PETRI NET MODEL
FOR
TIRAMISU BUSINESS

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Developed by:

Roland Schurig

Prerana Shamsundar Punjabi

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Executive Summary

Tiramisu is a popular coffee-flavoured Italian dessert. To start a business for making Tiramisu on a wide scale with the help of our family members and friends, we have developed a Petri Net Model.

Aim of this model is to represent the task done by the helpers, to efficiently utilize the resources and the ingredients in the best possible way of their availability within their respective time frame.

In the current setting our general business day starts with the processing of eggs and coffee from the store by *Helper1* and *Helper4* respectively. Next, the *Helper1* transits the processed eggs to *Helper2* and *Helper3*, which initiates the processing of cream. Parellely, *Helper4* prepares the biscuit base. When the cream and biscuit base are ready the layering process is initiated by the available Helper. Once the layering is finished, the dish is now wrapped with plastic and is refrigerated for 2 hours. After 2 hours, Tiramisu is dusted with cocoa and is served. This process of making many tiramisus is continued and processed parellely with the available Helpers during a business day.

The whole process of making Tiramisu is represented by PETRI NET model for easy understanding and also to address the enterprise problem to reach the business goal.

The final outcome of this PETRI NET modelling is to prepare Tiramisu indeterminately, by avoiding the over production of intermediate products or excessive storage of resources. Additionally, the model must also be designed such that there is no shortage of ingredients during a business day.

1 Model Description

Design Description:

The Main Aim of developing this Model was to involve appropriate number of helpers who can perform their task **concurrently** and also be **synchronized.** This is achieved by controlling the rate at which the intermediate products are being prepared in alignment with the production of the final item. To accomplish this, the developed model uses 4 Helpers (the enumeration of their task are as mentioned below)

Working Members	Task Assigned
Helper1	1. Separates the Egg whites and the yolks 2. Monitors all the ingredients required for preparing Tiramisu and is also responsible for buying / restocking of all the Ingredients
Helper2	Prepares the Yolk mixture by adding brown sugar, vanilla sugar and Mascarpone.
Helper3	1. Whip's the Egg White 2. Adds egg whites to the Mascarpone Mixture 3. Responsible for layering of Tiramisu 4. Refrigerates the Tiramisu 5. Dusts the cocoa on the cooled Tiramisu and serves them to the customers.
Helper4	1. Prepares Hot coffee 2. Adds Marsala to Hot coffee 3. Dips the biscuits in the coffee mixture and arranges these biscuits into the dish for the Layering process.

TABLE 1: TASK DONE BY EACH HELPER

In order, to have a **simplified** and a **compact** approach in our business model, we have identified the various transitions and places that would be required in the preparation of one dish of Tiramisu. The below table lists the predicate associated with each place and transition that have been identified.

Places / Transitions	Actions
Eggs Used	Triggered when enough eggs (Min. - *3 eggs*) are available to make one Tiramisu **Note**: '*Helper1*' will restock the ingredients, when the quantity of the resources reduces
Separate Y & W	'*Helper1*' is separating the *Egg Whites* from its *Yolks*. Once done '*Helper1*' will be released at transition 'T1'
Yolk	Initiate the process of making the cream from the egg yolks
White	Initiate the process of making the cream from the egg whites
Mix sugar	'*Helper2*' mixes the egg yolks, brown sugar and vanilla sugar.
Mix Mascarpone	'*Helper2*' adds Mascarpone to the *Yolk-Sugar* mix. Once the mix is ready '*Helper2*' is released during transition 'T8'
Whip white part	Concurrently '*Helper3*' beats the egg whites to form stiff peaks
Add egg & mixture	'*Helper3*' adds the Mascarpone mixture to the whipped egg white.
Cream is ready	*Helper3* splits the mixture into ***three*** units and keeps it ready to begin the **Layering process**.

Make hot coffee	In concurrency to *Helper1* - '*Helper4*' makes hot coffee
Mix Hot Coffee & Marsala	'*Helper4*' adds '*Marsala*' to the Hot coffee.
Dip biscuits & put on dish	'*Helper4*' dips the biscuits in the coffee mixture and place them on a 19 cm square dish
Biscuits base is ready	'Helper4' splits the Biscuit base into **three** unit and keeps them ready to begin the **Layering process**.
T9	Once the 3 parts of Mascarpone mixture and Biscuits base are available this transition is triggered and the Layering of Tiramisu Process is started.
Current num of layers in the dish	This place acts as a counter to indicate that the '*Helper*' is arranging layers of the Mascarpone mixture and the biscuit base alternatively into the Tiramisu Dish. This process is repeated thrice.
T15	The Layering Process is completed.
Cool & Refrigerate	The Tiramisu is covered and kept inside the refrigerator for 2 hours.
Tiramisu complete	After 2 hours the '*Helper*' dusts cocoa over the desert and serves. Both the available helpers are released. **Note:** The process of making **Tiramisu continues indeterminately**.

