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A Review of Methodologies for Automating a Simulation Process

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Abstract - Today's world is run by technology, wherein every field the primary aim has become to reduce manual intervention and reduce efforts put by humans. This reduction of effort helps in increasing value-added time and decreasing the nonproductive or the non-value added time. A few of the tasks such a creating a simulation model that requires heavy manual efforts has been a common topic for researches to automate and improve. If today the time taken to manually create a model can reduce then this can lead to saving not only time and also knowledge as then the application can be given more importance than the labor in building the model. This paper concentrates on automating the simulation model building process and speaks of the different approaches taken up by various authors to help automate it. The approaches are based on data, common tools or artificial intelligence.

***Keywords* — artificial intelligence, automation, data-driven, methodology, non-value added, simulation**

I. INTRODUCTION

Automation of any kind can only be performed once complete manual effort can be eliminated and the process can be automatic and automated in nature. Automation has played a key role in Industry 4.0 development and has become an increasingly famous topic to research and develop on by scientists. Automation of any kind has always be developed to reduce human labor and ease the working of humankind. Thus by automating something as complex as a simulation, the layman who has no prior knowledge of simulation also gets the courage to perform and improve its system's performance at little no additional costs to incur.

The manufacturing simulation is a simulation technique that uses computer modeling to virtually test manufacturing methods, processes and procedures; such as production, assembly, inventory, and transportation. This is done to reduce the time and costs that physical testing of a manufacturing system incurs. It pertains to replicating a plant such that a better understanding of its behavioral pattern and any foreseeable conditions can be predicted through the model. But simulation itself is a time-consuming the process which includes productive and non-productive time. This paper aims to understand how different authors have identified this problem. This paper discusses the various approaches taken up by the authors to tackle this problem.

II. PROBLEM STATEMENT

Simulation process is a tiresome and repetitive process, which takes a lot of time and effort. A lot of results and analysis derived from simulation can be done faster if this entire process would have been automatic in nature. It has been noticed that more than 20-25% time goes in model building and creation, this time is completely non value added and redundant in nature.

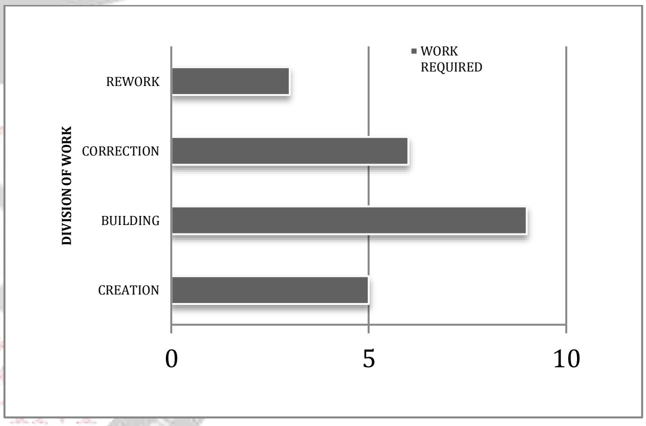

Fig 1.0- Work Division without automation

This causes the following problems:

1. Delayed analysis
2. Late deliveries
3. Longer time for model building

A. *Why to Automate?*

Automation can be described as a technology by which the method or a process requires little or minimal human assistance and support. Through research, it has been found out that automation helps makes tasks easier and increases production rates. A process such as simulation, where heavy manual assistance is required, introducing the concept of automation can help reduce the errors and makes the simulated models flexible to more change which can be performed is a lesser time limit.

Thus the advantages of automating a simulation model is as follows:

- It makes model building more flexible
- Requires less time to build models
- It reduces manual efforts

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- Makes the model more dynamic in nature
- Helps develop better models

B. Concept of Automating

Through research it has been found that at least 20-25% of the time taken by model builders in building the model and this effort spent in model building is regarded extremely futile in the age of this high technology available. Several authors have had different approaches to the problem of the human intervention needed to build the models. Authors MikeBarth ' AlexanderFay in their paper speaks of the automatic generation and states that it builds the base to overcome the manual effort that is normally needed for simulation-based test applications. With their approach, the use of simulation models can be focused on the test applications themselves and not on the modeling procedures.

