Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

LESSONS FROM A CONCEPTUAL MODELING EXERCISE

Margaret L. Loper

Georgia Tech Research Institute

Information & Communications Laboratory
Atlanta, GA USA

Louis G. Birta and Gilbert Arbez

School of Electrical Engineering and Computer Science, Faculty of Engineering
University of Ottawa
Ottawa, Ontario CANADA

ABSTRACT

There is considerable need to educate students in the process of developing conceptual models within the modeling and simulation discipline. The challenge is complicated by the fact that the specific form of a conceptual model is not driven by universally accepted criteria and one might argue that the ultimate purpose of such a model is itself ill-defined. In 2010 one of the co-authors initiated a *"Conceptual Modeling Corner*" segment in the Society of Modeling and Simulation International's M&S Magazine. To focus the discussion, a specific problem was outlined and readers were encouraged to propose conceptual models for the problem. The M&S course within the Georgia Tech Professional Masters in Applied Systems Engineering program recently used the problem as an assignment and 46 students developed conceptual models. In this paper we outline criteria developed to evaluate a subset of these conceptual models and a number of "lessons learned" from this exercise.

1 INTRODUCTION

The July 2010 issue of the M&S Magazine published quarterly (electronically) by the Society of Modeling and Simulation International (SCS) initiated a column called the *Conceptual Modeling Corner* to foster discussion about the important area of conceptual modeling within the discrete event modeling and simulation domain (Birta 2010). A specific problem called the Happyfaces Daycare Center (HDC) problem was outlined in order to provide a focus for discussion. Readers were encouraged to submit proposals for an appropriate conceptual model for the HDC problem with the objective of providing a basis for refinement of prevailing perspectives on the nature of the conceptual modeling task. The problem statement is included as Appendix A in this paper. It should be acknowledged that the problem, as outlined in Appendix A, is a variation of one used by Stewart Robinson in his presentation at a Conceptual Modeling Workshop held during the SCS SpringSim08 Conference (Robinson 2008).

In recognition of the need to educate students on developing conceptual models, the M&S course within the Professional Masters in Applied Systems Engineering (PMASE) program at Georgia Tech (GT) has used the HDC problem as a conceptual modeling assignment. Conceptual models from 46 students have been submitted in two separate offerings of the course. In this paper we provide 10 criteria that have been used to evaluate a subset of 10 of these student submissions. This evaluation process has, in itself, been a learning experience and the "lessons learned" are outlined. These insights will hopefully contribute to the improvement of conceptual modeling education.

2 PMASE M&S COURSE

The Georgia Tech PMASE program, described in Appendix B, looks at the systems engineering process as a comprehensive, multi-disciplined function. The core body of knowledge for this program relates to the underlying principles of the systems engineering process, systems requirements engineering, analysis and design, integration, modeling and simulation, verification and validation, systems engineering leadership and management, and complex systems. There are six core courses in the PMASE curriculum, one of which is a course called Systems Modeling and Simulation.

One of the fundamental ideas behind the PMASE Systems Modeling and Simulation course is that M&S is a broad discipline and systems engineers need to understand the breadth of technologies, methodologies and uses of M&S to be effective in their jobs. There are many M&S courses available at GT, but they focus on a specific slice of the discipline, for example discrete event simulation with Arena and Simio, principles of parallel and distributed simulation, model based design with SysML, continuous simulation with MatLab, and surrogate modeling. All of these methodologies are important to understand and each has a different purpose in the systems engineering life cycle. The PMASE course tries to capture the breadth of the M&S discipline and deliver it in a way that is meaningful for students.

Lecture material is divided into 7 themes, one for each week of the class. The themes include: Fundamentals of Modeling, M&S Foundations, Simulation Methodologies, M&S in the Systems Engineering Life Cycle, Optimization and Experimentation, Distributed Simulation, and Group Projects. For each of the first 6 themes there are 6-7 recorded lectures (students watch these lectures at a time convenient for their schedule) on different topics, a reading list of conference and journal papers on these topics, and an assignment. During the last week of class (Group Projects theme) students make presentations to the class on their simulation projects. Assignments for this course are posted at the beginning of the semester, so students know what is expected of them. However, experience shows that students typically start the assignment the week it is due.

At the end of Week 2, the students have watched lectures on topics such as the simulation process; fidelity, resolution and accuracy; data and ontologies; verification, validation and accreditation; and conceptual modeling. The assignment at the end of Week 2 is the Happyfaces Daycare Center conceptual modeling project. Of the three cohorts that have taken the core M&S course, two were given this assignment - Cohorts 10 and 11 (cohorts are identified by the year in which they start the PMASE program, for example students that started in the fall of 2010 are known as Cohort 10).