TABLE 2: PLACES AND TRANSITIONS USED

The developed Model has been segregated into three main sections:

1. Preparation of the Cream
2. Preparation of the Biscuit Base
3. Layering of Tiramisu

- **Preparation of the Cream:** '*Helper1*' performs the separation of the egg whites from its yolks. Once the separation is done, '*Helper2*' and '*Helper3*' will concurrently carry out further processing of the Cream. '*Helper3*' performs the whipping of the egg whites and 'Helper2' mixes the eggs yolk with brown sugar and vanilla sugar, then 1 pot (i.e. 1 token) of Mascarpone is added to this mixture. Once the Mascarpone mixture is ready '*Helper2*' is released. And '*Helper3*' continues the process by adding the whipped egg whites to the Mascarpone mixture.
- **Preparation of the Biscuit base:** In parallel to the Preparation of the Cream '*Helper4*' initiates the process of preparing the biscuit base. The process is started by preparing hot coffee and then adding Marsala to it. Then the biscuits are dip in this mixture and laid onto the dish for further processing.
- **Laying of Tiramisu Layers:** Two Helpers – '*Helper3*' and '*Helper4*' are allocated to accomplish this task. The available helper will start layering the dish with first, the Biscuit Base and then the Cream, this is repeated 3 times. To indicate this scenario in the developed model we have used a counter that is initialized with 3 tokens, the token is decremented every time a new section of layering is completed. Once the layering is done, the helper covers the tiramisu dish and refrigerates it for 2 hours. The cooled tiramisu is dusted with cocoa and served.

Additionally, to **Speed** up the preparation of Tiramisu, we have identified task that can be performed concurrently, for instance –

i. '*Helper1*' and '*Helper4*' start their task concurrently, once *'Helper1'* is released and the yolk and white transitions are triggered, now 3 helpers - '*Helper2*', '*Helper3*' and '*Helper4*' shall perform their respective tasks in parallel.

The Model shows a **Fair distribution** of tasks among the helpers, none of the Helpers are over loaded and the task distribution has been performed considering this in mind.

For instance - '*Helper1*' has a task to separate the egg whites and yolk. To balance the time and task distribution helper1 is also assigned the task to monitor all resources and to restock the storage. The Helper monitors the quantity of the ingredients and once the quantity reaches the critical amount (critical amount is the amount of ingredient that can used to prepare only one tiramisu), He restocks the storage.

'*TIRAMISU MODEL*' has been developed using PETRI NETS, the below figure provides a diagrammatic representation of the above mentioned details.