III. Aim & Objectives

A. Aim

The aim of this case study is to understand how a simulation process can be automated. This includes understanding the input required to build such a system, expected outputs and the basic methodology to build this process.

B. Objectives

The objective is to

- Reduce manual efforts in building the model
- Create a model completing through automation
- To be able to deliver and rework models faster

IV. Approach Design

Automation of a simulation can be implemented in several ways. As simulation includes simulation of plants, models, parts and technology, different ways have to be implemented to automate the individual processes. Thus the following paragraphs discuss the various approaches.

In this paper, 4 main approaches are considered, these approaches have been inspired by the works of other authors, who are Charu Chandra[8], Raymond Hill[2][3], Ivona Zakarija, Frano Škopljanac-Mačina & Bruno Blašković [5]and Avelino J. Gonzalez, Michael Georgiopoulos, Ronald F. DeMara, Amy Henninger, William Gerber[10]. Through this we can understand the various methods that can be deployed to undertake the mammoth task of automating the process of simulation and modeling. Each author has discussed their unique approach and the following will help us understand the basic methodology to execute it.

A. Data-Driven Approach

The data driven approach is the first approach, where the data is considered the main element to automate a simulation.

In the paper written by Charu Chandra[9][8], he speaks of a data-driven approach to create and automate models. The paper focuses on the preliminary analysis of multi-stage, multi-product manufacturing systems. To reduce the model building efforts, the units are approximated using a generic representation that focuses on common functions, and utility of the units. These include the flow, material handling, incoming and outgoing flow of products, movement of the material and transfer of the same. The main ideology behind this approach is to use the data to create as many templates as possible; these templates are later modified automatically by the interface. The automation of the model is attractive as 1) it includes the fact that most of the stations are following a similar pattern and can be easily replicated 2) by reducing the manual intervention they are decreasing the error possibility 3) it will be a much faster approach for model creation.

The created model follows to main criteria

- Separate the data and the model
- Represent the model in a generic form

The data is collected from various areas and recording tools. This collected data is used to build the model. The model will be created based on a predefined template. This template will not have any simulation objects but only control methods and procedures such that control of generic functions and data declaration can be done. All the procedures follow the same design and also perform a similar activity Thus, different management policies can be analyzed.

The model building the procedure can be understood from the following steps:

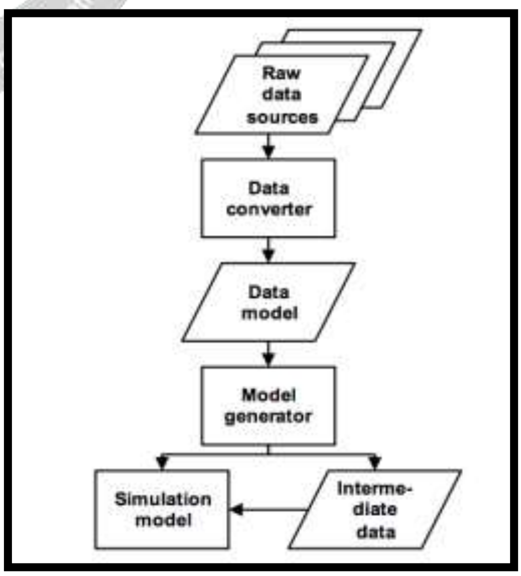

Fig 2.0(charu chandra 2002)[6]

A.1. Creation of data model

Collecting data from different points and nodes creates this data model. It includes data on model structure, properties of units, outside world interaction, etc. The data from

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various sources is taken into consideration and this raw data is put in the ontology system. An ontology system helps put the data into perspective. The output of the ontology is that the data gets converted into a format that can be used to create a data model. A data model is nothing but a database that stores all the relevant templates and data. This data model is then used to create a simulation model.

A.2. Simulation Model

A simulation model is automatically created using a model generator. The model generator creates one sub model for each generic unit.

A.2.1. How is this model created?

Using the data model creates this model. The simulation model is loaded with the data model. The intermediate data created is changed from the excel format to the format which the software will accept, in this the simulation software used is Arena. The intermediate data is mainly the data models saved in the excel sheets. Using the visual basic editor, the data from excels is converted into the format accepted by the arena. All these procedures whose data is collected are already included in the template. Using visual basic these templates are read and then later converted into the arena objects and entities such that the complete flow model can be created. Thus this is how the data fed into the templates are converted into the simulation model. Even though creating the template is a labor-intensive activity but once created it standardizes and eases the work of creating flow models.