Students are not given the grading criteria with the assignment. They are asked to develop a conceptual model for the HDC project – there is no required format and free form answers are encouraged. As guidance they have lecture material and a reading list on conceptual modeling (see Appendix C), along with any resources they choose to look up. The grading criteria used for the class is broken into five areas.

To date 46 PMASE students have been assigned the HDC project. Of these submissions, 10 assignments were selected (5 each from Cohort 10 and 11) to be evaluated in the context of a broader, more comprehensive set of criteria than what was used in the PMASE course. The description of those criteria and the process used for evaluation is described in the following section.

3 CONCEPTUAL MODEL EVALUATION

To define a set of evaluation criteria for a conceptual model, we must first define a set of features needed regardless of the problem domain. A conceptual model (CM) serves as a bridge from the problem statement (typically expressed in natural language and hence subject to ambiguity) to a simulation model (that is totally precise since it is expressed in the formalities of a programming language). Another feature is that the CM should be "transparent" to all stakeholders in the project. Here "transparency" means that everyone concerned can actually understand the presentation; it is not presented in an esoteric formalism that is not accessible to everyone in the community of stakeholders. The implicit notion is that all stakeholders use the CM as a vehicle for capturing the essence of the project and ensuring that there are no flaws in the model that evolves. There is also a requirement for a clear presentation of the project goal and this moves into the realm of "parameters" and "input" and "output" and the experiments that need to be undertaken to achieve the project goal.

Features of conceptual models have been discussed in earlier papers (Arbez and Birta 2010a) (Arbez and Birta 2010b) (Birta and Arbez 2007). Using this work as a foundation, the authors propose a comprehensive set of criteria for evaluating a conceptual model, as described in the next section.

3.1 Evaluation Criteria

The criteria proposed for characterizing a high quality CM are shown in Table 1 (we use the phrase System Under Investigation (SUI) as a reference to the project). A discussion of these criteria and their importance follows the table.

Table 1: Conceptual Modeling Evaluation Criteria

	Evaluation Criteria
1	Does the CM provide a view of the SUI that is meaningful (transparent) to all stakeholders (client, domain expert, program developer)?
2	Are the goals of the project properly outlined in the presentation?
3	Are parameters and/or policy options relating to the project goal clearly identified?
4	Are the input and output of the SUI clearly identified?
5	Does the presentation include a separation between the structural and the behavioral aspects of the SUI?
6	Is the granularity of the presentation consistent with the project goals (both too much and too little detail are bad)?
7	Are the simulation experiments needed to achieve the goals clearly outlined or apparent?
8	Does the CM provide an adequate platform for the subsequent stage of simulation program development?
9	Are data requirements clearly apparent (possibly still to be acquired)?
10	Are important assumptions that have been made clearly identified?

Does the CM provide a view of the SUI that is meaningful (transparent) to all stakeholders (client, domain expert, program developer)?

Lessons learned from working with non-technical customers indicates that a meaningful representation to a client is different than a meaningful representation to a program developer. Therefore, a recommended set of "views" (e.g., pictures, narrative, diagrams) might be useful for communicating the CM to a variety of stakeholders.

Are the goals of the project properly outlined in the presentation?

In "neatly packaged" project statements (e.g., those discussed in most academic environments) the project goals are typically quite straightforward and usually explicitly given. This is certainly the case with the HDC project. However, in the typical "real world" environment, project goals are often difficult to identify or, at best, are vaguely specified. Inasmuch as the CM is intended to be a discussion document for the project stakeholders, it is a reasonable expectation to have a clear statement of the project goals included as an integral part of the document. This in particular, provides the reference for many decisions that necessarily have to be made in the characterization of the model's behavior.

Are parameters and/or policy options relating to the project goal clearly identified?

The idea of a policy option is essentially a generalization of the idea of a parameter. It's very common for an M&S project to seek a best value for a parameter, like the number of servers to employ at a fast food outlet over the lunch hour or the number of elevators to install in a new office building. (The HDC project has the number of parking spots available; 4 or 5 which is highly constrained.) Suppose now a situation where there are 5 part-time employees and there are N tasks that need to be done over the course of an 8 hours shift. An M&S project might have the goal of determining how to distribute those 5 employees over the N tasks. We regard each alternative as a "policy option".

Are the input and output of the SUI clearly identified?