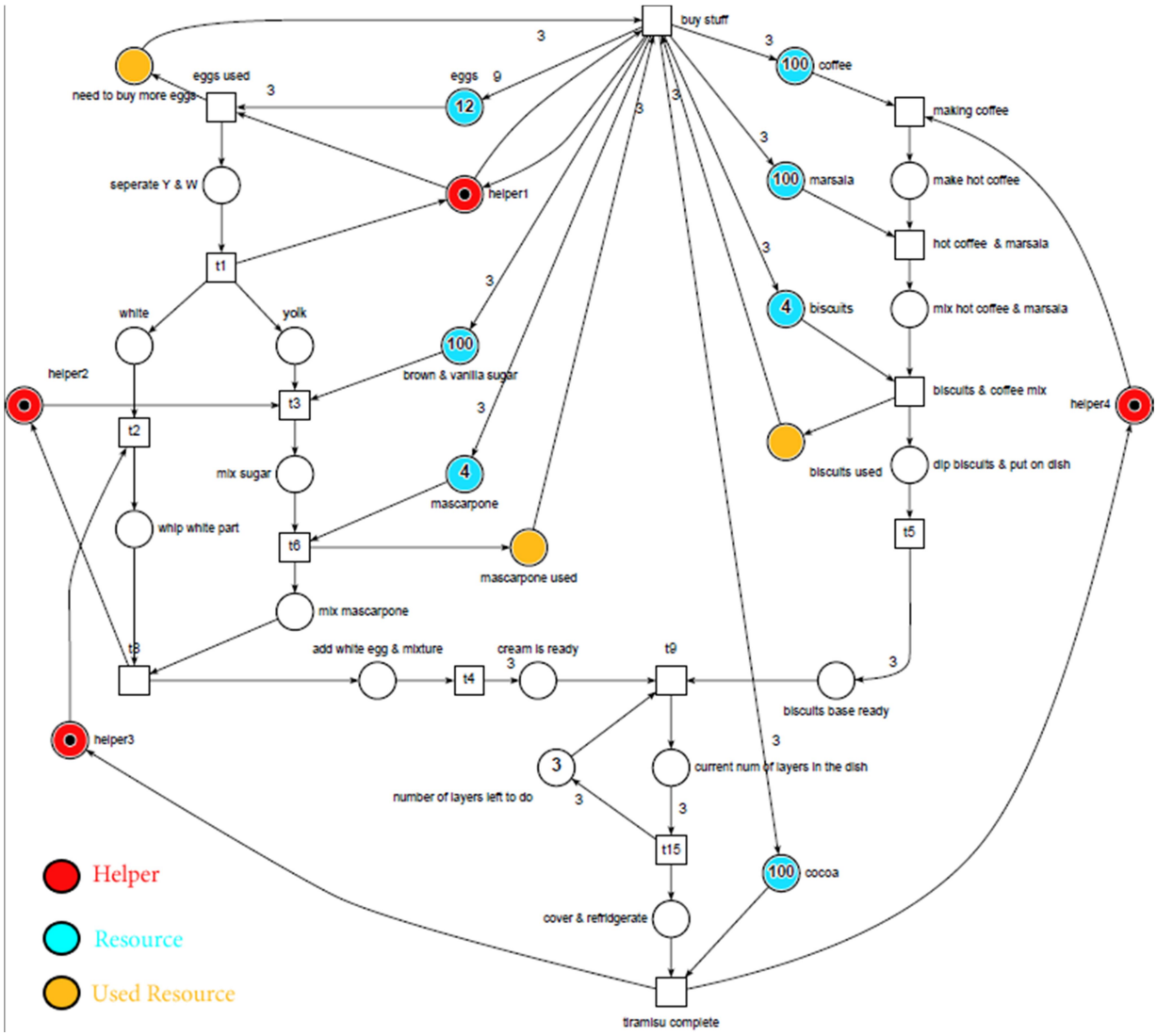


FIGURE 1: TIRAMISU MODEL

2 Assumptions

According to the problem statement we have assumed that at the start of a business day, the storage consists of

i. 12 Eggs, 4 pots of Mascarpone, 4 Packets of biscuits.
ii. The quantity of the other ingredients namely (Brown sugar, Vanilla sugar, Coffee, Marsala and Cocoa) are much higher than the quantity of the eggs, mascarpone and biscuits, hence they had to be considered as always available. For representation 100 tokens were allocated for each of them.
iii. The [**Token –to- Actual Quantity Mapping**] for each ingredient required to prepare one dish of tiramisu is given in the below table. It is assumed that one measurement unit corresponds to one token in PETRI NET.

The measure of ingredients to prepare 1 dish 19cm square dish of Tiramisu is as follows:

Ingredients	Measure	Measure in Terms of Tokens
Eggs	3 eggs	3
Mascarpone	1 pot (250 grams)	1
Biscuits	1 packet (24 biscuits)	1
Brown Sugar	100 grams	1
Vanilla Sugar	1 packet	1
Coffee	1/2 litre	1
Marsala	1/2 cup	1
Cocoa	30 grams	1