B. Using Spreadsheets for Automating

In this approach, the spreadsheets have been used to automate the simulation process. To make the process of simulation easy to understand and execute the tool used for automation plays a huge role in this. Thus in his paper, Raymond Hill [2][4][3] suggests the use of spreadsheets to simulate the process. He expresses his strong views on how spreadsheets are the most easily used tool and commonly known hence should be used as a tool to create flows. He creates a dashboard through which basic data can be entered and a basic model can be created. The model is created using simquick [4] and shows how something as complex as a manufacturing simulation can be carried out by following simple steps. In his paper, he suggests the method by Hartvigsen *(2001) and* lists three steps of the model building using SimQuick:

- Conceptually build a model of the process
- Enter the model into SimQuick
- Test process improvement ideas with the model

This model concentrates on two simulation types, discrete event simulation and Monte Carlo simulation, which concentrates on the static and dynamic modeling respectively [1]. He uses this model to teach and explain to his students how the simulation works and allows displays of basic examples to display the working of the model. By using spreadsheets [5] for automating the process, we can eliminate the time wasted in learning new software. Thus this method focuses on the easy learning and implementation of the model building process.

C. Using Process Mining

Most organizations record very minute steps or detail of the processes. These data points can be considered as digital footprints that people are leaving behind as they move along a process. Process mining is a tool that organizes and captures each of these footprints and records the deviation of the system from its path. This technique is very useful for a manufacturing process as the simulation is done to primarily recording and predicts plant behavior thus by using the process mining the process of simulation can be automated. This approach was suggested by Ivona Zakarija, Frano Škopljanac-Mačina & Bruno Blašković (2020)[5]. The paper presented a novel and new idea for performing the automated simulation. These models were built using process mining techniques. They proposed based on the ‘Inductive machine learning method’. Through this method, even business process models based on actual event log data can be built. The model in the paper was built based on a hotel's Property Management System (PMS). The PMS can be considered as a Multi-Agent System (MAS) because it is integrated with a variety of external systems and IoT devices.

The data collected included the entry and exit of the guests and the staff, this data can be used to understand the process models and helped predict the behavior and pattern followed by the hotel and the idleness or business of the hotel. This simulation is very similar to manufacturing or plant simulation as the entry or exit of guests is similar to parts entering and exiting stations. This paper focused on the automated analysis of the discovered process models using formal methods. Spin model checker was used to simulate process model executions and automatically verify the process model. (SPIN, a tool for verifies the correctness of models using automation)

D. Using Expert Knowledge

In the paper by Avelino J. Gonzalez, Michael Georgiopoulos, Ronald F. DeMara, Amy Henninger, William Gerber (1998)[10], the authors speak of automating a CGF model development and refinement process using expert behavior. This approach concentrated on building models based on expert knowledge of soft computing. This method falls into the category of the model building using data and having a feedback mechanism through which we can learn about the pattern being followed. Thus this approach of simulation concentrated on teaching the machine or the software on how to update or change the model based on the new data entries. In this

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paper, the automating system is the neuro-fuzzy the system, [6] it works on both the fuzzy logic and the artificial neural networks. This system uses fuzzy logic where the analysis concentrates on the mathematical analysis and the neural network, which is based on feed forward, and feedback loops. This is the system the data enters and the bias is calculated by seeing the difference between the actual and the expected results. The paper includes:

- developing a framework
- Data collection
- Model building

At each given point of data collection expert knowledge and fuzzy and neural network systems are used to build and correct the models.

These are four main approaches implemented by authors to automate a simulation process. These approaches can be implemented in different scenarios; the following table discusses these scenarios.