From a systems perspective the notions of input and output are extremely important. Output, in fact, embodies the fundamental reason why the simulation project is to be undertaken in the sense that output variables carry the information that makes it possible to resolve the project goals. Input is that aspect of the SUI's environment that affects its behavior but is not, in turn, affected by that behavior. Its identification is an integral part of the model building process.

Does the presentation include a separation between the structural and the behavioral aspects of the SUI?

It is important to appreciate that structure and behavior are two distinct features of a CM. Recognition of this helps to establish the communication bridge among the project stakeholders. Experience is that clients understand the behavioral side and "trust" developers when they talk about the structural side. However, unless there is a defined structure for the SUI, it's not possible to discuss behavior in a meaningful way. That follows because the characterization of behavior is all about manipulating structural properties (e.g., attributes).

Is the granularity of the presentation consistent with the project goals (both too much and too little detail are bad)?

When developing a CM, it is important to consider how much detail is really needed to accurately represent the problem. There is no concrete way of measuring how much is enough, but including unnecessary detail can create confusion as to the ultimate goal of the project. An example of too much detail goes like this. Consider a fast food outlet. Generally an order taken by the server would include hot drinks and cold drinks. If the goal of an M&S study was to evaluate efficiency of the operation, would it make any sense to worry about the sequence in which a server acquires the hot and cold drinks?

Are the simulation experiments needed to achieve the goals clearly outlined or apparent?

The experiments to be carried out with any model certainly cannot be regarded as a part of the model per se. Nevertheless the success of the M&S project depends critically upon these experiments and inasmuch as the CM is intended to serve as a "specification" it is not unreasonable to extend the interpretation of this notion to include the identification of the required experiments. If these experiments are improperly formulated the output that needs to be acquired will not materialize.

Does the CM provide an adequate platform for the subsequent stage of simulation program development?

This follows from both the structural and the behavioral aspects of the SUI. This discussion might address more detailed design issues such as model building paradigms (e.g., event-oriented, process-oriented) and modeling paradigms (e.g., fluid flow vs. queuing networks vs. cellular automata to represent traffic). The CM should contain (most) everything that is necessary for a software developer to create an executable simulation model that can be used to carry out the study.

Are data requirements clearly apparent (possibly still to be acquired)?

The intent here is to identify such things as the various probability distributions that are at play within the SUI and other details like the hours of operation of a Department Store or the number of electricians on a maintenance team in a manufacturing operation.

Are important assumptions that have been made clearly identified?

The assumptions section should list the simplifying assumptions to indicate how abstraction was applied to the modeling exercise. There is a close relationship here with the granularity criterion.

3.2 HDC Conceptual Model Evaluations

Each author used the criteria defined in the previous section to evaluate the 10 CM assignments. Each criterion was scored on a scale of 1-10, with 10 being the highest score. The three sets of evaluations were then averaged and the summary is presented in Table 2.

Table 2: Summary of Evaluations

	Evaluation Criteria										
Project ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	*Total*
1	5.7	5.3	7.0	4.3	2.7	7.3	3.7	4.0	3.7	7.7	51.3
2	3.3	3.0	2.3	3.7	3.3	5.7	3.0	4.0	3.7	5.3	37.3
3	5.7	6.0	6.0	4.7	3.3	6.3	6.7	3.7	7.0	7.7	57.0
4	5.0	2.0	4.7	2.7	4.3	4.0	5.0	3.3	6.3	3.0	40.3
5	3.0	4.3	3.0	3.3	3.0	5.0	2.0	3.3	4.7	6.3	38.0
6	4.3	7.7	3.3	4.7	4.7	6.3	2.0	4.7	7.3	7.0	52.0
7	5.3	5.0	2.3	6.7	6.7	7.0	2.7	5.7	4.7	6.7	52.7
8	3.7	7.3	3.7	3.7	6.0	4.7	2.0	7.7	2.3	2.0	43.0
9	5.0	6.7	3.7	5.7	3.7	4.7	2.0	3.7	5.0	1.7	41.7
10	4.7	5.7	4.0	3.3	5.3	5.7	3.7	4.3	4.7	6.0	47.3
Avg Score	4.6	5.3	4.0	4.3	4.3	5.7	3.3	4.4	4.9	5.3	46.1
Std Dev	1.9	1.2	1.4	1.6	1.6	1.3	1.5	1.2	1.5	1.5	14.6

At the bottom of Table 2, "Avg Score" represents a simple average and "Std Dev" represents the standard deviation of the three authors individual evaluations of the projects. As seen in the table, Criterion 6 received the highest and Criterion 7 the lowest average score from the authors. In terms of the level of agreement between the three evaluations, there is not a high variation from criteria to criteria except for Criterion 1. The large standard deviation for Criterion 1 reflects a significant difference in how the authors view what constitutes "transparency". While not shown in Table 2, the scores of the students from Cohort 10 and Cohort 11 are very similar, in other words, the level of understanding of the basic ideas of conceptual modeling was similar. Observations from evaluating these assignments are discussed below.

