BMC REGIONAL TRAVEL DEMAND MODEL UPDATE:
DEVELOPMENT OF A SYNTHETIC POPULATION GENERATOR

TECHNICAL MEMORANDUM 1.1
PROJECT MANAGEMENT PLAN

Ram M. Pendyala and Karthik C. Konduri, Arizona State University, Tempe, AZ
Maren Outwater and Bhargava Sana, Resource Systems Group, Inc., White River Junction, VT
Xin Ye and Fred Ducca, National Center for Smart Growth, University of Maryland, College Park, MD
Julie Dunbar, Dunbar Transportation Consulting, Bloomington, IL
Chandra R. Bhat, The University of Texas at Austin, Austin, TX
Konstadinos G. Goulias, The University of California at Santa Barbara, Santa Barbara, CA

1. INTRODUCTION

The Baltimore Metropolitan Council (BMC) has embarked on the development of a synthetic population generator as part of its regional travel demand model update process. The agency envisions transitioning towards the development of an activity-based travel demand model system that microsimulates the activity-travel patterns of all resident households and persons in the BMC model region which currently includes a population of about 4.8 million people. The Baltimore Metropolitan Council has awarded a project to a team led by Arizona State University to develop the synthetic population generator and a vision for the development of an activity-based travel model system. The team also includes Resource Systems Group, Inc., Dunbar Transportation Consulting (a registered DBE), the National Center for Smart Growth at the University of Maryland, and two advisory consultants – Professor Chandra R. Bhat of the University of Texas at Austin and Professor Konstadinos G. Goulias of the University of California at Santa Barbara.

This memorandum is the first deliverable for the project and is intended to provide a detailed description of the project management and execution plan to ensure that BMC receives an outstanding set of products that meet its planning needs on-time and within-budget.

2. DETAILED DISCUSSION OF PLANNED TASKS

The objectives of the project are primarily two-fold. First, the project aims to develop a state-of-the-art customized synthetic population generator for Baltimore Metropolitan Council that is seamlessly interfaced with the existing BMC Cube/TP+ travel demand model system. Second, the project aims to provide BMC a vision for the development of full-fledged activity-based microsimulation model system that is founded on sound behavioral theory and robust computational approaches that can be implemented in practice. It is envisaged that this project will offer BMC a blueprint for transitioning to advanced activity-based travel demand model systems that meet emerging policy needs at the agency.

The first task in the project involved the initiation of the project through a face-to-face meeting at the agency offices. This meeting was held on November 9-10, 2010 and offered the team the opportunity to make detailed presentations to agency staff on the methodology for synthetic population generation, the history and development of activity-based travel demand model systems, and practical considerations in

the move towards advanced travel model systems. The accompanying technical memorandum (Technical Memorandum 1.2) provides more details of the activities, discussions, and presentations that took place at the project kick-off meeting. A part of the project kick-off meeting was devoted to conducting a hands-on training for BMC staff on the use of PopGen, a stand-alone state-of-the-art synthetic population generation software package that has been developed by researchers at Arizona State University. The customized synthetic population generator for BMC will be largely based on the algorithms and methodologies incorporated in PopGen and hence this hands-on training session provided BMC staff a key opportunity to develop an early understanding of how the software performs various operations in the generation of a synthetic population for a region.

Over the past two weeks, the project team has been having internal discussions on the potential vision for the development of an activity-based microsimulation model system. In the context of Task 4 (Model Documentation), the team plans to put together a detailed white paper describing the framework, methodologies, behavioral relationships, and overall structure for an activity-based travel demand model system that may be considered by BMC. The team strongly believes that such a white paper should be developed in close coordination and consultation with the agency so that the needs (and constraints) of the agency are adequately addressed in the proposed model design. Over the next four to eight weeks, the team will hold a series of teleconferences with BMC staff to better understand the needs and desires of the agency in terms of the model functionality, capabilities, and computational performance. However, in order to initiate these discussions, it is useful to understand the many design considerations that should go into an activity-based model system design. Towards this end, the project team has put together an initial activity-based model design considerations document that has been primarily authored by the advisory experts on the team (Professors Chandra Bhat and Konstadinos Goulias). The activity-based model design considerations are presented in Technical Memorandum 1.2.

