Modeling and simulating the activities in an automobile repair shop using ARENA software – part 1

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Abstract. The automobile repair shop market is a highly competitive domain, also filled with opportunities; any competitive advantage can have a significant impact on the chances of success of a firm in this area of activity. The research contains two parts about modeling and simulating the activities in an automobile repair shop, by using ARENA software. Main steps are: simulating the firm's activities by using ARENA simulations software, analyzing the results, continuously seeking and implementing solutions to optimize the experimental model for an efficient use of the available resources. The analyzed automobile repair shop is performing the following services: concierge, diagnosis, mechanical repairs, bodywork and painting, maintenance and periodic technical inspections. Its activities will be simulated for a number of 289 vehicles in a 9600 minutes time interval, representing 20 working days of 8 h/day each, equal to an average working month. The statistical data are collected and studied; it can be observed that there are resources with a low degree of usage, yet with a high number of interventions performed, also others discrepancies in using human resources and equipment. The main results to be obtained are focused in the

1. Introduction

Most of the decisions that have to be taken concerning the activities of a firm require careful planning before implementation. The automobile repair shop market is a highly competitive one, but one that is also filled with opportunities. Therefore, any competitive advantage can have a significant impact on the chances of success of a firm in this area of activity.

Simulating the firm's activities by using a discrete event simulations software, like the Arena software, analyzing the results of the simulation, continuously seeking and implementing solutions to optimize the experimental model and to ensure an efficient use of the available resources, represents an important milestone in ensuring that the firm's activities are progressing smoothly [1].

By running a simulation using the Arena software, the effects of certain decisions are easier to understand and a positive outcome can be guaranteed with greater certainty, while choosing the optimal solution, from any number of possible solutions, becomes more accessible.

Arena is a discrete simulation and automatisation software, developed by Systems Modeling and owned by Rockwell Automation, which utilizes the SIMAN simulating language. In Arena, the user builds an experimental model using modules, which represent real-life processes or that have a role in the model’s logic. Connecting lines are used in order to link the modules or in order to set a certain process flow. Arena offers animation for the entities used, in order to better visualize the process flow. Also, a variety of statistical data can be recorded and shown, live during the simulation and as a report after the simulation has ended [2].
Arena also works very well with Microsoft-offered technologies, like Visual Basic (which is integrated into Arena), Visio, Excel and Access. By running a simulation using the Arena software, the effects of certain decisions are easier to understand and a positive outcome can be guaranteed with greater certainty, while choosing the optimal solution, from any number of possible solutions, becomes more accessible [3].

2. ARENA software overview
At the very core of modeling and simulating in Arena are the following concepts [2], [4]:

- **Entity** – any object that moves through the system. Each entity has its own characteristics named attributes.
- **Attributes** – objects that store data, associated with the entities. Each entity has its own set of attributes and an undetermined number of attributes can be assigned for each entity.
- **Variables** – objects that store data on a global level, used in order to store and modify the system state, at the beginning or during the simulation. Variables can be accessed, examined and modified from any of the model’s component.
- **Expressions** – objects that store data at a global level, used to store the value of an associated formula. For defining an expression any kind of variables can be used.
- **Stations** – the system’s elements in which the actual processing is happening.
- **Resources** – elements of the system that can be allocated to entities. Resources can represent persons, machinery or even storage space. There have a certain capacity and a set of states (for example: busy, free, inactive). A resource’s state can change and usually does changes during the simulation, within the defined limits.
- **Queues** – waiting lines for those entities for which movement through the model is temporarily suspended. Entities entry and exit to and from queues is achieved via modifying the elements’ associated state.
- **Sets** – allow the grouping of similar elements and referencing those elements through a common name. Virtually any element in a model may be assigned to a set. An element may also belong to multiple sets.
- **Sequences** – a set of ordered steps, that define a succession of stations that a certain entity has to visit. Sequences may also contain instructions about the entity’s processing in those visited stations.
- **Statistics** – data pertaining to a certain element, that Arena can collect during the simulations and later report the collected data as a report.
- **Modules** – objects used to build, represent and define the experimental model. There are two main types of modules:
  o Flowchart modules – describe the model’s process dynamics, the way in which the entities enter, go through and leave the model. Flowchart type models are usually interconnected.
  o Data modules – define the characteristics of the model’s elements (entities, resources, queues). Also, these modules can be used to define variables or expressions.

For modeling and simulating the automobile repair activities, only a few modules from “Common” module panel will be used: Arrive, Depart, Server, Inspect, Advanced Server, Sequences, Sets and Simulate.

3. Modeling and simulating the automobile repair shop activities

3.1 Summary of the automobile repair shop activities
The analyzed automobile repair shop is performing the following services for its customers: concierge, diagnosis, mechanical repairs, bodywork and painting, maintenance and periodic technical inspections.