<u>Criterion 1: Does the CM provide a view of the SUI that is meaningful (transparent) to all stakeholders (client, domain expert, program developer)?</u>

Transparency presents an interesting challenge since what is transparent to a client is generally different from what a program developer would consider transparent. Most students included visual representations of the problem that would appeal more to a client but lacked sufficient detail to be meaningful to a program developer. Other students focused more on data descriptions and state charts, which would appeal more to a program developer but lack meaning to a client. This raises the question of what views are understandable across the various stakeholders and whether it is possible to even define a single view that can serve the desired purpose.

Criterion 2: Are the goals of the project properly outlined in the presentation?

Some students dived into the model development quickly, while others simply listed output without providing adequate justification for their relevance. This, to a large extent, is a consequence of the problem statement itself which listed the desired performance measurements. In such academic exercises, there is a tendency to give much information/data that would otherwise have to be acquired as part of the modeling exercises. For example, it may have been preferable to simply state that the impact upon congestion that would result from the addition of the daycare center was of interest and let the modelers determine how such congestion is to be measured.

Criterion 3: Are parameters and/or policy options relating to the project goal clearly identified?

There seemed to be confusion between parameters and input for a number of students. It was quite common for these to be treated as equivalent.

Criterion 4: Are the input and output of the SUI clearly identified?

As noted in Criterion 3 there was often confusion between input and parameters. The flow of cars (either leaving residents or pass-through cars) were generally identified as input but in many cases data requirements (such as the time to turn onto Elm/Oak street) were not. Generally output was well defined but given that expected output was provided in the problem statement, this is not surprising (see Criterion 2).

Criterion 5: Does the presentation include a separation between the structural and the behavioral aspects of the SUI?

The separation of these aspects may depend on the modeling approach used. For example in more free format approaches, this separation was difficult to discern, while in more structured approaches (e.g., those based on a SysML perspective) this separation was more evident. It is not clear that students appreciate this difference.

Criterion 6: Is the granularity of the presentation consistent with the project goals (both too much and too little detail are bad)?

This was quite difficult for a number of students, as they provided too much detail. For example, one student identified both the driver and the car in the CM; another student defined queues for all streets, and specified a 0 time for moving from one queue to another; and another student specified the acceleration of the car when it left the HDC. This represents granularity gone wild! Students typically scored high on this criterion by including a wide variety of information, but many also included too much unnecessary detail.

Criterion 7: Are the simulation experiments needed to achieve the goals clearly outlined or apparent?

Clearly this was a considerable weakness with most students. In fact it received the lowest scores relative to the other evaluation criteria. It seemed to simply not be a consideration for many of the submissions. This may be related to Criterion 3.

Criterion 8: Does the CM provide an adequate platform for the subsequent stage of simulation program development?

This is another weakness with many students. It may not be clear enough to students that there are really two purposes for the CM – a means for communications with stakeholders and as the specifications for a simulation program. It did not appear to be adequately appreciated that software specifications must be detailed. Aspects left poorly specified can be misinterpreted by the simulation program developer and result in an incorrect simulation program.

Criterion 9: Are data requirements clearly apparent (possibly still to be acquired)?

There was a mix here – a number did well, while others had difficulty. The trouble may be related to misunderstanding the difference between input (which generally gives rise to data requirements) and parameters (See Criterion 3).

Criterion 10: Are important assumptions that have been made clearly identified?

The notion of assumption was not well understood. Most students did not list the simplifying assumptions that were implicitly applied in the modeling process. Many students simply listed data models, behavioral aspects, etc. In one submission, the entire model was described as a list of 31 assumptions.

4 LESSONS LEARNED

There is a considerable need to educate students in the process of developing conceptual models within the modeling and simulation discipline. The challenge is complicated by the fact that the specific form of a conceptual model is not currently driven by universally accepted evaluation criteria. Without a clear understanding of what is to be accomplished in a conceptual model, one might argue that the ultimate purpose will remain ill-defined. Below are our lessons learned from evaluating 10 HDC conceptual models from the PMASE M&S course. It is hoped that this evaluation will provide a noteworthy contribution to conceptual modeling education.