The project team is currently preparing a detailed technical memorandum that describes the data requirements for synthetic population generation. The identification of data needs for population synthesis forms the heart of Task 2. Essentially, the following data elements are needed for synthetic population generation:

- Marginal control totals for several household and person level variables at the level of geographical resolution at which synthesis will be conducted (say, traffic analysis zone, block group, or census tract)
- Seed joint distribution matrix for household and person variables of interest that may be available at the desired level of geographical resolution or at a geographical resolution that constitutes a more aggregate spatial scale than the level at which population will be synthesized
- Large sample survey file of household and person records from which to draw synthetic households and persons

Marginal control totals may be obtained from Census Summary Files for fine geographies; however, as these totals are usually not available for the model years desired by an agency, many agencies use their own control totals for any given year at the desired level of geographic resolution. The synthetic population generator developed and provided to BMC by the project team will certainly have the ability to synthesize a population using marginal control totals derived from the Census Summary Files. Updated census summary files from the 2010 decennial census will be available soon, and it is plausible to expect that 2010 will become the new base year for many travel demand model systems at agencies around the country. In order to facilitate the effective use of census summary files from the 2010 decennial census, the population synthesizer for BMC will have the ability to import and process census files to derive

marginal control totals. However, as BMC will need a synthetic population generated at the level of the traffic analysis zone, it is important to have the ability to incorporate and utilize zone level marginal control totals. BMC will need to generate marginal control totals for any desired year (base or forecast) at the level of the traffic analysis zone, using its in-house socio-economic and land use forecasting model systems.

The seed joint distribution matrix has traditionally been derived from the Census Public Use Microdata Sample (PUMS) of the PUMA (Public Use Microdata Area) to which the small geography (traffic analysis zone or block group) belongs. At this time, PUMS data may be derived from the decennial census or from the American Community Survey (ACS). The ACS PUMS data tends to be smaller in size, but more up-to-date than the decennial PUMS data, thus offering both advantages and disadvantages in population synthesis. The project team will provide the ability to use both decennial and ACS PUMS for generating the seed joint matrix based on control variables of interest. Within the context of this project, the team will test both sources of the seed matrix and determine which one appears to be performing better in replicating observed population characteristics.

The sample from which households are drawn probabilistically into the synthetic population should be as rich as possible so as to provide a rich distribution of and variation in socio-economic variables in the synthetic population. The project team has used the PUMS data for the entire state (to which the planning region belongs) in order to have a rich sample from which to draw the synthetic population. However, one may question whether the inclusion of sample households from outside the model region for purposes of drawing households is prudent; the project team has conducted tests in previous work and found that the inclusion of statewide PUMS households for purposes of generating the synthetic population offered significantly better performance and fit than the use of only PUMS households limited to the model region. The project team will perform extensive checks in the context of this project to identify the most appropriate source for drawing households into the synthetic population. The technical memorandum currently under preparation for Task 2 will describe these data sources and include some statistical descriptions of alternative data sets for the BMC model region so that the project team can assess data quality and suitability for synthetic population generation in coordination with BMC staff.

The addition of Task 5B, namely, the development of a prototype household evolution model, places greater demands on data requirements for synthetic population generation. Under the scenario where there is no household evolution model, one needs to provide forecasts at the level of the desired geography for each horizon/forecast year. The forecasts (marginal control totals) are used to generate the synthetic population in each year (independent of the synthetic population generated in prior years). The profession has been interested in the development of demographic microsimulation model systems capable of evolving households and transitioning persons over time. Within this project, the team will make an initial attempt at developing a skeletal prototype of a household evolution model for implementation in BMC. The project team will be engaged in internal discussions, and in discussions with agency staff, in the coming weeks to determine the nature and design of the evolution model that can be built within the time and resources of this project. At this time, it is envisaged that the evolution model will address the transition processes of aging, fertility (child birth), mortality (person death), child departure from home (e.g., child leaving home when reaching college age), household dissolution or break-up, and household formation (joining two households into one). All of these are complex demographic processes and careful consideration will be given to how best these processes can be modeled and represented in the prototype developed in this project. The project team will rely heavily on BMC to help obtain data about demographic transition and evolution processes for the Baltimore region.

Where local data is not available, some national statistics on demographic processes will be used as initial placeholders.

