DEVELOPING AN OPTIMAL MODEL FOR INFANT HOME VISITATION

A Dissertation Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

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August 2015

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DEDICATION

This dissertation is dedicated to my parents, Edward Atuahene and Esther Atuahene, great role models, my dearly beloved Grace Bema Yeboah and friends, and the rest of the family, for their relentless support, empathy, and love, and always believing in me, inspiring me, and encouraging me to reach higher in order to achieve my goals.

ACKNOWLEDGEMENTS

I wish to thank all those who helped me complete my Doctorate Degree in Industrial and Systems Engineering. First and most importantly, I would like to extend my sincere gratitude to my advisor, Dr. Rapinder Sawhney, for his support, patience, and guidance toward my PhD endeavor. I am deeply indebted to him for his willingness to support my work and the guidance throughout my studies which has allowed me to develop my skills as an expert researcher within academia and industry in a supportive team environment. Secondly, I would like to thank the remaining members of my committee, namely, Dr. Xueping Li, Dr. Alberto Garcia, Dr. William L. Seaver and Dr. Margaret Pierce for their valuable guidance through the research process. I would also like to thank my former advisor, Dr. Charles H. Aikens for his support and guidance during the early years of my program.

A special thank you is merited for Dr. Rolando José Acosta Amado and Ms. Marcela Villa Marulanda who helped me understand operations research concepts, applications and modeling.

I also would like to thank my fellow graduate students at the Center for Productivity Innovations group (CPI): Upreti Girish, Venkatesan Bharadwaj, Abrha Wolday Desta, Macias De Anda Enrique, Chimalapati Abhishek, Thakur kaveri, Agara Mallesh Dhanush, Han Zhixin, Mohammadhashemi Ali, Ghafoorivarzaneh Mostafa, Sanil Gurudatt Bhaskar, Patlolla Dinesh, Marella Lavanya Venkata Kamala, Zhu Xiaojuan, Ganji Lisar Vahid, Thomas Tomcy, Yang Hongbiao, Asudegi Mohammad Ali, Tan Zhibo, Li Yuting and Akram, Roshanak. Thank you for sharing the graduate school life together and for the supportive team environment.

A special thanks to the University of Tennessee, East Tennessee's Children's Hospital and the Nurse Family Partnership National Service Office for providing the essential resources for this dissertation. Finally, I would like to thank Dr. David Olds, Dr. Ted Miller and Mr. Sandy Dunlap for providing technical assistance and data from the Nurse Family Partnership program.

ABSTRACT

The United States, Great Britain, Denmark, Canada and many other countries have accepted home visitation (HV) as a promising strategy for interventions for infants after births and for their mothers. Prior HV studies have focused on theoretical foundations, evaluations of programs, cost/benefit analysis and cost estimation by using hospital/payer/insurance data to prove its effectiveness and high cost. As governments and private organizations continue to fund HVs, it is an opportune time to develop and formulate operations research (OR) models of HV coverage, quality and cost so they might be used in program implementation as done for adult home healthcare (HHC) and home care (HC). This dissertation introduces a new modeling approach and proposes a solution methodology which helps to determine the schedules of follow-up nursing care providers (NCP) to visit discharged patients in order to minimize total follow-up cost at the planning and operational level, and to improve the quality of care. The model improves the quality of treatment of infants and mothers during pregnancy, after birth and discharge from the hospital by maximizing the quality of assignment of the right NCP with the right skill, nurse type and years of experience to the right patient with the specific health need. The modeling approach is based on a mixed-interger programming (MIP) formulation that represents the dynamics of the system comprising aspects such as visit schedules and total program's cost while satisfying a variety of requirements modeled as constraints. The model is tested and validated with real life data. Computational results for the formulation for real life instances of the problem with the Nurse Family Partnership Program (NFP) obtained using IBM CPLEX optimization Studio version 12.6.1 are presented. The intent is to enhance the administrative and deployment process of HV programs, minimize risks, allow planners to explore the best scenarios under different conditions related to cost, treatment and coverage requirements, and highlight the best course of action when assigning NCPs to clients. Results show significant cost savings and enhanced quality treatment in several cases studied and tested. Finally, the study identifies and presents fertile avenues for future research for this field.