1. There appears to be difficulty in distinguishing between the objectives of the M&S study and the outputs that have been identified. In other words it does not seem to be adequately appreciated that the outputs are the means to an end, the end being achievement of the goals of the study. Furthermore there needs to be some recognition of the fact that the data captured in the outputs may, upon analysis, not adequately serve the hoped for purpose; thereby necessitating further experimentation, possibly focusing on alternate outputs.
2. An overview of the experimentation phase of the M&S study ought to have recognized that a “base case” needs to be specified, namely, the case where the HDC center does not yet exist. The data collected from such an initial study would establish a reference for evaluating the impact of the HDC.
3. By and large the graphics chosen to convey the features of the model fall short of their purpose. In many cases the various labeled geometric shapes that are presented are difficult to interpret and often there is a lack of consistency in usage. Rarely is there an attempt to provide a glossary to clarify intended meaning.
4. By far the emphasis in most presentations is upon the objects (entities) within the SUI and the data requirements (in terms of stochastic distributions). Regrettably a coherent presentation of the behavior aspects of the model are rarely apparent. This seriously undermines a key purpose of a conceptual model; namely to provide a specification for the simulation program.
5. Abstraction poses a challenge with most students as indicated in comments on results from Criterion 6. This is probably related to the issue of understanding the purpose of the objectives of the study as discussed in point 1 above and the comments on Criterion 2. Without a good clear understanding of the project goal and objects of the M&S study, how can one start abstracting out unnecessary details.
6. The problem statement, as presented in the M&S Magazine article, had missing relevant details which none of the submissions addressed. The implication here is that students tend to assume “plug-and-chug” problem statements, i.e. those that are neatly packaged and presented. This is especially inappropriate within the M&S context where there is often missing relevant detail that needs to be “discovered”. For example, in the case of the HDC problem there is no mention of what happens to the “pass-thru” traffic flow from Oak St when the emergency vehicle passes by; also, the possible overflow of waiting “drop-off” vehicles onto Cedar Ave cannot be addressed until the dimensions of the building and of a “typical” vehicle are known.
7. Information in many cases was diffused across the submission, e.g. list of assumptions up front vs. embedding assumptions in the data or picture. So it was a challenge to locate places where relevant material was presented. This is not surprising inasmuch as different presentation styles for the CM

give rise to different places where this material fits in. There would be a benefit to having items like Assumptions, Input, Output and Data Requirements highlighted with an explicit heading within the CM.

ACKNOWLEDGMENTS

The authors would like to thank the students from the GT PMASE program in Cohorts 10 and 11 for allowing us to evaluate their homework submissions for this paper.

REFERENCES

Arbez G. and L.G. Birta. 2010a. "An Activity-Object World View for ABCmod Conceptual Models." In *Proceedings of the 2010 SCSC*, Ottawa, Ontario (Canada), July 11-15.

Arbez G. and L.G. Birta. 2010b. "Chapter 6 – The ABCmod Conceptual Modelling Framework", in *Conceptual Modelling For Discrete-Event Simulation*; Stewart Robinson, Roger Brooks, Kathy Kotiadis, and Durk-Jouke vand der Zee (eds), Taylor and Francis Group.

Birta L.G. and G. Arbez. 2007. *Modelling and Simulation: Exploring Dynamic System Behaviour*. Springer-Verlag London Ltd.

Birta L.G. 2010. "Conceptual Modeling Corner." *M&S Magazine* 1:3. http://scs.org/magazines/2010-07/index_file/ConceptualModelingCorner.htm.

Robinson, S. 2008. "Conceptual Modeling: Definitions, Concepts and Future Research." In *Proceedings of the 2008 Spring Simulation Multiconferenc*e. Ottawa, Canada.

AUTHOR BIOGRAPHIES

MARGARET L. LOPER is the Chief Scientist for the Information & Communications Laboratory at the Georgia Tech Research Institute. She holds a Ph.D. in Computer Science from the Georgia Institute of Technology, a M.S. in Computer Engineering from the University of Central Florida, and a B.S. In Electrical Engineering from Clemson University. Margaret has twenty-seven years of experience in Modeling & Simulation and her technical focus is parallel and distributed simulation. She is a member of ACM SIGSIM, SCS, SISO and IEEE. She is currently involved in projects related to data intensive systems and the interoperability of live, virtual and constructive (LVC) simulations. Dr. Loper is an instructor and course developer for Georgia Tech's PMASE program, teaching the Systems M&S course. She also teaches three M&S professional education courses and runs the M&S Certificate program. Her email address is margaret.loper@gtri.gatech.edu.

