**Author(s)**

<table>
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<tr>
<th>First Name</th>
<th>Middle Name</th>
<th>Surname</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norman</td>
<td>E.</td>
<td>Collins</td>
<td>Professor</td>
<td><a href="mailto:ncollins@udel.edu">ncollins@udel.edu</a></td>
</tr>
</tbody>
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**Affiliation**

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<tr>
<th>Organization</th>
<th>Address</th>
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<tbody>
<tr>
<td>Delaware Experimental Station</td>
<td>Department of Bioresources Engineering</td>
<td>USA</td>
</tr>
<tr>
<td>Department of Bioresources Engineering</td>
<td>260 Townsend Hall</td>
<td></td>
</tr>
<tr>
<td>College of Agriculture and Natural Resources</td>
<td>531 South College Avenue</td>
<td></td>
</tr>
<tr>
<td>University of Delaware</td>
<td>University of Delaware</td>
<td></td>
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<tr>
<td>Newark, DE 19716-2140</td>
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<tbody>
<tr>
<td>Nathan</td>
<td>Touchstone</td>
<td></td>
<td>Graduate Student</td>
<td><a href="mailto:pugbug804@charter.net">pugbug804@charter.net</a></td>
</tr>
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<tr>
<td>Department of Biological and Agricultural Engineering</td>
<td>Driftmier Engineering Center</td>
<td>USA</td>
</tr>
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<td>University of Georgia</td>
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<tr>
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<tbody>
<tr>
<td>Eric</td>
<td>R.</td>
<td>Benson</td>
<td>M0251424 Assistant Professor</td>
<td><a href="mailto:ebenson@udel.edu">ebenson@udel.edu</a></td>
</tr>
</tbody>
</table>

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<tr>
<th>Organization</th>
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</table>
| Delaware Experimental Station  
Department of Bioresources Engineering  
College of Agriculture and Natural Resources  
University of Delaware | Department of Bioresources Engineering  
264 Townsend Hall  
531 South College Avenue  
University of Delaware  
Newark, DE 19716-2140 | USA |

### Author(s)

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<tbody>
<tr>
<td>Garrett</td>
<td>L.</td>
<td>Van Wicklen</td>
<td>Associate Professor, Extension Engineer</td>
<td><a href="mailto:gvw@udel.edu">gvw@udel.edu</a></td>
</tr>
</tbody>
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| Department of Bioresources Engineering  
Cooperative Extension  
College of Agriculture and Natural Resources  
University of Delaware | Department of Bioresources Engineering  
University of Delaware  
Georgetown, DE 19947 | USA |

### Author(s)

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</thead>
<tbody>
<tr>
<td>Michael</td>
<td></td>
<td>Czarick</td>
<td>Senior Public Service Associate</td>
<td><a href="mailto:mczarick@engr.uga.edu">mczarick@engr.uga.edu</a></td>
</tr>
</tbody>
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### Affiliation

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<th>Organization</th>
<th>Address</th>
<th>Country</th>
</tr>
</thead>
</table>
| Department of Biological and Agricultural Engineering  
University of Georgia | Room 306  
Biological & Agricultural Engineering | USA |

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Development of an Internet-Based Broiler House Production Model

N.E. Collins
Professor, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware

E.N. Touchstone
Research Student, Department of Biological and Agricultural Engineering, University of Georgia

E. R. Benson
Assistant Professor, Delaware Experimental Station, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware

G.L. Van Wicklen
Associate Professor, Extension Engineer, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware, gwv@udel.edu

M. Czarick III
Senior Public Service Associate, Department of Biological and Agricultural Engineering, University of Georgia

2003 ASAE Annual International Meeting
Riviera Hotel and Convention Center, Las Vegas, Nevada, USA
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Abstract. The UD Broiler House Model has almost unlimited potential to evaluate different scenarios for broiler house construction and flock management. The model was originally developed during the 1970’s as a systems analysis of on farm production. Given the past history of the model, updates to the model were geared towards current practices and ease of inclusion of future practices. The model allowed hypothetical or planned situations to be easily evaluated with minimal economic risk. The model currently includes house construction and siting modules. The model has been revised to allow Internet access. The online version of the model currently includes the housing model, which allows users to input their current or projected housing plans into the model.