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ABBREVIATIONS AND SYMBOLS

AAP	American Academy of Pediatrics
ASTHO	Association Of State And Territorial Health Officials
C	Crime
CNA	Certified Nursing Assistant
CP	Constraint Programming
D	Districting Problem
GIS	Geographic-Information-System
H	Health
HC	Home Care
HHC	Home Health Care
HHCP	Home Health Care Problem
HITS	Health Information Technology And Simulation
HPP	Horizon Planning Period
HRA	Human Resource Assignment
HRD	Human Resources Dimensioning
HV	Home Visitation
HVP	Home Visitation Program
LPN	Licensed Practical Nurse
MAPTWTC	Man-Power Allocation Problem With Time Windows And Job-Teaming Constraints
ESPPTW	Elementary Shortest Path Problem With Time Windows
MCTCSP	Multi-Activity Combined Timetabling And Crew Scheduling Problem
MDVRPTW	Multi Depot Multi Vehicle Routing Problem With Time Window
ME	Mental Development and Education
MILP	Mixed Integer Linear Programming
MIP	Mixed Integer Programming
MPA	Man Power Allocation Problem
MVRPWT	Multi (Period) Vehicle Routing Problem With Time Window
N/A, NS	Not Available/Not Specified
NCP	Nursing Care Provider
NFP	Nurse Family Partnership

NP	Nurse Practitioner
NS	Not Stated
NSO	National Service Office
OR	Operations Research
PVRPTW	Periodic Vehicle Routing Problem.
R	Routing Problem
RN	Registered Nurse
S	Scheduling Problem
SA	Simulated Annealing
SDSS	Spatial Decision Support System
TS	Tabu Search
TSPTW	Traveling Salesman Problem With Time Window
US/USA	United States Of America
VRP	Vehicle Routing Problem
VRPTW/VRPTWSV	Vehicle Routing Problem With Time Window And Shared Visits
VRPTWTD	Vehicle Routing Problem With Time Window And Temporal Dependences
WoP	Week Of Pregnancy

CHAPTER I

INTRODUCTION

Infant Home Visitation programs and interventions, here after termed "HV", play an important role in the lives of infants and their mothers as well as yield great effects and benefits to communities. HVs are programs designed to follow-up on infants and their mothers during the period of pregnancy and following postpartum discharge. They are designed to promote optimal child development and function to prevent child abuse, neglect, and other negative outcomes such as academic underachievement, psychological maladjustment and antisocial behavior [1]. For a typical HV, nurses and paraprofessionals are hired, trained and assigned families to visit at their homes on a regular basis. Since not all the care providers are licensed nurses, this study uses nurses and nursing care providers (NCP) interchangeably, where "nurses" refers to NCP. During the visits, the NCP assesses the health of the infant, provides training to the mother and recommends treatments among others. A high percentage of mothers enrolled in HV programs have histories of substance abuse which affects the infant's health and the mothers' ability to care for them, and is compounded by financial struggles that arise from difficulties in maintaining employment. Drug use during pregnancy affects the development of babies in different ways before and after their birth [2]. This places babies at risk for immediate and lifelong health concerns such as Neonatal Abstinence Syndrome (NAS), difficulty in school, serious health problems, sleep disorders, developmental delays, impulse control problems, behavioral, emotional and learning problems as well as addictive behaviors [2]. NAS is a group of problems that occur in a baby who has been exposed to certain drugs while in the mother's womb [2]. These infants demand an exceptional level of care, treatment, and nurse and physiatrist follow-ups in order to attain better outcomes. This is necessary because parents with substance abuse issues face a wide variety of complexities including inexperience in caring for infants with health issues; hence, risking the safety and quality of health of infants. For parents and even foster parents with critically ill infants, the transition to parenthood is compounded by worry and concern about their baby's medical condition, including fear of death [3-8]. Most importantly, HVs targets specific groups of the population; disadvantaged and disabled children [9], at risk children's families and communities [10], adolescent mothers [11], low-income families, low-income single teen mothers, low birth-weight infants, premature infants [12], women at high risk for a variety of maternal and child health problems [13, 14], and impoverished children [15] among others. A comprehensive list of infant HV models may be found in [16, 17]. Numerous studies confirm and support the hypothesis that HV has significant lifelong advantages and benefits. The concern is the increasing cost of these programs with the ever increasing population. From the Operations Research (OR) perspective, this may be called the Home Health Care Problem (HHCP) where the home visit paradigm is modeled mathematically for visit scheduling, nurse and patient assignment and routing among others, and