LOUIS BIRTA is a Professor Emeritus in the School of Electrical Engineering and Computer Science at the University of Ottawa, Ottawa, Canada. His research interest in the modelling and simulation domain has extended over many decades. Areas of particular interest have ranged from numerical software (continuous system simulation and optimization) to parallel processing utilization and artificial intelligence methodology in simulation model validation. He has contributed to both the identification of the Body of Knowledge that defines the modelling and simulation discipline and to the formulation of a Code of Ethics for the modelling and simulation profession. Dr Birta has been directly involved in the affairs of the Society for Modeling and Simulation International (SCS) having held positions on the Executive Committee and carried out a variety of editorial functions with respect to the Society's flagship publication, SIMULATION, including the position of Editor-in-Chief. He also served as Editor-in-Chief of the recently rejuvenated SCS M&S Magazine. Dr. Birta was recently awarded the SCS Distinguished Service Award.

GILBERT ARBEZ has been teaching university courses since 1994 and has occupied a full time position as a Teaching Associate at the School of Electrical Engineering and Computer Science (EECS) since 2003. Part of his teaching load includes a course on computer modelling and simulation fundamentals. He has co-authored books and published articles on the subject, in particular conceptual modeling. Current interests include modelling and simulation of discrete event dynamic systems and continuous systems (particularly modelling and simulation of solar cells) as well as teaching in engineering. He is starting an exploration of problem based learning and its application to engineering curriculum and courses. When he joined EECS, he brought with him 20 years of information technology experience gained from industry and government projects in various areas.

A THE HAPPYFACES DAYCARE CENTER M&S PROJECT

Cedar Avenue is a pleasant residential street in the commuter town of Warentry. Recently the Happyfaces Daycare Center (HDC) applied for permission to build a daycare center on Cedar Avenue to accommodate the needs of this growing community. The residents of Cedar Avenue are concerned about the impact of the center and have challenged HDC's application.

There are 63 houses on Cedar Avenue and the adjoining Cedar Court (see Figure 1). Residents leaving by car generally encounter difficulty in turning into the adjacent main streets (Elm St and Oak St) because of the relatively heavy traffic flow on these streets. This situation is especially aggregated during the morning and evening rush hour periods because many vehicles use Cedar Avenue as a "pass-thru" between the Elm St and Oak St. Congestion is certainly going to be further aggravated by the traffic resulting from parents arriving to drop-off and collect children from the proposed HDC. The impact on residents will be most severe in the morning rush between 7.30 am and 9.00 am because of the interference with departing residents on their way to work. A simulation study has been commissioned by the municipality and it will focus on this morning period.

All of the houses on Cedar Avenue and Cedar Court have off-street parking for one car. There are, furthermore, 26 parking places on these streets but these are reserved for the exclusive use of residents who own more than one vehicle (permits must be acquired). Each workday morning, approximately 60 vehicles belonging to residents leave during the 7:30 am to 9:00 am period. These vehicles exit in equal numbers to Elm St and Oak St.

A single traffic lane exits onto to both Elm St. and Oak St. and because both of these streets are major thoroughfares, entry onto them is particularly difficult during the rush hours (there are no traffic lights). The pass-thru component of the Cedar Ave traffic is heaviest during the morning rush period and averages about one car every two minutes in the Oak St to Elm St direction and one every three minutes in the Elm St to Oak St direction. It has been observed that in the morning rush period the turning maneuver from the lead position in the exiting lane may require as much as one minute and queues of considerable length often form.

HDC plans to provide four parking spaces at the rear of the building for use by parents dropping off and picking up children. These will be accessed via a driveway that passes around the building. It is expected that parents will occupy one of these spaces for about 2 minutes and possibly up to 5 minutes in cases where conversations with staff or other parents take place. The planning application indicates that the daycare center will be designed to handle up to 50 children which translates to possibly 40 cars that deliver children in the 7:30 am to 9:00 am period. It is anticipated that the majority of these cars will arrive in the 8:00 am to 8:30 am period. Departing parents are expected to exit in equal numbers to Elm St and Oak St.