The concierge services are there to assist the customer with assessing the damage/technical problems with his vehicle, both for insurance as well as repair purposes. The customer describes the damage to his vehicle or the problems he’s experiencing, after which the concierge assists him with...
filling an insurance claim, if necessary, and planning the repairs. The concierge plans and manages all the actions needed to ensure that the vehicle is repaired and given to the customer in excellent condition.

The diagnosis is performed by a professional technician and may either entail a basic diagnosis or a complete diagnosis. The basic diagnosis is simply an electronic reading of the vehicle data, using a specialized apparatus, while a complete diagnosis also includes a technical inspection of the vehicle’s components, in order to evaluate their status and compliance after which a report will be submitted, giving the technical status of the vehicle as well as recommendations for improving its condition [5].

Maintenance work and mechanical repairs are performed based on either the instructions received from the concierge or the result from a diagnosis. Any mechanical repair that includes replacing components will be performed only using new parts, either OEM (original equipment manufacturer) parts or parts produced in conformity with the manufacturer’s standards.

Bodywork and dyeing jobs include a variety of operations, like: disassembling body panels and ornaments, fixing and straightening body parts where possible, cleaning and degreasing body parts in preparation for the actual painting and reassembling the body parts when properly fixed and painted. All body parts will be repaired as long as the manufacturer’s imposed standards and tolerances can be respected. If there is a risk of compromising the quality and/or safety of the body panels, new parts will be ordered and installed. The dyeing will be done only after proper preparations and in suitable conditions, to ensure a quality paint job and colour matching with the rest of the bodywork as much as possible [5].

The periodic technical inspection is performed according to Romanian law and in accordance with the regulations imposed by the Romanian Auto Register (RAR).

3.2 Initial data
The automobile repair shop activities will be simulated using an experimental model developed in Arena, for a given time interval of 9600 minutes, representing 20 working days of 8 h/day each, which roughly translates into an average working month. The premise is that in a certain working station a certain intervention (or operation) is made on the vehicle. Each station has a distinct intervention, with a certain duration. A vehicle may need one or more interventions, which implies it must pass through one or more stations. The interventions that a vehicle may possibly need were grouped in intervention categories, based on the process flow they follow.

Table 1 presents the ten intervention categories, defined as model’s sequences, to which ten occurrence probabilities were assigned, following a cumulative distribution model. Table 2 centralizes the intervention categories and the length of time for each one.

| Intervention category (Sequence) | Occurrence probability | Intervention | Station(s) in sequence |
|---------------------------------|------------------------|--------------|------------------------|
| Diagnosis                       | 5%                     | Diagnosis    | Concierge              |
|                                 |                        | Diagnosis    | Final assembly         |
| Diagnosis and minor repairs     | 20%                    | Diagnosis    | Concierge              |
|                                 |                        | Minor repair | Minor repairs          |
| Intervention category (Sequence) | Occurrence probability | Intervention        | Station(s) in sequence |
|----------------------------------|------------------------|---------------------|------------------------|
| Maintenance                      | 5%                     | Maintenance         | Final assembly, Concierge |
| Minor repairs                    | 10%                    | Minor repair        | Final assembly, Concierge |
| Minor repairs, Bodywork and Dye-works 10% | | Bodywork            | Final assembly, Concierge |
| Major repairs                    | 10%                    | Major repair        | Final assembly, Concierge |
| Major repairs, Bodywork and Dye-works 25% | | Bodywork            | Final assembly, Concierge |
| Bodywork and dye-works           | 10%                    | Dye-works           | Final assembly, Concierge |
| Periodic technical inspection (ITP) | 3.5%                  | ITP                 | Final assembly, ITP |
| ITP and minor repairs            | 1.5%                   | ITP                 | Minor repairs, Final assembly |
Table 2. Intervention duration.

| Station       | Intervention                                      | Distribution used | Duration [min] | Minimum duration | Most probable duration | Maximum duration |
|---------------|---------------------------------------------------|-------------------|----------------|------------------|------------------------|------------------|
| Reception*    | Welcoming client                                 |                   | 5              | 15               | 60                     |                  |
| Concierge**   | Damage evaluation and concierge services          |                   | 15             | 30               | 60                     |                  |
| Diagnosis     | Diagnosis                                         | Triangular        | 30             | 40               | 60                     |                  |
| Maintenance   | Maintenance                                       |                   | 30             | 60               | 90                     |                  |
| Minor repairs | Minor repair                                      |                   | 60             | 120              | 180                    |                  |
| Major repairs | Major repair                                      |                   | 120            | 240              | 360                    |                  |
| ITP Station   | Periodic technical inspection                     |                   | 30             | 40               | 60                     |                  |
| Bodywork      | Bodywork                                          |                   | 60             | 120              | 180                    |                  |
| Dye-works     | Dye-works                                         | Discrete cumulative |               | Duration [min]  | 60 120 180 240 300 360 |                  |
|               |                                                   |                   |                | Probability [%]  | 15 20 40 10 10 5       |                  |

* The duration associated with this station do not represent the duration needed for an actual intervention, but the time interval between two successive customers entering the automobile repair shop.

