cnter As Integer
Dim Sorted(6) As Integer
Public cleared As Boolean
Public fruitindex As Integer
Sub Calc()
    If Not cleared Then
        ClearArray
        cleared = True
    End If
    Dim idx As Integer

    Dim FruitName As String
    Dim Rate As Double
    Dim ref
    Dim amount As Double
    Dim Hours As Double
    Dim results As Range
    amount = CDbl(TextBox1.Text)
    Hours = CDbl(TextBox2.Text)
    If Hours >= 1# And Hours <= 11 Then

    idx = Sheet1.Range("C3").Value
'    ref = Application.Workbooks(1).Names("Fruit").RefersToRange
    ref = ThisWorkbook.Names("Fruit").RefersToRange
    FruitName = CStr(WorksheetFunction.Index(ref, idx)(1))
    If Not CheckFruit(idx) Then

    Sorted(fruitindex) = idx
    fruitindex = fruitindex + 1
    Rate = CDbl(Sheet2.Range("B" & (1 + idx)).Value)
    Set results = Sheet1.Range("A" & (9 + Cnter), "E" & (9 + Cnter))
    results.Item(1, 1) = FruitName
    results.Item(1, 2) = CStr(amount)
    results.Item(1, 3) = CStr(Hours)
    results.Item(1, 4) = Rate
    results.Item(1, 5) = WorksheetFunction.RoundUp(amount / (Hours * Rate), 0)
    Cnter = Cnter + 1
```

```
    Else
        MsgBox "You have already added information for " & FruitName & ". Please select another fruit."
    End If

        Else
         MsgBox "You entered " & CStr(Hours) & " hours. The maximum hours available is 11 hours, and minimum hours is 1 hour."
        End If


End Sub
```

```
Sub ClearArray()
Dim I As Integer
I = 0
For I = 0 To 6
    Sorted(I) = -1
Next


End Sub
```

```
Function CheckFruit(ByVal ID) As Boolean
    Dim I As Integer
    I = 0
    Dim found As Boolean
    found = False

    For I = 0 To 6
        If Sorted(I) = ID Then
            found = True
        End If
    Next
    CheckFruit = found


End Function
```

```
Sub Clear()
    Sheet1.Range("A9", "E13").Clear
    Cnter = 0
    ClearArray
    fruitindex = 0
End Sub
```

```
Sub Submit()

If CInt(Sheet1.Range("A3").Value) = 1 Then
    For I = 0 To 6
       If WorksheetFunction.Text(DTPicker1.Value, "DDD") = Sheet3.Range("B" & (I + 4)).Value Then
           Sheet3.Range("E" & (4 + I)).Value = Sheet1.Range("E14").Value
           Sheet3.Range("A" & (4 + I)).Value = DTPicker1.Value
       End If
    Next
Else
    For I = 0 To 6
       If WorksheetFunction.Text(DTPicker1.Value, "DDD") = Sheet4.Range("B" & (I + 4)).Value Then
           Sheet4.Range("E" & (4 + I)).Value = Sheet1.Range("E14").Value
           Sheet4.Range("A" & (4 + I)).Value = DTPicker1.Value
       End If
    Next
End If

    Dim idx
```

```
Dim J As Integer
Dim found As Boolean
J = 0
found = False

While Not found
    Dim b
    b = Sheet5.Range("A" & (2 + J)).Value
    If b = Empty Then
        found = True
    Else
        J = J + 1
    End If
Wend
If Not Sheet1.Range("A10").Value = Empty Then
    Sheet5.Range("A" & (2 + J)).Value = WorksheetFunction.Index(Sheet2.Range("A10", "A11"), Sheet1.Range("A3"))
    Sheet5.Range("B" & (2 + J)).Value = DTPicker1.Value
    Sheet5.Range("C" & (2 + J)).Value = Sheet1.Range("A10").Value
    Sheet5.Range("D" & (2 + J)).Value = Sheet1.Range("B10").Value
    Sheet5.Range("E" & (2 + J)).Value = Sheet1.Range("E10").Value
End If


If Not Sheet1.Range("A11").Value = Empty Then
  Sheet5.Range("A" & (3 + J)).Value = WorksheetFunction.Index(Sheet2.Range("A10", "A11"), Sheet1.Range("A3"))
  Sheet5.Range("B" & (3 + J)).Value = DTPicker1.Value
  Sheet5.Range("C" & (3 + J)).Value = Sheet1.Range("A11").Value
  Sheet5.Range("D" & (3 + J)).Value = Sheet1.Range("B11").Value
  Sheet5.Range("E" & (3 + J)).Value = Sheet1.Range("E11").Value
End If


  If Not Sheet1.Range("A12").Value = Empty Then
      Sheet5.Range("A" & (4 + J)).Value = WorksheetFunction.Index(Sheet2.Range("A10", "A11"), Sheet1.Range("A3"))
      Sheet5.Range("B" & (4 + J)).Value = DTPicker1.Value
      Sheet5.Range("C" & (4 + J)).Value = Sheet1.Range("A12").Value
      Sheet5.Range("D" & (4 + J)).Value = Sheet1.Range("B12").Value
      Sheet5.Range("E" & (4 + J)).Value = Sheet1.Range("E12").Value
  End If

  If Not Sheet1.Range("A13").Value = Empty Then
      Sheet5.Range("A" & (5 + J)).Value = WorksheetFunction.Index(Sheet2.Range("A10", "A11"), Sheet1.Range("A3"))
      Sheet5.Range("B" & (5 + J)).Value = DTPicker1.Value
      Sheet5.Range("C" & (5 + J)).Value = Sheet1.Range("A13").Value
      Sheet5.Range("D" & (5 + J)).Value = Sheet1.Range("B13").Value
      Sheet5.Range("E" & (5 + J)).Value = Sheet1.Range("E13").Value
  End If

  If Not Sheet1.Range("A14").Value = Empty Then
      Sheet5.Range("A" & (6 + J)).Value = WorksheetFunction.Index(Sheet2.Range("A10", "A11"), Sheet1.Range("A3"))
      Sheet5.Range("B" & (6 + J)).Value = DTPicker1.Value
      Sheet5.Range("C" & (6 + J)).Value = Sheet1.Range("A14").Value
      Sheet5.Range("D" & (6 + J)).Value = Sheet1.Range("B14").Value
      Sheet5.Range("E" & (6 + J)).Value = Sheet1.Range("E14").Value
  End If

  Clear

End Sub
```

```
Private Sub DTPicker1_CallbackKeyDown(ByVal KeyCode As Integer, ByVal Shift As Integer, ByVal CallbackField As String, CallbackDate
dteDateSelected = DTPicker1.Value
End Sub
```

```
Private Sub Workbook_Open()

    Sheet1.ClearArray
    Sheet1.fruitindex = 0
    Sheet1.cleared = False
    Sheet1.Clear

Application.ScreenUpdating = False
Workbooks.Add
ActiveWindow.Close
Application.ScreenUpdating = True



End Sub
```