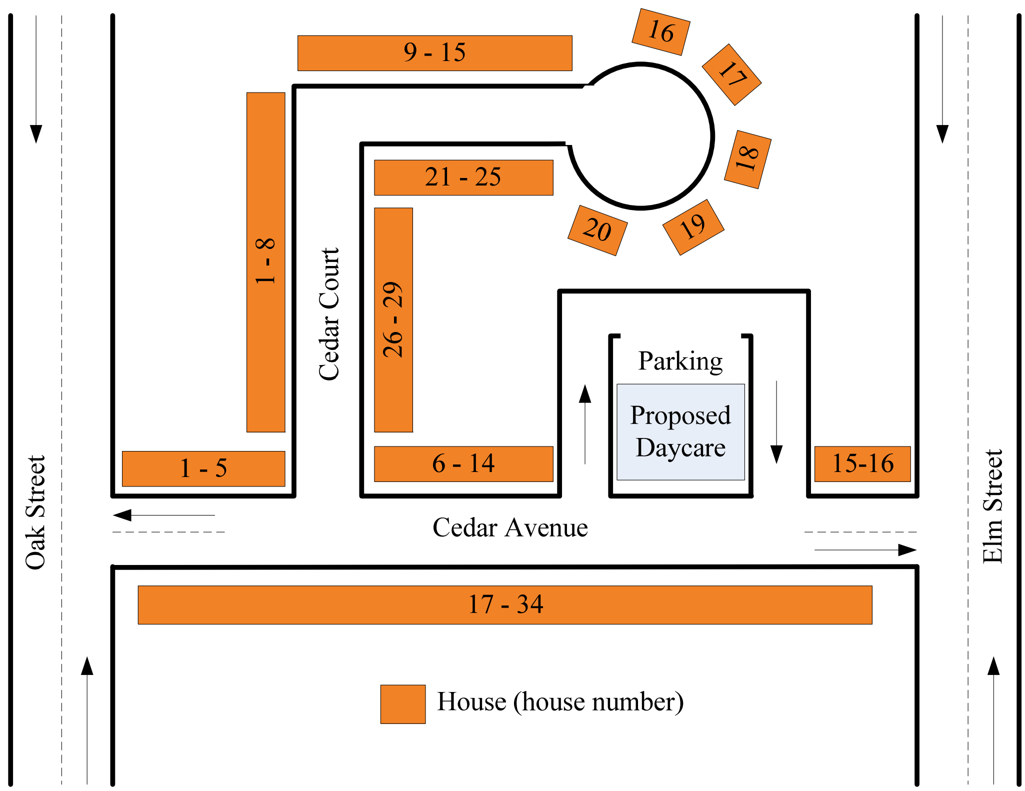

Figure 1: Cedar Avenue and the Proposed Daycare Center

The primary goal of the study is to obtain insight into the exit queues that develop at each of Elm St and Oak St. during the morning rush period (7:30 am to 9:00 am). With respect to this goal, the following output data has been identified as having particular relevance:

a) The average time to exit to Elm St by parents and as well, the maximum waiting time (measured from the completion of the drop-off task)
b) The average time to exit to Elm St. by residents and as well, the maximum waiting time (measured from the time of exiting their respective homes)
c) The average length and the maximum length of the queue of cars waiting to exit to Elm St
d) The average time to exit to Oak St by parents and as well, the maximum waiting time (measured from the completion of the drop-off task)
e) The average time to exit to Oak St by residents and as well, the maximum waiting time (measured from the time of exiting their respective homes)
f) The average length and the maximum length of the queue of cars waiting to exit to Oak St

A secondary goal is to determine the time spent waiting for one of the four parking spaces by parents and the average and maximum lengths of the queue of vehicles waiting for one of these parking spaces. Because this queue may spill out onto Cedar Avenue, the municipality is also interested in the effect of having an additional parking space (5 rather than 4).

Extension

An Emergency Services Center is located nearby on Oak St. When there is a call for an emergency service vehicle, the traffic flow on Oak St is significantly impacted. As an extension of the main study, there is an interest in the impact on the primary output data of an emergency vehicle call that occurs at 8:00 am.

A satisfactory approach for handing the effect of the emergency call is as follows: (a) the traffic flow onto Oak St is halted for 5 minutes and (b) for the 3 minutes following the 5 minute stationary period the time to turn onto Oak St is doubled for all cars exiting from.

B PMASE PROGRAM

Georgia Tech's College of Engineering, the office of Distance Learning and Professional Education and the Georgia Tech Research Institute (GTRI) collaboratively designed the Professional Master's in Applied Systems Engineering (PMASE) program for experienced professionals interested in building and expanding their systems engineering expertise. The systems engineering master's program was started in 2009 and offers a practical, hands-on approach to learning.