** In this station no actual interventions on the vehicle are taking place, just an operation that needs to be done before certain interventions can take place.

*** The duration associated with this station is not relevant for the simulation proposed.

3.3 Structure of the experimental model
The model’s structures was built around the various departments in an automobile repair shop. Figure 1 presents the block diagram of the experimental model used to simulate the operation of the automobile repair shop.

The model’s core are the “Sequences”, which represent real life automobile repair activities in a structured form, following certain process flows and occurrence probabilities. The sequences depend upon the distribution models used as well as each station’s process’ duration [6]. Each station’s role and impact on the model is summarily described below:

- Reception – *Arrive* module
  - Simulates the process of the customers entering the repair shop and being welcomed by generating entities at varying intervals of time.
  - The entities are generated based on a triangular distribution, with the values presented in Table 2.
  - A time attribute registers the entity’s time of entering the model. When the entity leaves the model, the same attribute will mark the length of time the entity has spent inside the mode.
Each entity will be assigned an intervention category, based on a discrete cumulative distribution, with the occurrence probabilities presented in Table 1.

The entities are routed to the next station in sequence, Concierge.

Figure 1. Block diagram of the experimental model

- **Concierge – Server module**
  - Utilizes a resource with capacity set at 3.
  - The process time is determined based on a triangular distribution, with the values presented in Table 2.
  - The entities are routed to the next station in sequence, either Mechanical repairs or Bodywork.

- **Diagnosis, Minor repairs, Major repairs and Maintenance – Advanced Server modules**
  - Utilize a resource set of 5 resources, each with capacity set at 1, representing the mechanics in the repair shop. The resource set is shared between the four stations and the resources are seized based on a cyclical rule.
  - The process time for each station is determined based on a triangular distribution, with the values presented in Table 2.
  - The entities are routed to the next station in sequence, as shown in Table 2.

- **Bodywork and Dye-works – Server modules**
  - The two stations are closely linked, as there are no dye-works interventions without prior bodywork interventions, as per the designed sequences.
  - Each utilizes its own resource, with capacity 3 and 2 respectively.
  - The process times are determined based on the distribution models and values presented in Table 2.
  - The entities are routed to the next station in sequence, from Bodywork to Pain job, from Dye-works to Final assembly.

- **Periodic technical inspection – Inspect module**
  - Utilizes a resource with capacity 1.
o Has two branches, Pass and Fail. The entities that pass the inspection will be sent to exit the model. The entities that fail the inspection will follow sequence number 10.

- The failure probability is set at 0.01 for technical purposes, but the actual failure probability is determined through the initially set occurrence probabilities.

- Final assembly – Depart module
  - Simulates the process of the customers leaving the repair shop.
  - The entities generated by the Arrive module, which passed through the model, are being discharged by this module, with the collection of statistical data and the appropriate adjustment of counters and tally counters.
  - The station has no actual resources, its only purpose is to collect information and mark the model’s exit.

4. Results

The simulation proceeded yielded a number of 289 vehicles serviced by the automobile repair shop, in a time interval of 9600 minutes. The statistical data collected are presented Tables 3, 4 and 5. The number of serviced vehicles (Table 3), which represents practically the repair shop capacity, depends mainly upon the occurrence probability that assigns a certain number of vehicles to each intervention category. Still, the repair shop’s capacity is also influenced by each intervention’s duration and the resultant queue at each station, both factors which contribute to increasing the duration that each vehicle spends in the repair shop.

The occurrence probability is considered immutable in the experimental model proposed. In a real world scenario it would be at most a random, uncontrollable variable. Therefore, only the interventions durations can be adjusted, as the queues are a result of the stations capacities and the duration of the interventions at each of those stations. As the actual interventions durations cannot be reduced, we need to examine the queues, specifically the distribution of the queues in relation to the resource allocation, in hopes of optimizing the overall automobile repair shop efficiency.

| Intervention category | Serviced vehicles | Mean intervention duration [min] |
|------------------------|-------------------|---------------------------------|
| Diagnosis              | 18                | 119                             |
| Diagnosis and minor repairs | 83         | 279                             |
| Maintenance            | 10                | 146                             |
| Minor repairs          | 24                | 209                             |
| Minor repairs, Bodywork and Dye-works | 24        | 1390                            |
| Major repairs          | 31                | 959                             |
| Major repairs, Bodywork and Dye-works | 49        | 2207                            |
| Bodywork and Dye-works | 25                | 1227                            |
| Periodic technical inspection (ITP) | 20 | 47                             |
| ITP and Minor repairs  | 5                 | 206                             |

The data presented in Table 4 show that a large number of vehicles form queues at the Major repairs and Dye-works stations, which reflects negatively in the form of high waiting time for this stations. Not only that, but the delays caused by this two stations impact the whole process thereafter. Also, there is a high discrepancy between the lowest and highest mean waiting times. Correlating these observations with the results shown in Table 3 brings us to the conclusion that the high waiting
times and long queues for the Major repairs and Dye-works stations affect the entire repair show process flow and are an impediment towards higher capacity.