Type / USES	DATA DRIVEN	SPREADSHEETS	PROCESS MINING	NEURO FUZZY
Plants	□□	□	□	□
Teaching	×	□	×	×
Models	□	×	□	□
Supply chain	□	×	□	□
Logistics	□	×	□	□

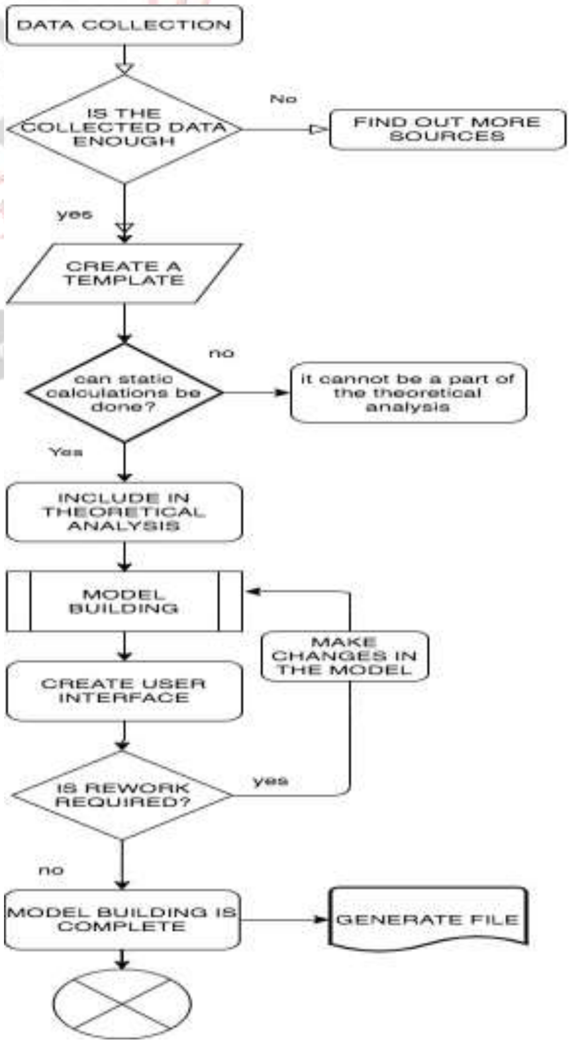
Table 1.0 – Usability of the Methodology

As shown in the table above, the usage of these approaches has been broadly classified into simulation used for plants, teaching, models, suplly chain and logistics simulation. As data driven method, process mining and neuro fuzzy system ie expert knowledge systems are all based on collecting heavy data and then analyzing the data and making a model based on it, these can be used used in a wide range of applications, wherein spreadsheets can only be used to develop flows of factories or other processes, as it was created keeping in mind that the tool should act as a tecahing aid and not a commercial tool to simulation. But the concept of using spreadsheets[5]to automate is a promising ideology as it includes using a simple tool which is easily available in all systems and using it to automate the process of model making by using few clicks of a button. In the detailed design approach, the advanatges of using this methodology over the others has been shown.

V. Material And Methodology

After acquiring the relevant information about the various approaches to automating a simulation process, this paper concentrates on developing a methodology to develop a process through which a simulation process can be automated.

The aim behind automating is that it will be to reduce the manual efforts and also the errors that get incorporated in the model due to the manual intervention. Thus the best method to solve this issue as suggested by various papers as well is to use machine learning. Machine Learning is an approach by which the software or tool itself can be taught how and why the plant or any other process is working in a certain manner. This learning will take place once relevant data ie input and output is fed into the system. The methodology behind creating the automated flow will be the same as suggested by Avelino J. Gonzalez, Michael Georgiopoulos, Ronald F. DeMara, Amy Henninger, William Gerber(1998)[10], in their paper of automating a CGF model. Their paper concentrated on building an automated model to predict vehicle patterns and behavior. A similar ideology can be suggested for a plant or any other process.



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A. Material

The tools required are as follows:

1. Coding language to form a structure and framework
2. Sensors to collect data
3. SPIN model/ Simqick to validate model

B. Methodology

Using the combined efforts of process mining and expert knowledge a simulation tool can be developed which can help simulate processes of any kind or nature. The basic methodology includes:

B.1. Data collection

The first initial and some important step towards building automated software of any kind are to collect relevant data related to the process or system [1]. This input data helps us understand the necessary scenarios that the software might have to deal with and helps record the deviation from the data, as this input data helps form a database. This database keeps a record of the various expected plant behavior, such that if at any given time the software can learn the expected behavior of the plant. Thus data collection and its importance can be understood from the application of machine intelligence in any field or domain. In the paper written by Wilfred Ralph Gonzales Gomez [9] focuses on building basic CAD models, which can be used as base templates to system simulation. He speaks of the data collection importance and describes how it is important to collect the necessary data as that acts as the main input which the developed system can be fed and the model can be based on the same. Depending on the simulation modeling that needs automating, the data needs to be collected. This collected data helps understand the actions that the model needs to perform. The collected data helps form a data model, which is used to understand how the system behaves in specific scenarios. For example for a manufacturing simulation, data such as machine availability, breakdown data, shift schedule, numbers of workers available etc. helps understand what the simulation is supposed to analyze.