Keywords. animal housing, broiler, building construction, building materials, computer simulation, poultry, poultry housing

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Introduction

Poultry is an important component of the Delaware and regional economy, representing a $1.6 billion industry that employs approximately 14,000 employees across the Delmarva Peninsula (DPI, 2002). Poultry production involves managing bird, environmental and housing variables to maximize economic return. Growers and integrators are frequently confronted with new technology and techniques. Changes to the housing or management practice can require significant capital; choosing inappropriate techniques or technology can adversely affect bird health and profitability.

Broiler growers have found it increasingly difficult to turn a profit, especially in recent years when the price of LP gas has risen to well over $1 per gallon and the cost of electric energy has continued to rise as well. High-energy prices offset tremendous advances made in nutrition and genetics that allow heavier birds to be produced over a shorter growout period. Alternative methods of evaluating building construction, management, along with more efficient heating and ventilation equipment are frequently proposed to increase profitability. Reliable evaluation methods of potentially beneficial ideas are needed to identify those that have the most promise for success.

Currently, when the broiler industry is presented with new materials or methods of house construction, management methods involving control of the house environment, or incorporating new equipment such as controllers, fans, lights and heaters, the opinions and experiences of engineers are relied upon to judge potential benefits. In some cases, innovative equipment or methods are tested in the field; however, field testing is costly and time-consuming. A web based computer-based model of broiler production that can predict the value of changes in building construction technique, house management practices, and new equipment is one viable way of broiler production before resorting to expensive field testing. For example, industry is now considering building 60 ft x 500 ft (18.3 m x 152.5 m) poultry houses. The cost of building and operating an experimental house to test and evaluate new ideas is very high.

When one starts to construct a model to evaluate the cost of broiler production, the number of variables and factors involved quickly begin to skyrocket. In a previous modeling effort, the variables definition file alone was over 130 pages. As one begins to think about developing a model or computer program that would attempt to systematically answer questions about the cost of broiler production or other similar questions about the effect of about ventilation rates, fuel and electricity use, construction costs or the influence of vegetative environmental barriers, one then begins to realize that some boundaries or limits to the scope of the analysis must be drawn. At the same time, one begins to realize certain features need to be incorporated in the model. As this project was initiated, these issues were foremost on the minds of the investigators.

One of the principal investigators had been involved in an extensive computer modeling effort – Systems Analysis of On-Farm Production - that had been undertaken 25 years ago and fallen dormant. Earlier efforts focused on the farm and grower. Hatchery, feed mill and processing issues were not addressed. Veterinary issues are a concern to the grower but are not currently addressed. From the desired features aspect, an important segment of the previous effort was a physiological model of broiler growth and response to the house environment. Expansion or revision of the broiler growth algorithm would permit a systematic analysis of tunnel ventilation, lighting programs, etc.
Objectives
The objective of this research is to create a computer model of broiler production that predicts the economic impact of changes in broiler house construction and management, and using more efficient equipment on the cost of production. Specific objectives of the project were:
1) Update an existing computer model to reflect advances in the industry
2) Develop a web interface for the model

The intended users of this model are poultry engineers, computer literate growers, and company personnel such as housing directors, flock supervisors and production managers who desire to evaluate innovative design ideas.