with varying constraints with the aim of achieving efficient and cost effective treatments service. Typically, the problem consists of the following tasks: assignment of nurses to jobs, planning schedules and rosters, planning visit routes and planning the effective utilization of available funds for the jobs. The problem has been solved in different ways as the vehicle routing problem, the nurse rostering problem and multiple travelling salesman problem with time window among others to achieve various objectives (minimizing travel distances, time and operational cost). In the real world of infant HV, home visits are planned manually by assigning each nurse a caseload with visits scheduled. The nurse supervisor spends a substantial amount of time performing this task, and there are no possibilities of optimizing to save cost and time. Also the quality of treatment and service cannot be effectively captured. Serious problems could arise in the event of disruptions where a nurse is absent or quits her job, or a family drop out of the program causing an unbalanced caseload. Little attention has been given to this problem and only for adult care. The first attempts of OR application to homecare were presented by Begur et al. [18], Chen and Rich [19], and Deangelis [20] respectively in the 1990's. Since then the problem has gained attention in the OR commmunity and several approaches have been presented. The subsequent sections describe prior OR applications to homecare. The goal in this research is to develop a model that assigns and determines the schedules of follow-up nurses to visit discharged patients in order to minimize total follow-up cost at the planning and maximum operational levels, while improving the quality of care and satisfying a variety of constraints.

Background

Infant intervention programs have been proven to be a potent means of preventing maltreatment and abuse, while enhancing growth and promoting good health [21-24]. HV programs have also been effective in enhancing the quality and safety of infant lives through their effects and impacts on intellectual and academic achievements [25], children's cognitive and affective development [26], cognitive and linguistic intervention, child maltreatment, social development in children [27], school outcomes [28], mother child relationships, single-parent families, low-birth-weight and premature infants [29], families of low socio-economic status [30], depressed mothers, and families dependent on public assistance [31]. Evidenced based HV programs improve quality of child-care [31-34], prenatal and perinatal health, nutrition, safety and parenting, child development [35], and at the same time help to decrease infant morbidity, maternal school dropout [36], drug substance use, emergency department visits and hospitalizations caused by injury, and unintended subsequent pregnancies. Prior studies have confirmed the successes of these programs in increasing mothers' participation in the work force [37] and their impact on government cost saving. Studies in literature indicate that there are thousands of publicly and privately funded HV programs

in the U.S. which provide services to at least half million children [1], [38], [39]. A plethora of literature on the subject of HV programs for infants are found in various databases including journals, reports, dissertations, conference proceedings, government legislatures, books, etc. Over the past 40 years, more than 250 home visiting models have been developed by researchers and service providers, ranging widely in their approach to staffing, curriculum, length of service delivery, and demonstrated effectiveness in reducing rates of child maltreatment [38]. Paul et al. [39] noted in his study that because the compliance of practitioners with the AAP guidelines has been inconsistent and is at times impractical as a result of office hour limitations, alternative models of follow-up care must be explored. A study by Escobar et al. [40] focused on randomized comparison of HV and hospital-based group follow-up visits after early postpartum discharge. The study noted that current guidelines provide scant guidance on how routine follow-up of newly discharged mother–infant pairs should be performed. The study used a randomized clinical trial design with intention-to-treat analysis in an integrated managed care setting serving a largely middle class population with the aim of comparing 2 short-term (within 72 hours of discharge) follow-up strategies for low-risk mother–infant pairs with postpartum length of stay (LOS) of less than 48 hours; HV by a nurse and hospital-based follow-up anchored in group visits. The study concluded that mothers in the HV group were more likely than those in the control group to rate multiple aspects of their care as excellent or very good, and that for low-risk mothers and newborns in an integrated managed care organization, HV compared with hospital-based follow-up and group visits were more costly but achieved comparable clinical outcomes and were associated with higher maternal satisfaction [40]. Similarly, Paul et al. [39] concludes that HV after newborn nursery discharge is highly cost-effective for reducing the need for subsequent hospital-based services. The results of this study are in agreement with those that describe a reduced need for hospital and emergency services when guidelines for primary care of infants are followed and accessibility of this care is improved [41-48]. Another study by Lieu et al. [49] focused on randomized comparison of home and clinic follow-up visits after early postpartum hospital discharge. The study concluded that for low-risk mothers and newborns in an integrated health maintenance organization, HV compared with pediatric clinic visits on the third or fourth postpartum hospital day were more costly, but were associated with equivalent clinical outcomes and markedly higher maternal satisfaction. Although decisions to implement intervention programs involve many factors, U.S. policy makers often think in economic terms [50]. In contrast, policy makers in Great Britain and Denmark have accepted universal HV programs as the optimal process for linking families of newborns with other governmental health and social service programs [51]. Black et al. concluded that their findings support a cautious optimism regarding home intervention during the first year of life provided by trained lay home visitors.