B.2. Theoretical Analysis

For the simulation model to give the expected results from it's important for it to perform the required analysis or calculations such that the output can be correctly interpreted. This is done by understanding the model's requirements and performing a mathematical analysis of the model. This mathematical analysis includes error analysis and calculating the deviation of the system from its actual behavior. The development of fuzzy controls [6] and a neural network model can perform this analysis. The system will store the historic data and will use that to calculate the deviation in the system. The back propagation algorithm which reverses calculates the error points and identifies the input data calculates this deviation. This theoretical analysis includes system behavior and pattern recognition of system behavior. Before including and building this system, it is important to understand which soft computing principle will work the best for the required system and based on its desired performance this analysis can be performed.

B.3. Model Building

The main idea of building a simulation tool is to eliminate the manual intervention required to build any model. To do this after collecting relevant data and performing theoretical analysis, it becomes necessary to create a platform on which this can be completed integrated. This integration is carried out on the backend of the platform. The main concept behind building this model is to collect the data, store the data into data models in excel, create an application or use a preexisting tool such as excel, (like being done in simquick), where using VbA the model has been built. As per the inputs fed into the system the model is expected to update the database. The preexisting templates will also get revised based on the new fed data, and using the methodology that has been applied in simquick the entire model itself can be created. The model created can then be changed into a software readable format, as described by Charu Chandra[8]. Now the model has the ability to be also run dynamically in the simulation model, besides this creating a neuro fuzzy system the data inputted into the system can help calculate the deviation observed in the system. In the neuro-fuzzy system as suggested by Avelino J. Gonzalez, Michael Georgiopoulos, Ronald F. DeMara, Amy Henninger, William Gerber (1998)[10], the inputs are the new fed data and the membership functions are the functions created from the pre-existing data, thus these functions calculate the deviation and analyses the behavior of the simulation. The creation of such a technology though is complex and complicated but once performed has the ability to solve the entire problem of model building and development. Thus the programming done will ensure that the model is created and the behavior of the simulation is estimated through the analysis performed. This includes building the model using programming language and making the program as dynamic as possible such that it includes different scenario analyses. The model can be built using java, python or even C++. The model is supposed to record the different plant behavior and according perform when a similar data is given.

B.4. Create a User Interface

The user interface is what the customer sees and interacts with. The creation of this is of utmost importance as mentioned by Raymond Hill [2] repeatedly in his paper. This interface should have all the necessary buttons and should act and behave as an interface, which will show and present all the needed data. In the simquick dashboard we can see how various buttons and tabs are present, this is the

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first interface or sheet the user sees and is immediately able to understand how the system should work, as each button has its usage given. This dashboard is though simple but replicates the simulation carried out in any simulation software. In the picture below we can see how the simquick dashboard looks; taking inspiration from this a similar dashboard can be created.

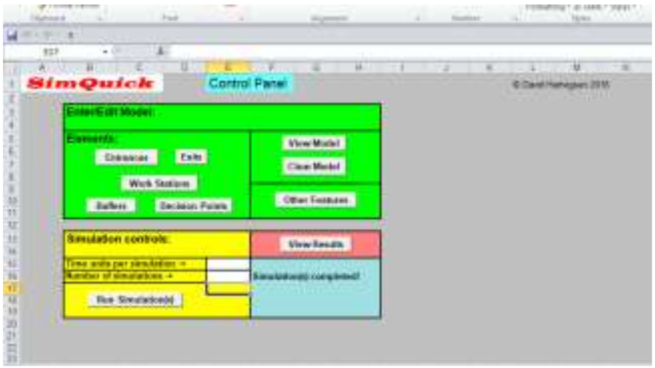

Figure 3.0- The simquick dashboard [11]

B.5. Rework and improve

The importance of checking the validity and credibility of any product or software is extremely important as this defines if it will be able to work in a real-time scenario or not. This credibility check is iterative in nature and depends on the deviation of the model behavior from its expected or desired results.