Model Overview
The computer model - Systems Analysis of On-Farm Broiler Production – consists of several programs that are executed in sequence to evaluate a proposed set of conditions. By modifying the specifications/conditions and executing again, the investigator can obtain a comparison of outcomes. The programs comprising the model are:
1. Broiler House Construction
2. Broiler Growth
3. Climate/Weather
4. Litter
5. House Management
6. Crisis

The programs used in an analysis depend on the question asked or the result desired. If the question is how much will the broiler house cost to construct, only the broiler house program is used. A more involved question would be, ‘what is the cost of fuel and electricity for a given broiler house for a specified time period?’ This type of economic analysis would require the first five programs. Crisis, as the name suggests, is used to answer questions dealing with catastrophic events, such as an electrical power failure and is not considered part of the ‘normal’ sequence. The order of program execution and the flow of information are illustrated in Figure 1.

All programs have or will be converted to FORTRAN90. The Broiler House Construction program is modified, compiled and executed routinely as new programming or cost data is added and evaluated. Both the Broiler Growth and House Management programs have been converted and compiled. Routine execution will begin when the new versions of the pass through files created by the Broiler House Construction program are finalized. Climate, Litter and Crisis programs will be brought on line at a later date.

The decision to use the existing model – Systems Analysis of On-Farm Broiler Production – provided the project team with over 13,000 lines of code, but did not provide a model and/or the computer programs required to immediately satisfy the current project objectives. The existing model, which was developed in the late 1970’s and early 1980’s, provided a framework and an approach that had been successfully used in the past (Collins and Walpole, 1979; Collins and Walpole, 1981; Elliot and Collins, 1982). To meet the project objectives, the existing programs needed be modified, updated and altered not only to include the industry practices of the early 21st century but be easily modified for future expansion. The priority has been to incorporate
current construction practices and equipment options in the Broiler House Construction program. As a matter of course, meetings are held with a variety of practitioners to discuss current practice. These meetings also serve as model verification and cost calibration opportunities. Continued discussions with industry will make this an evolutionary, open-ended process.

Figure 1. Information flow diagram.

Given the project goal of a national model and the continual evolution of construction and management practices, the construction and cost estimating procedures of the 1970’s model needed to be replaced. A more general, regionally adaptable, approach to describing construction events and cost estimating was required. Meetings with a Delmarva building contractor and an industry housing specialist identified the activities required to prepare/develop/build the site and the foundation/lower wall. With the task list approach, it becomes easier to consider future practices and regional differences. Once the potential of the task list concept was realized, attention was turned to the related issue of cost estimation. After review, the RSMeans system was chosen (Building Construction Cost Data, 2000).

The new procedure identifies a broiler house construction task or event that can be found (or closely approximated) in the RSMeans Cost Data Manuals, i.e., Building Construction Cost Data and Light Construction Cost Data. Once a broiler house construction task can be equated or approximated by a RSMeans line item, crew size, equipment requirements and related costs can be determined. With experience, the material, labor and equipment cost are adjusted to local conditions and the special skills of the broiler house builders. Meetings with the building contractor have allowed the RSMeans information to be tailored to specific broiler house construction practices. Finally, each meeting with a potential industry user of this program produces new insight and, frequently, modifications to the program. Hence, past and future references to the ‘evolving version’ of the model.
Broiler House Construction Program

The Broiler House Construction program, like the model itself, consists of several major parts. The major parts of the program are delineated as the main and subroutines. The Main segment of the program accesses data in the public user file and develops the floor plan. The floor plan involves determining the size of the house and subdividing it according to the brooding practice (whole house, end room, center) specified. Then, the main section controls the use of (or calls) the subroutines, which are:

1. Air Handling
2. Equipment (feed, light, water)
3. Doors and Windows
4. Base (site preparation, foundation/lower wall)
5. Roof (and Ceiling)
6. Wall

In addition to these major parts, there are several other subroutines that deal with specific or repeated calculations within the model. Examples of specific use subroutines would be MFFOUND (machine formed foundation/lower wall) and BWFOUND (footing plus concrete block). Examples of repeated use subroutines would be WIRE (size of wire for equipment) and CONSCOST (calculates labor and equipment costs for various tasks).

When the program is executed, the subroutines are accessed in the order listed above to facilitate data transfer between subroutines. For example, the information about fans is transferred from the Air Handling subroutine to the Wall subroutine. Discussions with industry cooperators have provided potential model improvements.