Task 3 is at the heart of the synthetic population generation project. This task involves the actual design, development, calibration, validation, and implementation of the synthetic population generator for BMC. Within this task, the project team will also undertake extensive sensitivity tests to see how the synthetic population generator is able to respond to changes in the socio-demographic structure of the region that might occur in the future (for example, the aging of the population). The project team envisages conducting four subtasks within the context of this task. The first subtask is concerned with the development of model design specifications and conducting model estimation. The project team recognizes that the needs and desires of each planning agency are unique. As such, the project team will work closely with agency staff to understand the design specifications and functional capabilities desired by BMC. At this time, PopGen, the synthetic population generator which will form the basis of the product delivered to BMC, has many features that help users generate a synthetic population and assess the performance of the model quite easily. In an effort to customize the product to the needs of BMC, the project team will engage in discussions with BMC staff and develop a set of specifications and functional capabilities that will be incorporated in the final products delivered to BMC. The second subtask is primarily concerned with the development of two versions of the PopGen software for BMC. BMC is interested in having both a stand-alone software package as well as a software package that is seamlessly interfaced with its existing four-step travel demand model system in Cube/TP+. As part of this subtask, the project team will first enhance the stand-alone software application to make a customized version of PopGen for BMC. This version, to be called PopGen-BMC, will have all of the functional capabilities and design specifications identified in the first subtask of Task 3. Then, the project team will isolate the core algorithmic code of PopGen-BMC and interface this code with the Cube/TP+ model system of BMC. The idea is that the core PopGen-BMC code will be kept intact and interfaced with the Cube/TP+ model system through the Cube Application Manager, thus providing the ability to easily update PopGen-BMC over time. The input and output user interfaces and database manipulation and management, however, will be completely integrated within the Cube software environment. The user will be able to specify all input data, control variables, and control parameters (e.g., number of iterations, convergence criteria, number of trial draws) within the Cube software environment. The project team members will work together to determine the extent to which some of the processes automated within PopGen (such as the automated downloading and processing of census data from the Census website) can be incorporated into the Cube environment. It is possible that some of these automated processes cannot be incorporated into Cube, and the user will have to do some processing outside the Cube environment (say, using PopGen-BMC). The project team will work hard to ensure that such processes (external to Cube) are kept to an absolute minimum. It is also possible that some of the data processing steps can be coded native to Cube, thus making the capabilities part of the travel demand model itself.

The other two subtasks are essentially concerned with validating and assessing the synthetic population generator with respect to its ability to effectively replicate population characteristics in the region. As part of subtask 3.3, the project team will undertake extensive model calibration and validation exercises to ensure that the model system effectively represents the population of the region. The most important element of this process is determining the optimal set of control variables at the household and person level that need to be used to generate the synthetic population. In addition to identifying the control variables themselves, the categories for each control variable need to be determined. The optimal set of control variables and categorization can have far reaching implications for model performance, both from a computational standpoint and a goodness-of-fit standpoint. The set of control variables should, at a minimum, include those that are considered important determinants of travel demand in the region. In

addition, those variables that are important, but not effectively captured by other control variables, may also be included among those to be controlled. Calibration and validation will be performed by comparing the distributions of controlled *and uncontrolled* variables in the synthetic population with known population distributions provided by BMC and available in the census. In general, one would expect the distributions of controlled variables to match closely; however, the distributions of uncontrolled variables may not match very well, particularly if the uncontrolled variables are not adequately "covered" by the controlled variables. The project team will identify the optimal mix of control variables, and associated categories, so that the resulting synthetic population closely resembles the actual population. In the final subtask of Task 3, the project team will subject the population synthesizer to a host of sensitivity tests to see how well the synthesizer responds to changes in population characteristics. If the population ages (thus resulting in a different age distribution for the population in the future), the model should be capable of producing a synthetic population that reflects this changing demographic composition of the population. In this subtask, the project team will use the sensitivity testing capability of PopGen to essentially determine the limits of the model. The project team will try to break the model and determine the extreme situations or conflicts in control distributions that result in a poorly fitting synthetic population. By performing the sensitivity analysis, the project team will be able to provide effective guidance on the limits of the model, the types of conflicts in control distributions that the BMC staff should keep an eye out for, and the circumstances under which the model may simply break down and offer a poor fit.