VI. Application Of Methodology

In this section we have focused on application of this methodology considering a hypothetical situation or scenario. This methodology can be used in various areas of use, such as to simulate plants, models, and also in system simulations such as hotels, or any other fields. In the paper by Ivona Zakarija, Frano Škopljanac-Mačina & Bruno Blašković (2020) [5], they used their methodology to automate the simulation of a hotel, where they used the simulation to understand the guest pattern and the areas of focus of the system. Similarly this methodology of automating a simulation has a wide range of application and can be used to even automate manufacturing flows, automobile movement, traffic prediction, spread of diseases etc.

Taking the example of a factory, where the simulation can be used for understanding the plant movement and the individual movement of parts, (as suggested by Charu Chandra (2002))[6][7]. We can use this methodology to automate the simulation process.

A. Implementation

STEP 1

The first step will include recording the various plant data such as, cycle time details, takt time, resource availability, shift patterns, any holiday data, maintenance of machines, breakdowns and failures of the machines. The rework station details, the details of the plant, work in progress details, details of delivery. This data is collected through sensors and directly from the plant managers. The importance of this data is that it helps make the system understand the plant behavior such that a predictive model of it can be made. The model will be of higher accuracy when the model is dealing with more scenarios and data points. This gives the model a predictive approach. The data that has to be collected from plants is as follows:

- Cycle time
- Shifts
- Number of workers
- Number of resources in use
- Machine breakdown data
- Machine Availibility
- Bottleneck stations
- Buffer Capacity
- Holiday and exception data
- Transportation/Logistics
- Delivery
- Inventory
- Dock Usage
- Tools and Equipement
- Takt time
- Part movement
- Facility design
- Placing of the stations
- Time spent by the worker to move from one point to another

This data helps develop a model that will exactly replicate the model. It is important to know how and where the parts, objects and people move such that the simulation model acts as a real life scenario. It will also help understand the ergonomic constrains. It's helps understand the complete model behavior. Data collected helps record the model, can understand the diversions that the model may be showing. This collected data, is processed and input into a system, which will help create a database, such that the stored data acts as a historic base through which model behavior can be predicted in a better fashion.

STEP 2

Theoretical_Analysis, it is important to understand the expected results from the simulation. This includes performing theoretical calculations to predict the model behavior. Theoretical calculations performed for a plant include calculating capacity, utilizations, idleness of stations, bottlenecks, throughput, available production hours, non productive hours, productive hours, worker ability, worker idleness, % of machine breakdowns, predicting machine breakdown, transportation time, non value added but necessary time like time used in transferring parts from one station to another etc., delivery time, etc. Thus we can say that from the data given we

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should be able to make as many inferences as possible. These inferences are static in nature, but will also have the ability to be dynamically updated as the database gets updated. Using standard formulas can do these calculations.

STEP 3

Model building includes, creating a backend processing and streamlining the data gathered such that any the pattern obtained can help understand the system diversion. Model building as suggested by Charu Chandra(2002) [6][7] includes creating a platform through which data is stored in the database, the model generator uses the database and the per existing templates to create the simulation model. This created model is converted into a software readable format and then can be run in the software.

STEP 4

The model building process should be such that any one can execute it with or without having enough software knowledge, to execute this the simulation needs to have a basic interface which the user or customer can interact with. This user interface is used as a dashboard where all the model parameters need to be fed and according the model behaves. This interface should include