Base Subroutine

The Base subroutine that was developed and used 25 years ago was woefully lacking when compared to the current and evolving version of the subroutine. In the past, only the foundation of the building was considered. Even more limiting was the fact that the Delmarva industry considered only one type of foundation (hand laid block). In 2003, the industry has a greater interest in the area around the broiler house and is more proactive in evaluating alternatives. This broader prospective has evolved for a variety of reasons, i.e., changing construction practices, longer and heavier trucks, environmental concerns, zoning laws and more.

The Base subroutine can be divided into two parts – Site Development/Preparation and Foundation/Lower Wall Construction. Site development/preparation deals with the positioning of the broiler house on the site and then several site development activities. Proper positioning of the house involves zoning laws, use of a vegetative environmental barriers, traffic flow and
building size. Zoning laws, which differ by county and/or other political units, provide the required setbacks from the public road and property lines. The setback from the public road may be increased due the size of the front traffic area and/or the installation of a vegetative environmental barrier. The site development/preparation algorithm is an example of the 'evolving version'. The current model includes site development plans with the house perpendicular to the road and a simple front vegetative environmental barrier.

The decision to temporarily limit the scope of the site preparation algorithm has an important short-term benefit. The existing Base subroutine will become a stand-alone program and made available to public users through the web site (see below for additional information). By doing this, the model can be made available as a demonstrator/trainer exercise for public users, i.e., industry personnel, growers and others with an interest in on farm production. Furthermore, feedback from these early users can be used to enhance both the web site and the model.

Current vehicle weights require an all-weather surface for the driveway, front traffic yard and side access lane and a rear traffic yard of lesser surface quality. Earthwork around the broiler house serves two purposes. First, the end and side yards are graded to form swales to insure adequate drainage of the site. Second, the resulting spoils are frequently used to form the house construction pad. If yard grading does not provide enough material for the house construction pad, the grower has the option of digging a pond or buying fill. A schematic diagram of the site is shown in Figure 2.

The final portion of the subroutine deals with the construction tasks needed to build the foundation/lower wall and incorporate energy conservation options. With regard to the foundation/lower wall, two options are now available. The first option, carried over from the 1970’s work, is a foundation/lower wall consisting of a poured concrete footing and several courses of concrete/cinder block. The second option, developed as part of this project, is a continuous poured, machine formed concrete foundation/lower wall.

Many growers and contractors refer to the masonry unit of the broiler house as the foundation. In terms of construction activity, this is not a serious issue; however, when estimating building heat loss a systematic delineation of the masonry unit must be made. In the project, foundation is that part of the masonry unit below the grade line. The heat loss from the foundation is referred to as perimeter heat loss. The lower wall component of the masonry unit, which is above grade, requires a different algorithm to calculate heat loss.

The last portion of this subroutine deals with energy conservation options. These include core filling of blocks, placement of rigid insulation along the foundation and lower wall, and sealing the lower/upper wall interface (i.e., caulking the crack). These options may raise questions about practicality, but can allow users to evaluate ‘what if’ ideas. This series of options can address concerns from public users, allowing the users to evaluate ‘what if’ questions about the effect of additional insulation and other potential improvements to the house.

Earlier in the paper, it was noted that including tunnel ventilation and evaporative cooling pads in the building program also required modifications to the broiler growth program. In a similar
manner, adding insulation changes the R-value of the wall and will change the temperature of the wall surface. The temperature of a wall surface is a factor in the magnitude of the heat loss from the bird and thereby influences broiler performance. Finally, the next iteration of this subroutine will add the concrete pads required for the feed bins and mechanical catching equipment.