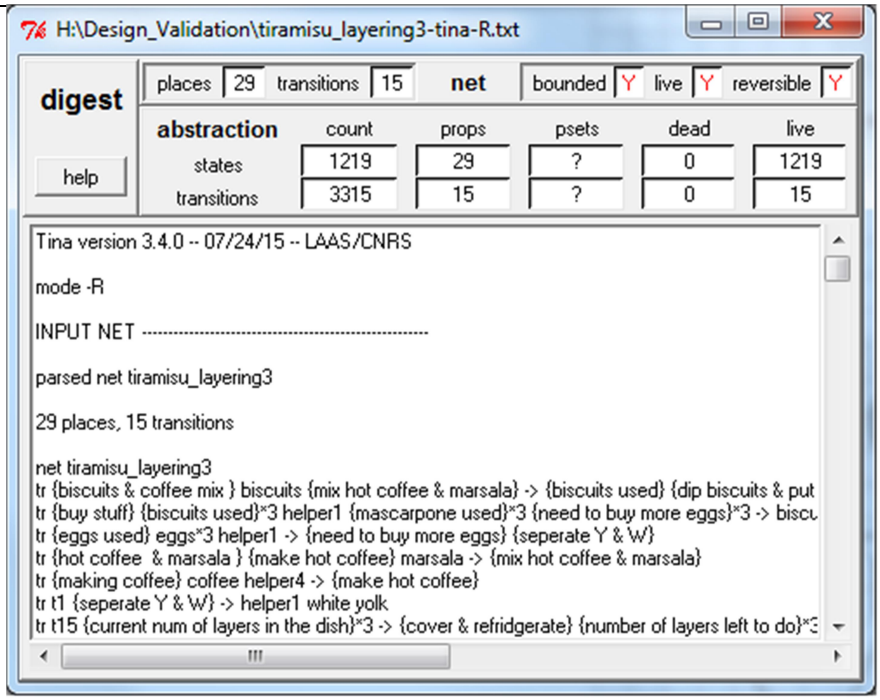
TABLE 3: INGREDIENTS REQUIRED TO PREPARE 1 DISH OF TIRAMISU

iv. In PETRI NETS two transitions cannot be fired at the same instance of time, due to this the Model that is developed executes task that appear to be concurrent. A virtual concurrency is achieved.

3 Reachability Analysis


ReachabilityAnalysis.txt

The Reachability Analysis of the developed Model is obtained from Tina, which confirms that the Model is **Bounded**, **Live** and **Reversible**. The below screenshot has been captured to indicate the same.



The detailed report that was generated during the analysis has been attached for further reference.

Live -> Our model is deadlock-free

Reversible -> Our model can go back to its initial state from any marking

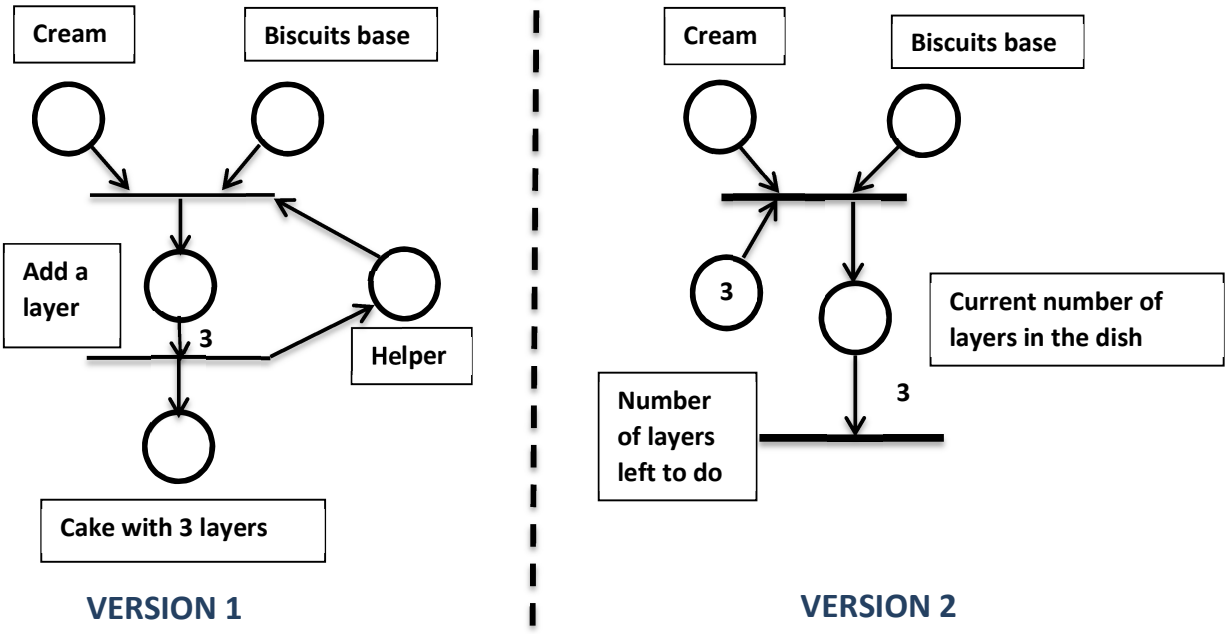
Bounded -> There is a maximal number of tokens for all markings

4 Challenges Encountered

There were few interesting challenges encountered in the development of this Model. To accomplish the final Model that has been presented here we had 2 iterations. Few of the changes that have be adapted are mentioned in detail below.