The project team clearly recognizes the value of good documentation. The project team will work in Task 4 to document the model system thoroughly. While the various technical memoranda at the end of each task are likely to be rather short documents, the documentation produced in Task 4 will be a comprehensive stand-alone set of documentation that describes the model system, its functionality, installation and operation procedures, and calibration-validation-sensitivity test results. The documentation will include examples and illustrations together with numerous screen shots so that even a new user or staff member at BMC can pick it up and become an expert PopGen-BMC user within a very short period of time. Considerable documentation will be provided on the source code itself. The project team recognizes that BMC staff may desire to have the ability to modify the source code for any desired customization in the future. BMC should be able to at least accomplish simple modifications without having to depend on consultant support. The source code will be thoroughly documented and instructions will be provided on how various changes can be made to the source code in the event that a user desires to customize the program in any way. The project team will work closely with BMC staff to determine how best to document the source code as any model developer is likely to have a reasonably high level of programming knowledge (those without programming knowledge should be given the role of model user as opposed to model developer). The project team will clearly articulate the training and knowledge needed prior to an individual being considered a model developer capable of modifying the source code. The In addition to generating comprehensive user documentation on PopGen-BMC, the project team will produce a white paper that presents a detailed vision for an activity-based travel demand model system consistent with the needs, desires, and constraints of BMC. The activity-based model system will be sensitive to a range of policies of interest in the Baltimore region and have data needs that are not necessarily more demanding than the existing four-step travel demand model system. The project team will work closely with the BMC staff in developing this vision document; the document will be written in a way that provides the agency flexibility in terms of how it wants to move forward with the adoption and implementation of an activity-based model system. The team envisions that the agency is best served by adopting a phased approach with an initial phase devoted to developing a fully functional activity-based travel demand model system that replaces the generation, distribution, and mode choice steps of the four-step model. In the initial implementation, time-of-day based static traffic assignment procedures may be

integrated with the activity-based model system, while subsequent implementations may consider the move towards full-fledged dynamic traffic assignment models. The preliminary design considerations and concepts are presented in a separate technical memorandum (Technical Memorandum 1.2), including ideas for integration of an activity-based travel demand model system with land use and traffic assignment model systems.

One of the most critical tasks of the project is Task 5, which entails the replacement of the existing socio-economic disaggregation model with the population synthesizer developed in this project. As understood by the project team at this time, BMC has a socio-economic disaggregation model that is used to determine joint multi-way distributions of population characteristics in each traffic analysis zone given zonal population forecasts (marginal control totals). These joint multi-way distributions are often necessary in the context of the trip generation step where one is interested in determining the number of households or persons that fall into various cell categories of a multiway distribution (for example, how many households have two persons, one worker, two cars, and no children?). At this time, the Southern California Association of Governments (SCAG) is using PopGen in the context of its existing four-step travel demand model system to do exactly this, i.e., generate multi-way frequency distribution tables with the number of households and persons in each cell of the cross-classification matrix. It is certainly plausible that BMC can also implement the population synthesizer in this mode in the short-term in the context of the four-step travel demand model system. Having said that, the project team recognizes that there may be other applications and functions of the socio-economic disaggregation model that the population synthesizer must be able to fulfill by the end of this contract. The project team will consult with BMC staff and fully understand the role and function of the socio-economic disaggregation model that is currently in place. In fact, the project team will ask BMC staff for a copy of the model and will use the model to identify the functional capabilities of the disaggregation model. After making this determination and ensuring that PopGen-BMC is able to fulfill all functions performed by the socio-economic disaggregation model currently in place, the team will work with BMC staff to replace the existing socio-economic disaggregation model. The replacement will happen within the Cube/TP+ modeling environment. This replacement process may require the generation of some programs or scripts native to the Cube modeling environment. The project team (primarily, Resource Systems Group, Inc.) will perform this task and work with BMC staff to conduct full model runs utilizing the new PopGen-BMC in the place of the socio-economic disaggregation model. The model outputs from these runs will be scrutinized carefully to ensure that the model is functioning properly and is able to replicate validated model results from the previous model system. Differences, if any, will be resolved in consultation with BMC staff by further refining PopGen-BMC based on an identification of the sources and causes of the differences.