![Figure 2. Schematic diagram of the site](image)

**Doors and Windows Subroutine**

The Doors and Windows subroutine allows the designer/grower to specify the type and placement of these openings in the end-walls and/or sidewalls of the house. Doors are divided into two types – equipment and service. The updating of this subroutine is based on familiarity with houses on the Delmarva Peninsula and the Georgia/Alabama region. The equipment doors refer to the large doors located at the ends of the broiler house and provide access for mechanical catching equipment. The user now has the three equipment door placement options – none, one end only or both ends. After locating the equipment doors, the crack area around the doors and heat loss through the doors are calculated. This information is passed to the management program so that infiltration rates and fuel usage can be determined.

With regard to service doors, they are classified as end or side and typically are used for grower access and litter & chick placement. This subroutine has been enhanced to permit placement in the end and/or sidewalls. Currently, the positioning of the service doors is influenced by the use of cooling pads, chamber size, integrator specifications and grower preference. End service door position options follow the equipment door options, i.e., none, one end or both ends. Side service door position options, on the other hand, permit the designer to specify either the number of doors or the spacing of the doors. The program then assigns the appropriate number of service doors to each chamber and calculates crack areas and heat losses. Again this information is passed to the management and/or the crisis program.

The last part of this subroutine deals with the windows. The subroutine supports both options that were common in the 1970’s and includes the current industry practices – continuous curtain
and windowless. The term windowless is recommended instead of solid sidewall when referring to a house without window openings because the house will have other openings for doors, fans, cooling pads, etc. Other inputs, such as brooding practice (side or end) or type of construction (shed or other), were used to control the placement of the windows.

Finally, the issue of cost needs to be addressed. The researchers are currently developing the RSMeans compatible task list for the door and window options. When this task list is verified, the algorithm in the Base subroutine can be quickly modified to use pass through information in the Door and Window subroutine.

**Roof (and Ceiling) Subroutine**

The Roof subroutine deals with the roof, ceiling and trusses. Since current construction and production practices rely on clear span trusses, the user selects the truss from an array of commercially available trusses. The use of the truss array produces two improvements in the model. First, the user will be limited to properly engineered trusses. Secondly, the cost calculation will be based on the actual price of the truss rather than a linear extraction based on cost per foot. Also being developed for this subroutine is the construction task list. For example, a cooperating builder uses a crew of 11 men to set and brace the trusses. Similar information has been provided for tasks such as stringers, roofing sheet metal and ceiling. This is a great example of how the RSMeans listing is modified to take advantage of special industry practices.

The predominance of truss construction in the industry has produced a modeling issue that work on this subroutine has highlighted. That is, how much of the older construction practices should be maintained. When the original model was developed in the 1970's, fuel use estimates for shed houses were still useful to the Delmarva industry. In 2003, few shed style houses are still in production. Recent discussions have investigated the use of steel framing. It seems that evolution will affect the model by eliminating shed and simple rafter construction and will add steel framing as the modeling effort continues.

The truss specifications establish the outside width of the house and also provide data required for determining roofing and ceiling material requirements. Information passed from the Air Handling subroutine has been a factor in inlet placement but now includes the need for information to extend the roof over the evaporative pads. With the calculation of ceiling area and specification of insulation material and thickness, the heat loss through the ceiling can be estimated. In the 1970’s and 1980’s, the original model was a very effective tool for determining the optimum thickness of insulation.

This subroutine uses available information to determine the building height correction factor. This parameter is a function of building height and influences air infiltration rates. This short algorithm in the Broiler House Construction program permits an elementary evaluation of house profiles when used in conjunction with the House Management model.

**Wall Subroutine**

The Wall subroutine deals with the portion of the sidewall above the masonry construction, which is referred to as the upper wall. As with the foundation/lower wall portion of the Base
subroutine, a major change has occurred in construction practice. Instead of being built board by board on site, the sidewalls are now constructed of prefabricated panels. The material requirements for studs, wall coverings and insulation do not change significantly, but labor costs and quality may be quite different. Another structural change is the elimination of the sill plate when a machine formed masonry unit is for the foundation/lower wall. The use of prefabricated panels requires two additions to the model – prefab task list and prefab algorithm. Discussions with the builder revealed that the end walls are still built board by board and integrated into the end trusses to prevent bowing.