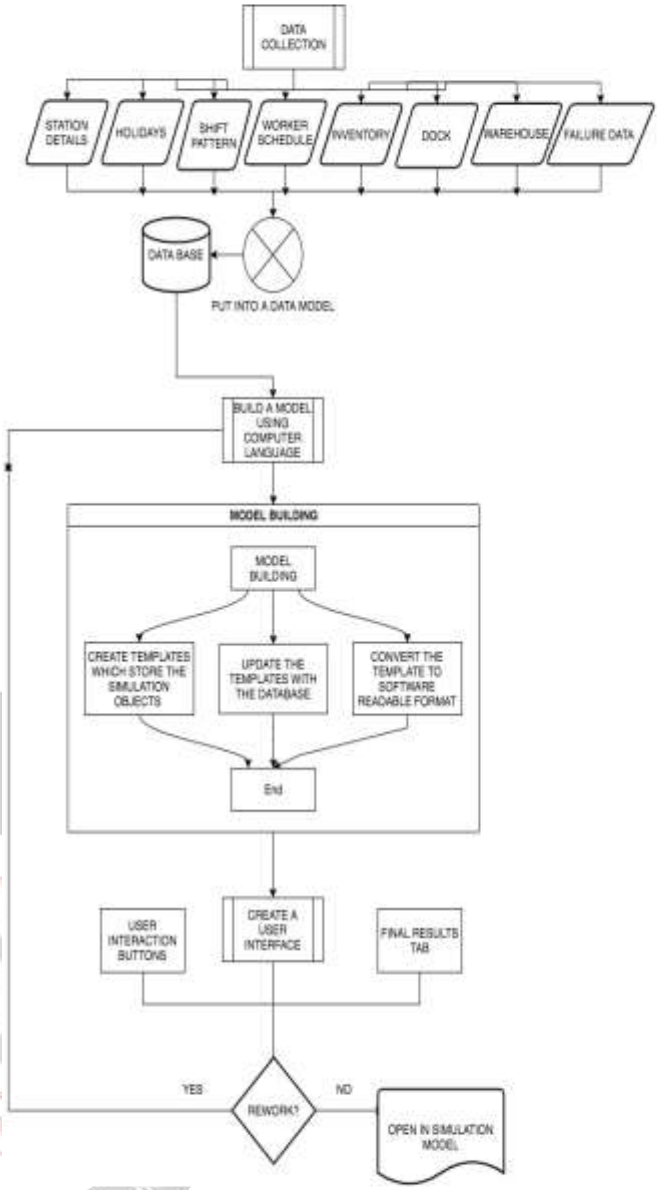
- Entering new data
- The number of times the simulation needs to run
- Seeing old data
- Running the model
- Saving the model
- Performing calculations
- Error proofing the data

This mainly acts as the last and most important step, as this needs to be as user friendly as possible, the user will be interacting with this and the easier it is for the user to use it the better will be the productivity and usage of the framework created.

STEP 5

This step is essentially interactive in nature, as it depends on the model building accuracy. As accurate the model performs the lesser will be the rework required.

The application of the methodology can be understood in detail through this flowchart.



VII. RESULT ANALYSIS

If the automation of the simulation process is done, it will be seen that the following reduction in time will take place.

Fig 3.0- Work division with automation

This shows that considerably the model building time reduces.

The methodology analysis of the approaches has been done as follows:

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METHODOLOGY					
APPROACH	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
DATA DRIVEN	DATA COLLECTION	DATA MODEL	DATA CONVERTER	MODEL GENERATOR	SIMULATION MODEL
SPREADSHEETS	DATA COLLECTION	DASH BOARD	SIMQUICK TEMPLATE	CREATE MODEL	
PROCESS MINING	DATA COLLECTION	PATTERN RECOGNITION	SPIN MODELER	SIMULATION MODEL	
NEURO FUZZY	DATA COLLECTION	ENTER DATA INTO NEURO FUZZY SYSTEM	STEAMLINE PROCESS	SEE DEVIATIONS	SIMULATION RUN

Table 2.0- Steps to implement the methodologies

VIII. Conclusion

The methodology discussed in this paper primarily focuses on automating the generation of a basic simulation model. This simulation model building process ensures that the model created includes little or no manual intervention. The methodology aims at identifying the key areas to collect relevant data. Using this data to identify a behavioral pattern and to build a standard template. When the user inputs the data the template gets modified and this modified template is then converted into the simulation model of particular software. The interaction of the user and the model is done by a user interface that acts as a dashboard or a mediator between the customer or user and the backend processing. Even though the approach or the idea to create a platform, which can identify the model requirements, is a mammoth task to develop but once created it makes the entire process of model building an easy and credible task.

Thus, from this paper we can conclude that by combining the approaches proposed by the above mentioned authors, we can combine the data driven, neuro fuzzy system, process mining and spreadsheets concepts to create one platform on which the simulation can be carried out. The end result of this creation will be following:

1. Faster model building
2. Better accuracy
3. Quicker calculation
4. Better delivery and development

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