The addition of Task 5B to the work scope affords a unique opportunity for BMC to become a leader in the development and implementation of socio-economic or household evolution models. Such models are critical to the forecasting of household and population characteristics in a horizon year. In the current scheme of population synthesis, agencies must provide socio-economic forecasts at the traffic analysis zone for each horizon year for which a travel forecast is desired. Then, the synthetic population generation process is run independently in each horizon year prior to developing a travel forecast for that year. There is no evolutionary process built into the synthetic population generator that would allow one to capture the dynamics of societal transitions over time. In this task, the project team will design and develop an initial prototype of the household evolution model that could be further enhanced in future phases of activity based model development. The household evolution model will age individuals, handle fertility and mortality, and facilitate household dissolution and formation. These basic processes are critical to evolving a population over time and the project team will work closely with BMC staff to acquire the data needed to specify a rich set of evolution models that capture household dynamics over time.

Within the scope of this project, the evolution model prototype will be integrated within PopGen-BMC with the ability to turn it on or off depending on whether an analyst desires to evolve the population in annual time steps. In addition, the population that is evolved into a forecast year will be checked against externally provided TAZ-level socio-economic forecasts to ensure that that the evolved population has characteristics consistent with the given forecasts. Where discrepancies occur, adjustments will need to be made to the evolved population to ensure that it accurately represents forecast conditions. The project team will formulate, design, develop, and program a household evolution adjustment module that is capable of making adjustments to a synthesized and evolved population to match known external target distributions.

The team is dedicated to the transfer of knowledge and technology prior to the end of this project. The project team already embarked on this task by conducting a hands-on PopGen training for the BMC staff as part of the project kick-off meeting. The project team will prepare a set of training materials and conduct training sessions, both virtual and on-site, in May/June 2011 to train BMC staff and anybody else that BMC wishes to train (e.g., Maryland Highway Administration staff, consultants who work on BMC projects) in the use of PopGen-BMC. The training sessions will be largely hands-on to ensure that the attendees are comfortable using the software. The training will be conducted for both the stand-alone version and the Cube/TP+ version of PopGen-BMC. An executive training session that is more appropriate for managers or policymakers (shorter in duration and not hands-on) will also be offered to BMC in the event that there might be interest for such a version of the training. The project team will be available to provide on-site and virtual technical support in the use of PopGen-BMC for a period of at least six months beyond the life of the project. At this time, it is envisaged that the on-site training session will be a two-day event with one day devoted to learning about PopGen and its application, and the second day devoted to running the model in the context of the Cube/TP+ BMC travel demand model system. The exact nature of the exercises to be undertaken in the training session will be determined after consultation with the BMC staff.

3. PROJECT TASK AND TEAM COORDINATION PLAN

The project team is committed to delivering products to the complete satisfaction of BMC on-time and within-budget. The end date of the project is June 30, 2010; in order to meet this deadline, the project team will be completing one task approximately every six weeks. Some tasks can get done faster (within four weeks) while other tasks may take a little longer (about eight weeks). The project team has nearly completed Task 2 which is dedicated to identifying and synthesizing data needs for synthetic population generation. The memorandum for Task 2 will be provided to BMC by the end of this calendar year. Tasks 3, 4, and 5 are all substantial tasks that involve the design, development, validation, and documentation of the model system. As such, these tasks may take about 6-8 weeks each, with Task 6 being undertaken in the last month of the project. In other words, this is what BMC can expect to see going forward:

1) Completion of Task 1 – December 15 with memo delivered by December 20
2) Completion of Task 2 – December 31 with memo delivered by January 5
3) Completion of Task 3 – February 28 with memo delivered by March 5
4) Completion of Task 4 – April 15 with memo delivered by April 20
5) Completion of Task 5 – May 30 with **Final Deliverables** delivered by June 10
6) Completion of Task 6 – June 25 with Final Invoices delivered by June 30 (or a date specified by BMC)

The project team realizes that the schedule is ambitious; however, it should be recognized that the project team has extensive experience in the development and application of synthetic population generators and in the design of activity-based modeling frameworks. The team includes several key partners and the division of labor across partners will greatly aid in ensuring that the work gets accomplished in a timely manner (in fact, the project team hopes to finish this project earlier than the deadlines identified above).