This subroutine receives input from the Air Handling, Equipment and Doors & Windows subroutines to account for the wall area reduction caused by openings. With the specification of insulation thickness, the heat loss from the walls can be determined.

**Air Handling Subroutine**

The Air Handling subroutine deals with the equipment that moves the air. The original version of the model permitted the evaluation of a variety of ventilation fans & control practices, inlet systems, fan shutters, heat exchangers, and attic heat recovery. The data input starts with the specification of the design ventilation rate and whether one or two fan types are used. If multiple fans are used, the percentage of the air moved by each fan must be specified. The ventilation fans used for moisture removal may be continuous-constant speed or time clock-constant speed. In 2003, the time clock option would be replaced by setting the on-off cycle of the controller. The number of thermostat set points is also specified. In 2003, this would be a controller function with different set points. In the 1970’s, a common practice was to move the sidewall fans into the house for summer conditions. In 2003, this practice has been replaced by tunnel ventilation.

The input files for the model specify the types of ventilation fans and shutters in use. The electric motor data, fan diameter and fan discharge curves are included in the input files. With two different fan sizes becoming more common, the use of a shutter array is being evaluated. Included in the model are provisions for a ventilation heat recovery system, an attic heat recovery system, and stratification control. The mentioned options stem from frequent questions about the economic viability of these equipment options. Finally, as with the other subroutines, the construction task list is being developed and reviewed with contractors.

**Equipment Subroutine**

The Equipment subroutine deals with the non-air handling devices and includes cooling, watering, feeding, lighting and heating. Additional information is being gathered to properly design the cooling size based on tunnel fan capacity. With regard to the watering system, the nipple drinker option needs to be added to the model. The feeding system elements, with the exception of the feed carrier, are being updated. Discussions with industry have identified several questions about lighting programs. As the topic is explored, additional data will be added to the building data. Expansion of the lighting system data will require additional adjustments in the broiler growth program. The tasks of cost updating and construction task list development for the equipment subroutine are on going.
Web Interface

The model was developed in FORTRAN on a University mainframe. To allow the target audience to access the model, an easy to use interface was required. Several options were debated, including Microsoft Excel Visual Basic modules and a web-based interface. A web-based interface would allow the research group to control the source code and make improvements to the system without requiring the users to download new, “improved” code.

The code was modified to run under Lahey/Fujitsu Fortran 95 v6.1 on a Linux server running an Apache server. A series of webforms were created to receive data from the user. Standard PHP form commands were used to bring the data in from the webform and save it to an input file for the model. After the query and save process was completed, a command line interface was used to call the precompiled FORTRAN model. A flowchart of the process is shown in Figure 4.

![Flowchart](image)

**Figure 4.** Flowchart for user interface

Sample Results

Site development is an important element in the construction of a new broiler house. While researching for the site preparation portion of the Broiler House Construction model, it became apparent that the siting considerations varied significantly from county to county. In Somerset County, MD, for example, houses can be positioned relatively close to the center of the road (19.8 m, 65 ft.). In Kent County, MD, a 600 ft. (182.9 m) setback is required. Additional constraints, such as the front traffic yard and drainage ditches, may increase the actual house
setback above legal minimums. The setback distance influences the size of the driveway and the overall size of the site. In order to ensure access for feed trucks and other service vehicles, the integrators specify an all weather driveway.

The Broiler House Construction subroutine was used to compare the site preparation costs for the same 41 ft. x 500 ft. (12.5 m x 152.4 m) house located in Somerset and Kent counties. A summary of the differences is shown in Table 1. The additional setback adds an additional ¼ acre of land per house. Discounting the variable cost of land and the lawn area, the additional setback distance adds $1,681.01 in materials and labor for the additional driveway and vegetative environmental barrier.