To find a possible solution to the identified problem, further study into resource distribution and usage is needed, as the available resources might be used in an uneven manner (Table 5). The degree of usage represents the percent of the total simulation time interval in which a certain resource were seized. A resource’s mean degree of usage shows the way in which that resource is used, and the distribution of the mean degree of usage between all of the available resources show how balanced the resource’s usage is.

Table 4. Station’s queue.

| Station                  | Waiting time [min] | Number of vehicles waiting |
|--------------------------|--------------------|----------------------------|
|                          | Min.   | Mean  | Max. | Min.   | Mean  | Max. |
| Concierge                | 0.056  | 7.642 | 0.002| 1      |
| Diagnosis                | 29.398 | 103.270 | 0.321| 5      |
| Maintenance              | 41.233 | 69.755 | 0.043| 1      |
| Minor repairs            | 49.333 | 216.570 | 0.797| 7      |
| Major repairs            | 739.830 | 2271.260 | 10.260| 24     |
| Bodywork                 | 9.533  | 94.714 | 0.146| 4      |
| Dye-works                | 1044.750 | 1971.300 | 13.943| 32     |
| Periodic technical inspection | 0.349 | 8.716 | 0.001| 1      |

Table 5. Resource distribution and usage.

| Resource            | Degree of usage [%] | No. of interventions performed |
|---------------------|---------------------|--------------------------------|
| Name                | No. | Min. | Mean | Max. |                                |
| Concierge           | 3   | 40.17| 334  |
| Mechanic            | 5   | 95.80| 74   |
| Tinsmith            | 3   | 54.62| 134  |
| Dyer                | 2   | 95.52| 100  |
| Technician          | 1   | 11.09| 25   |

Studying the data presented in Table 5, it can be observed that there are resources with a low degree of usage, yet with a high number of interventions performed. The main discrepancies are as follows:

- The concierges are massively underused, with a degree of usage under 50%, meaning they are mostly “free” for much of the simulation’s 9600 minutes. Yet, the number of interventions performed by the concierges is higher than the total number of vehicles serviced by the repair shop (334 vs. 289). This is mostly a result of the Concierge station being the first one in most of the
sequences. Still, the number of concierges can certainly be reduced without negatively impacting the repair shop’s capacity.

- The bodywork and dye-works activities are successive, which means that, in order for both stations to function efficiently, the number of interventions performed by the dyers must match (as closely as possible) the number of interventions performed by the tinsmiths. Given that the number of interventions performed by the tinsmiths is 34% higher than the number of interventions performed by the dyers, and that the tinsmiths’ degree of usage is 40.9% lower than that of the dyers’, the obvious conclusion is that tinsmith-to-dyer ratio is too high and that there should be more dyers than tinsmiths.

5. Conclusions
Most of the decisions that have to be taken concerning the activities of a firm require careful planning before implementation. The automobile repair shop market is a highly competitive one, but one that is also filled with opportunities. Therefore, any competitive advantage can have a significant impact on the chances of success of a firm in this area of activity.

Simulating the firm’s activities by using a discrete event simulations software, like the Arena software, analyzing the results of the simulation, continuously seeking and implementing solutions to optimize the experimental model and to ensure an efficient use of the available resources, represents an important milestone in ensuring that the firm’s activities are progressing smoothly. By running a simulation using the Arena software, the effects of certain decisions are easier to understand and a positive outcome can be guaranteed with greater certainty, while choosing the optimal solution from any number of possible solutions becomes more accessible.

The repair shop capacity depends mainly upon the occurrence probability that assigns a certain number of vehicles to each intervention category, being also influenced by each intervention’s duration and the resultant queue at each station. By analysing the resource distribution and usage, the degree of usage for the mechanics is relatively evenly distributed between the 5 of them, as is the number of interventions performed. Correlating this to the high workload and long queues for the Major repairs stations (as shown in Table 4), a reasonable conclusion is that increasing the number of mechanics might lower the queues for the corresponding stations and thus improve the overall performance and potential capacity.

The mean degree of usage for the technician is very low. Still, there is not much room for improvement in this situation, as partially relocating the technician to other station might have negative repercussions for the overall performance. The station itself could be removed, but that would reflect badly on the services the automobile repair shop can provide to its customers.

6. References

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