Given the ambitious time schedule and the need to coordinate closely among team members and agency staff, the project team will conduct web- or teleconference meetings once every two weeks. The principal investigator will communicate with all team members and BMC staff to set up a fixed bi-weekly time for project teleconferences. These teleconferences will be used to monitor project progress, discuss action items, identify and resolve problem spots or data issues, and allocate tasks in the most efficient manner possible. Despite the team members having clearly defined roles and responsibilities, the team plans to be nimble and flexible at all times so that adjustments in task allocation can be done as needed to ensure that progress is being made in accordance with the schedule identified above.

The project team is in the process of setting up a wiki site for the project. This site will serve as a collaborative resource for the project team and BMC staff and will serve as a repository for all progress updates, meeting notices and notes, deliverables and presentations, and links to the code repository. The site is just being setup at this time, and as such, it is not yet mature and populated with information. The site is: http://simtravel.wikispaces.asu.edu/BMC+Project+on+Population+Synthesis and the ASU project team is working on populating the various pages of this site. The site will have a calendar noting all meeting times, dates, and logistics (dial-in and log-in information for teleconferences and web meetings). The calendar is currently being prepared and updated and the project team and BMC staff are encouraged to check the page on a frequent basis for project updates and progress.

Every two weeks, following a teleconference (or even if a teleconference did not take place), the project team will update the wiki site with a progress update, action items, and resolutions to issues or problems that might have come up. The progress updates will serve as an archive of the discussions and decisions that took place during the course of the project. All project team members will have read access to all parts of the wiki site and the ASU team is currently exploring ways in which team members can get write-access to the wiki pages as well. Project communications and recordings of web meetings may be archived at this wiki site as well. The project team is likely to use a Google code repository for the source code developed in this project. Links to the Google code repository will be provided from the project wiki site so that team members and BMC staff can easily access the repository for the latest set of code. All project team members will be placed on a strict protocol of checking code in and out of the repository every time a change is committed to the code. This will allow a close tracking of changes to the code and ensure that all team members are constantly operating with the same set of changes and the latest versions of code.

The project team has not yet determined a schedule for face-to-face meetings with the BMC staff at BMC offices. The project team will discuss a schedule for face-to-face meetings with BMC staff during the upcoming teleconferences. At this time, the project team envisages having a face-to-face meeting in April to demonstrate the first versions of the Cube/TP+ implemented PopGen-BMC. This meeting will allow the project team to make detailed presentations on the work accomplished in the project up to that date and to demonstrate how the software will operate, both on a stand-alone basis and in conjunction with Cube/TP+. Feedback and comments obtained at this 1-2 day meeting will allow the project team to make changes and respond to the needs of the agency. It should be noted that the face-to-face meeting is not the only opportunity for the agency to provide feedback. The bi-weekly teleconferences will mostly be held via the web (using web meeting technology) and the project team will be sharing the latest versions

of the software with BMC staff on a periodic basis. BMC staff and others will be able to provide feedback in response to what they see during the web meetings. The project team members are committed to being responsive to the agency. If BMC would like to have a face-to-face meeting with any project staff member or would like the project team to make a presentation or two at any time, the project team members are ready to show up at a moment's notice.

The roles and responsibilities of the project team members are rather well-defined. However, as noted earlier, the team members are nimble and flexible and will be always ready to adapt their role to ensure that the project is progressing at a steady pace. Arizona State University is the project team lead and will have responsibility for project management, delivery of products and deliverables on a timely basis, progress reporting, and invoicing. Arizona State University will be responsible for isolating the PopGen core code and developing appropriate systems that would allow the PopGen code to be hooked to other software systems such as Cube/TP+. ASU will be responsible for transmitting this code to Resource Systems Group, Inc. which has the main responsibility in turn to build PopGen into the Cube/TP+ modeling environment through the Application Manager. Resource Systems Group, Inc. will work closely with BMC staff to obtain access to the Cube/TP+ BMC model system and to design and build the interfaces to PopGen in a way that meets the specifications of the agency. ASU will be directly involved in this effort as well to provide support and clarification on any aspects of the PopGen code and to discuss ways in which the PopGen functionality and capabilities can be effectively replicated through the Cube interfaces. Resource Systems Group, Inc. also has primary responsibility for working closely with BMC staff to replace the existing socio-demographic disaggregation model and to test the new PopGen-BMC model with respect to its performance in comparison to the existing model.