Table 1. Comparison of poultry house costs and specifications for Somerset and Kent County, MD

<table>
<thead>
<tr>
<th></th>
<th>Somerset County, MD</th>
<th>Kent County, MD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setback from centerline of road (Zoning code)</td>
<td>65 ft (19.8 m)</td>
<td>600 ft (182.9 m)</td>
</tr>
<tr>
<td>Actual setback from centerline of road</td>
<td>127 ft. (38.7 m)</td>
<td>600 ft. (182.9 m)</td>
</tr>
<tr>
<td>Front vegetative environmental barrier length and breadth</td>
<td>31 ft. x 25 ft. (9.4 m x 7.6 m)</td>
<td>71 ft. x 25 ft. (21.6 m x 7.6 m)</td>
</tr>
<tr>
<td>Area of front vegetative barrier</td>
<td>775 ft.² (80 m²)</td>
<td>1775 ft.² (164.9 m²)</td>
</tr>
<tr>
<td>Driveway entrance (W x L)</td>
<td>60 ft. x 35 ft. (18.3 m x 10.7 m)</td>
<td>60 ft. x 50 ft. (18.3 m x 15.2 m)</td>
</tr>
<tr>
<td>Driveway transition length</td>
<td>0 ft. (0 m)</td>
<td>50 ft. (15.2 m)</td>
</tr>
<tr>
<td>Driveway lane (W x L)</td>
<td>20 ft. x 0 ft. (6.1 m x 0 m)</td>
<td>20 ft x 408 ft (6.1 m x 124.4 m)</td>
</tr>
<tr>
<td>Total driveway area</td>
<td>2,100 ft.² (195.1 m²)</td>
<td>13,160 ft.² (1,222.6 m²)</td>
</tr>
<tr>
<td>Front traffic area and lane at side of house</td>
<td>16,400 ft.² (1,523.6 m²)</td>
<td>16,400 ft.² (1,523.6 m²)</td>
</tr>
<tr>
<td>Total all weather surface area</td>
<td>18,500 ft.² (1,718.7 m²)</td>
<td>29,560 ft.² (2,746.2 m²)</td>
</tr>
<tr>
<td>Area of construction site</td>
<td>1.76 acres</td>
<td>2.05 acres</td>
</tr>
<tr>
<td>Driveway cost (crushed shells)</td>
<td>$2,355.32</td>
<td>$3,763.43</td>
</tr>
<tr>
<td>Vegetative barrier cost (L. Cyprus or Red Cedar)</td>
<td>$64.00</td>
<td>$144.00</td>
</tr>
<tr>
<td>Other site preparation and masonry materials cost</td>
<td>$5,816.36</td>
<td>$5,816.36</td>
</tr>
<tr>
<td>Site prep and masonry labor cost</td>
<td>$3,136.42</td>
<td>$3,226.92</td>
</tr>
<tr>
<td>Site prep and masonry equipment cost</td>
<td>$1,889.18</td>
<td>$1,991.30</td>
</tr>
<tr>
<td>Total site prep and masonry cost</td>
<td>$13,261.29</td>
<td>$14,942.30</td>
</tr>
<tr>
<td>Additional cost</td>
<td></td>
<td>$1,681.01</td>
</tr>
</tbody>
</table>
Multiple houses at the same property impact the overall cost as well. Typical farms have multiple houses and the interaction between the houses becomes important. As communities, such as Kent County, MD, restrict poultry housing through increased setback distances, it becomes important to consider alternative site plans. The Broiler House Construction subroutine allows potential alternatives to be evaluated.

**Conclusion**

Broiler management is a complex process that involves managing a variety of factors. The multipart model of the broiler house construction, broiler growth, broiler management, climate, litter, and crisis was developed during the 1970’s and 1980’s. The model has been modernized to reflect advancements in housing and management. The Broiler House Construction module was mated to a web interface to allow users to interact with the model. An example use of the model with results is presented.

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**For More Information**

For additional information or to be added to the electronic mailing list for the Coopsters Research Group at the University of Delaware, contact Garrett Van Wicklen at gvw@udel.edu.

**References**