The majority of HV studies documented in literature found positive effects of HV. A review by the Council on Child and Adolescent Health [52] highlighted the role of HV programs in improving health outcomes for children and families. The review found that Denmark established HV by law in 1937 after a pilot program was successful in lowering infant mortality. France provides free prenatal care and HV by midwives and nurses to provide education about smoking, nutrition, alcohol, drug use, housing, and other health-related issues. In England, every prospective mother is visited at home at least once before birth, with six more visits typically occurring before the child is 5 years of age [52]. The council on child and adolescent health [52] reported in 1998 that in the U.S., HV services have been perceived by many as too costly and unnecessary for all new families when the program began in the late 19th century. At the beginning of the 20th century, the New York City health department implemented a HV program, using student nurses to instruct mothers about breastfeeding and hygiene. This program reduced the high mortality rate of inner-city infants suffering from diarrhea when previous efforts of private agencies had failed [53]. In the late 20th century, as funding for public health nurses had declined relative to the need, HV programs became focused on families with special problems such as premature or low-birth-weight infants, children with developmental delay, teenage parents, and families at risk for child abuse or neglect [54].

In 1992, Olds reported that HV programs cost between $300 and $1750 per family per year depending on the level and frequency of services provided [55]. Studies on the Nurse Family Partnership (NFP) program, established by David Olds, indicated that women who are home visited by nurses have fewer subsequent pregnancies and births as well as increased spacing between births [54], [56-59]. Olds [60] noted that participation in the NFP is also associated with an increase in use of prenatal care, increases in birth weight, decreases in the incidence of preterm birth, reductions in maternal smoking, improved nutrition during pregnancy, and increased interest of fathers in the pregnancies. The Association of State and Territorial Health Officials (ASTHO) reports that the total cost of home visiting were estimated to be approximately $5000-$9000 per child [61, 62]. On average, HV programs for at-risk mothers (e.g., teen mothers, women with low incomes, etc.) and their children return $2.24 for each dollar invested [61]. The NFP reports returns of $2.88 to $5.70 [58], [63] for each dollar invested when targeted to at-risk mothers. Johnson's [64] review analyzed HV programs in all states of the U.S. The study reports a list of State HV programs, key program characteristics, general approach, promising practices and future directions of each specific program. The programs identified typically are administered by a State Department of Health, Department of Human Services, or a combination of these two agencies [64]. Other studies on HV may be found in [65-70] among others. The methodologies and objectives presented in these studies include systematic reviews [65], longitudinal studies [66], meta-analysis [67, 68], and empirical review [69] among others. HV literature is

scattered all over and this dissertation identifies that none of these studies present a categorization for them, hence the need for one which is addressed in the subsequent sections.

From the mathematical and OR point of view, care at the home may be called Home Health Care Problem (HHCP), manpower-deployment decision problem, home care crew scheduling or routing problem among others. The HHCP problem involves the scheduling and assignment of nurses to visit patients, optimization of routes, time constraints and travelling distances, etc. The various OR models and solution techniques that are available in the HHC, HC and HV literature include [71], [72] and [73] which address the balancing of workloads of the operators; [18], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84] and [85] which considers the minimization of total travel time, distance and cost while respecting constraints related to route construction, scheduled hours, operators' time windows, and skills requirements; [19] which considers minimization of the total cost associated with the overtime hours; and [20], [84], and [85] which considers the maximization of the number of newly admitted patients based on resource availability constraints, minimum standard of service, variability of demand, transition rates among classes, and budget constraints. The aim of OR application to the HHCP are numerous. For instance, minimization of the number of resources involved, balancing of workload, minimization of transportation cost, maximization of satisfaction of patients, nurses and coverage, optimization of planning and operational efficiency among others. This dissertation includes a survey of relevant studies in this field and their methodologies, with aims and contributions further presented in Chapter 2.