The National Center for Smart Growth (NCSG) at the University of Maryland is primarily the local resource that will provide on-site support, technical assistance, and database assembly and preparation. NCSG staff will be involved in refining the PopGen algorithm to make it more efficient, in assisting RSG as needed in the interface of the customized PopGen-BMC with Cube/TP+, and in preparing the datasets needed for population synthesis. NCSG is familiar with the Cube/TP+ model of BMC and this knowledge will prove to be invaluable as the project team works to ensure that PopGen is seamlessly integrated with the travel demand model system. NCSG will coordinate closely with BMC to obtain zonal forecasts of socio-economic variables at the traffic analysis zone level that are needed to run and test the synthetic population generator. NCSG will also be primarily responsible for preparing and analyzing the various decennial and ACS census data sets needed for population synthesis. NCSG will also be heavily involved in the preparation of training materials and in the actual conduct of training on-site at BMC, and further, in providing technical support on-site whenever BMC staff needs assistance. Dunbar Transportation Consulting is a registered DBE that lends the much needed project coordination and documentation preparation skills needed for the success of the project. DTC will participate in all teleconferences and document all minutes of meetings to be posted at the project wiki site. DTC will assist in the preparation and review of technical memoranda and PowerPoint presentations based on progress reported and work accomplished by various team members. DTC will play a heavy role in Task 4 in preparing high quality user documentation for PopGen-BMC. DTC will work closely with ASU and RSG team members in preparing the user documentation to ensure that it is accurate, comprehensive, and easy to understand even by a novice user of PopGen.

Finally, the two advisory experts, Professors Chandra Bhat and Konstadinos Goulias, are tasked with the preparation of the white paper on the vision for an activity-based travel demand modeling framework for BMC. They will work closely with the project team members and with BMC staff to prepare this vision document. The activity-based travel demand model system vision white paper will be delivered in

conjunction with Task 4 with a view to providing BMC a pathway to the development and implementation of activity-based model systems. The document will provide a blueprint for putting such a model system in place in a phased manner, while offering flexibility in the way BMC goes about accomplishing this.

Finally, Arizona State University will submit invoices to BMC for payment in conjunction with the submission *and acceptance* of technical memoranda or task deliverables by BMC. After ASU submits deliverables, it will wait for a written (via e-mail) message from BMC staff that clearly indicates that the technical memorandum and/or deliverables pertaining to a task are complete and accepted. After the receipt of such a message, ASU will submit an invoice in accordance with the task-based invoicing table included in the executed contract.

4. PROJECT PRODUCTS

The project team is committed to delivering high quality products that meet the needs and desires of the Baltimore Metropolitan Council. In addition to the technical memoranda that are submitted in conjunction with all project tasks, the project team will deliver the following major products:

- *Stand-alone PopGen-BMC*: This software product is a stand-alone synthetic population generator customized to the needs and data of BMC. Arizona State University will have primary responsibility for the development of the stand-alone PopGen-BMC. This version of PopGen-BMC can be used in the absence of the Cube/TP+ travel demand model system and completely operates outside the travel demand modeling environment. BMC staff will receive the software, source code, and all data sets.

- *Cube/TP+ PopGen-BMC*: This software product is the version of PopGen-BMC that will be seamlessly integrated with the Cube/TP+ modeling environment through the application manager. The version that is integrated in Cube/TP+ will have all of the same functionality, capabilities, and methodology as the stand-alone version of PopGen-BMC, although there may be some natural differences in the input and output interfaces by virtue of the capabilities (and limitations) of the Cube/TP+ modeling environment. BMC staff will receive the software, source code, and all data sets.

- *User Documentation*: The project team will deliver to BMC a complete set of user documentation that is suitable for a model developer and a model user. The documentation for a model user, which describes the operational procedures for the stand-alone and Cube/TP+ PopGen-BMC, will be primarily prepared by Dunbar Transportation Consulting. Documentation for the advanced model developer, describing the source code and how it can be modified, will be primarily prepared by Arizona State University (stand-alone PopGen-BMC) and Resource Systems Group, Inc. (PopGen-BMC interfaced in Cube/TP+).

- *Training Materials*: The project team will prepare a set of tutorials, PowerPoint presentations, and exercises that can be used as training materials for a PopGen-BMC training workshop. There will be two versions of training materials – one version is suitable for a short executive training session (not hands-on) and another elaborate version of training materials is suitable for a technical hands-on training session at least one full day in length (although 1.5-2 days may be more ideal).