The PMASE program looks at the systems engineering process as a comprehensive, multi-disciplined function. The core body of knowledge for this program relates to the underlying principles of the systems engineering process, systems requirements engineering, analysis and design, integration, modeling and simulation, verification and validation, systems engineering leadership and management, and complex systems.

Admission to the PMASE program is primarily based on a student's professional experience, their prior education, and the capabilities that they can bring to the classroom. A bachelors degree in Math, Hard Science (chemistry, physics, etc.) or Engineering from an accredited college or university are required. Each student belongs to a close-knit group of peers, called a cohort, to work on projects and assignments. A cohort is a group of students that are taking the same classes on the same schedule in pursuit of the same goal. PMASE believes that a team environment is the best way for students to grow leadership and communication skills.

During the two-year program students are required to come together with their cohort on Georgia Tech's Atlanta campus three times, each for a 4-day visit. However, PMASE utilizes distance learning technology to enable students to continually interact with program faculty and peers at a distance, as well as access online pre-recorded learning modules on-demand. In addition to real time, two-way instructional sessions that occur approximately every three weeks, course materials and assignments are always accessible to students via a learning management system.

During the two-year systems engineering program, students take five courses per year. They focus on one course at a time during a seven-week time period, preventing them from becoming strained with both a full-time career and full schedule of different classes. The PMASE curriculum includes six Core courses and four courses in a Complex Systems Track sequence. All courses are three semester hours of credit for a total of 30 program hours for completion of the degree. The six core courses and four complex systems track courses are shown in Table 3.

Table 3: PMASE Curriculum

Core Courses	Complex Systems Track Courses
ASE 6001 Introduction to Systems Engineering	ASE 61X1 Analysis and Synthesis (choose one: sensor systems, information systems, human systems integration)
ASE 6004 Leading Engineering Teams	ASE 6102 Systems of Systems and Architectures
ASE 6002 Systems Design and Analysis	ASE 6103 Lifecycle and Integration
ASE 6003 Systems Modeling and Simulation	ASE 6104 Complex System Capstone Project
ASE 6005 Systems Modeling with SysML	
ASE 6006 Systems Engineering Laboratory	

The Capstone Project is an experiential workshop that integrates what students have learned in the program through a complex system conceptual design. Projects are designed to fit the particular needs for a students' job, industry, and career.

C PMASE M&S CONCEPTUAL MODELING READING LIST

Borah, J. 2002. "Conceptual Modeling - The Missing Link of Simulation Development." In *Proceedings of the Spring Simulation Interoperability Workshop*, Paper 02S-SIW-074, Orlando, FL.

Borah, J. 2003. "Conceptual Modeling - How do we do it?—A practical example." In *Proceedings of the Spring Simulation Interoperability Workshop*, Paper 03S-SIW-114, Kissimmee, FL.

Borah, J. 2007. "Informal Simulation Conceptual Modeling -- Insights from Ongoing Projects." In *Proceedings of the Fall Simulation Interoperability Workshop*, Paper 07F-SIW-012, Orlando, FL.

Chapman, R. 2000. "Conceptual Modeling Framework for Complex Synthetic Systems – an Example from F-15C Distributed Mission Training." In *Proceedings of the Spring Simulation Interoperability Workshop*, Paper 00S-SIW-088, Orlando, FL.

Correia, G. and J.M. Viegas. 2009. "A conceptual model for carpooling systems simulation." *Journal of Simulation* 3:61-68.

Onggo, B.S. 2009. "Towards a unified conceptual model representation: a case study in healthcare." *Journal of Simulation* 3:40-49.

Pace, D. 1999. "Conceptual Model Descriptions." In *Proceedings of the Spring Simulation Interoperability Workshop*, Paper 99S-SIW-025, Orlando, FL.

Robinson, S. 2008. "Conceptual modelling for simulation Part I: definition and requirements." *Journal of the Operational Research Society* 59:278-290.

Robinson, S. 2008. "Conceptual modelling for simulation Part II: a framework for conceptual modelling." *Journal of the Operational Research Society* 59:291-304.

Robinson, S. 2011. "Choosing the Right Model: Conceptual Modeling for Simulation." In *Proceedings of the 2011 Winter Simulation Conference*, Phoenix, AZ.

Sisson, B., Gustavson, P., and T. Chase. 2007. "Graphical Abstract Representation of Design (GARD): Better M&S Through Earlier Visualization & Better Design Through M&S." In *Proceedings of the Spring Simulation Interoperability Workshop*, Paper 07S-SIW-106, Norfolk, VA.