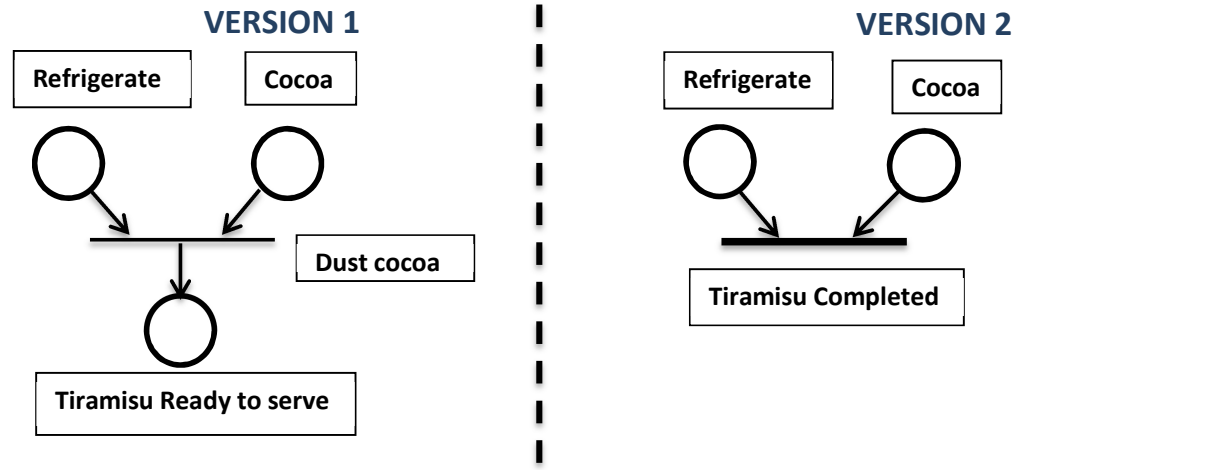
1. **The Layering Process**: The first version of the model was developed using '**Top Down Approach**' (where in few section of the model was not represented in detail). For instance the layering part that was developed earlier did not indicate how the layering was achieved and neither had it showed the number of times the layering was performed. However, this Model lacked clarity and did not match a real time scenario, as the helper was just producing a layer rather than adding a layer to the dish.

   Therefore, a looping mechanism was introduced and few more transition and places were added to indicate that the Cream and Biscuit Base were divided into 3 units. Later the Helpers would add these into a dish by layering them alternatively.
   As shown below: The Place – '*Number of layers left to do'* adds a token to the transition every time a layer (1/3 part) of the biscuit base and cream has been received.



2. Version 1 of the developed Model utilized 5 Helpers. Helper3 and Helper4 were freed at Transitions T4 and T5 after the preparation of Cream and the biscuit base. Helper5 performed the Layering of Tiramisu. With This model we observed that the intermediate products were accumulated in much higher number than the final product (which resulted in an Unrealistic model / An Industrial Model). This is because Tina fires the transition randomly and the time taken to accomplish a task is not taken into account in the tool Hence to avoid such scenarios and to developed a Realistic Model Helper 5 was removed and the helpers were synchronized.

3. Version 1 of the developed Model had a place dedicated after the last transition to indicate the numbers of Tiramisus that had been successfully prepared. This place has been removed as, when the reachability analysis was performed on the first version of the model, it was observed that the model was unbounded due to infinite number of tokens being stored in the last place. Hence to demonstrate a bounded, live and reliable model we had to remove this last place.



5 Conclusion

The development of Tiramisu Model gave us the opportunity to learn to model a PETRI NET in Tina. The session gave us a unique exposure to realize a real time business model and provided us with an insight on the “Industrial aspect of business modeling”.

Additionally, as a team we could share our view points and understand each other’s ideas and come up with a common solution. This seemed to be an interesting part of the project as each of us come from a different technical background and culture and we have our own unique ways to approach a given problem and find solutions.

Nevertheless, in the end we were able to develop a Deterministic, Reliable, Reversible and a Live PETRI NET Model for a small scale business.