This dissertation first conducts a literature review of studies in the field relating to only infant HV and presents a categorization on the subject. Secondly, a literature review of studies dealing with the application of OR to care at home in general is presented. The study then investigates whether mathematical methodologies have been applied to specifically infant HV's for optimality, effectiveness and cost efficiency as in the case of adult care. Thirdly, the study presents a description of OR applications in regards to discharged patients in the home environment (HHC and HC), and compares the applications with the case of infant HV to identify significant disparities between them. Finally, a novel mathematical model for infant HV is presented which focuses on prenatal and postpartum HV programs that are tailored to the care and healthy growth of children.

Motivation of the Study

The dissertation was motivated by a study conducted on infants of NAS mothers, low income mothers, first time mothers and mostly teenage mothers at a children's hospital located in the southwest part of the U.S.

The initial study was focused on reducing hospital length of stay for these infants after birth. The target group is a concern since children of adolescent mothers, who lack parenting skills, are sometimes substance abusers and also more likely to be affected with a variety of health and developmental problems [86-88]. These mothers are more likely to have rapid, successive pregnancies with infants of low birth weight, be unemployed, dropout of school, and become dependent on government programs [89], [90], [91], [92]. Due to the critical conditions of these infants, they are scheduled for hospital appointments, monitored and visited at home by nurses after discharge. Prior studies show that the cost of infant home visitation is growing and hence the need to develop methodologies and models of cost optimization while maintaining the program's fidelity, reducing risk, enhancing the quality of treatment and also increasing coverage and benefits [16], [93], [94] and [95]. A potential solution is the development of OR models to enhance nurse assignments, scheduling and routing to benefit from cost savings and effectiveness of care among others. OR models aid health workers to efficiently and effectively match available resources to patient demand. However, the comprehensive infant HV program includes various policies, requirements, fidelity elements, resources and activities which lead to a complex problem. OR has the ability to develop a solution to this complex problem as endeavored in this study. OR methodologies employ various problem solving techniques such as mathematical models, queuing theory, simulation, and stochastic process models for obtaining optimal or near-optimal solutions, as well as provide insights for complex decision making. Further explained in the subsequent sections, there have been few research efforts to solve the home care problem for adults, hence the need for contributions that endeavor to solve the unique problem regarding infant HV.

This study considers cases where the HV programs are comprehensive and incorporate prenatal and post-discharge home visitation. It is worth noting that the field of early intervention is vast and extends beyond this study hence certain areas of intervention (for instance child abuse related HVs) are beyond the scope of this dissertation. Future research may include some of these other areas. As part of the study's purpose, the dissertation discusses the state of the art research in the field, aims to stimulate interest and awareness among researchers, health professionals and governments, as well as highlights the impact of these programs on budget allocation within the health care system.

Contribution

The HHC, HC, HV problem comprises mainly 4 tasks: scheduling, routing, assignment of nurses to patients, and planning for uncertainties. A major challenge in this field is the development of a complete model at the planning and operational level that represents the dynamics of the system and its various complexities. One critical problem with the assignment of nurses is the structuring of a novel mathematical model that

incorporates the comprehensive nurse qualification matrix; skills/training, nurse type, and nurse years of experience in order to increase effectiveness of care. A second task is the consideration of long-term planning and disruption management [96] on larger subsets of both patient and nurses. Prior studies consider nurse skill just as one component (i.e. specialty), but nurse expertise comprises various elements if quality of treatment is to be achieved. The HV problem is not a new problem but still calls for unexplored modeling and solution approaches.

This dissertation contributes by

- Providing a comprehensive literature review which contains a complete taxonomy and databank for infant HV studies by classifying prior research into six categories according to the focus of the study; cost benefit, randomized trial, impact/effect, evaluation/comparison, review and general HV studies which is not available in prior literature. The trend of the problem of interest, research in the field and perspectives, authors and their contributions are presented. The study presents an investigation on whether OR methodologies have been applied to infant HV as done for adult HHC and HC; and, enlightens professionals in the field about the possibility of applying these successful methodologies to infant HV for effectiveness, optimality and cost efficiency. Most importantly, the study identifies the significant differences between adult HHC/HC and infant HV, stimulates research interest and identifies fertile avenues for future research.
- Developing a novel HV model for the problem of assigning and sequencing schedules of follow-up NCP to visit discharged patients in order to minimize total follow-up cost at the planning and operational level, and to improve the quality of care as well as reduce risk. The model improves the quality of care for infants and mothers by maximizing the assignment of the right nurse with the right skill, nurse type and years of experience to the right family with specific health need. The models developed are different from the classical literature, due to the possibility of the set of patient classes that nurses can best care for based on their skills/training, years of experience and nurse category, which is defined as a matrix for quality assignment. Moreover, the model introduced complements the studies in literature by adding the unique features of the infant HV described earlier, and also considers long-term planning where a plan that spans a year to two is presented with consideration of disruption management. This represents a contribution to highlighted research question posed in [96]. In instances of disruption management where a nurse quits her job, the solution is to provide a new, feasible plan in a timely manner with as few alterations to the original plan as possible. In many cases, a disruption

only directly affects a smaller subset of the home carer's [96], but in the problem considered, it may affect a larger subset as the caseload of nurses are larger for the entire planning horizon.

Organization of Dissertation

Literature review on the problem of interest emphasizing the different HV programs in the healthcare system, as well as OR application to home care, are presented in Chapter 2. Chapter 3 presents the modelling approach of the infant HV program. In Chapter 4 the formulation of the mathematical model, illustration of the problem and data used are presented. Chapter 5 presents the computation of the model with computational experiments, the proposed solution methodology and a discussion on its performance. Chapter 6 presents the analysis of results and model validation. The summary, conclusions and recommendations are presented in section 7. Finally, references and a section devoted for appendixes are presented at the conclusion of this document.

CHAPTER II

LITERATURE REVIEW

This chapter presents a review of literature related to the HV problem. The review is divided into two parts; first, a review of infant HV programs, and second, OR application to home care. Articles reviewed in this study comprise studies that involve scenarios where pregnant mothers are visited in their homes before and after discharge from the hospital upon delivery. The HHC, HC and HV problem involves scheduling, routing and assignment of nurses to a number of visits in patients' homes, with the aim of maximizing the overall quality of service. This problem is sometimes considered as a generalization of the vehicle routing problem with time windows (VRPTW) with respect to a variety of constraints. In the first section of this chapter, a review of literature related to prenatal, postpartum discharge HV and intervention programs are presented. The specific kinds of visitations and follow-up models are explored. 511 relevant publications are considered which include 355 Journal articles, 95 reports of health institutions, associations and organizations, 43 books and book chapters, 11 conference proceedings, and 7 dissertations/theses. The subsections are devoted to categorization of the different studies and research focus, and finally, a summary of findings presented. The second section of the chapter presents a literature review of OR application to HHC, HC and HV. 29 relevant references are considered in the survey of publications. 3 types of publications were surveyed: journal articles (22), thesis/dissertations (4) and conference papers (18). For each study, the modeling approach, optimization criteria, assumptions, solution procedures, planning period and problem type are considered. Each section presents an overview of the problem and research perspective. Finally, conclusions about both surveys conducted as well as suggested directions for future research are presented.

Infant HV Studies

Problem Overview and Research Perspectives in this Field

In this section, a summary of the research on the problem of HV of mothers and infants after postpartum discharge from the hospital is presented. Conclusions of these research reviews are provided and future research directions proposed. To examine the status of HV knowledge and research conducted thus far in the field, the diagram in Figure 1 is proposed which shows up to date studies on the home visitation paradigm. Figure 1 shows HV and its concentration on infants and their parents, the various focus areas, categories of studies in the field, the targeted population, the beneficiaries (infants, parents and the community, government and tax payer), and decisions/policies that these studies have initiated, influence and implemented. Inferring from Figure 1, research on HV has concentrated on evaluation/comparison,

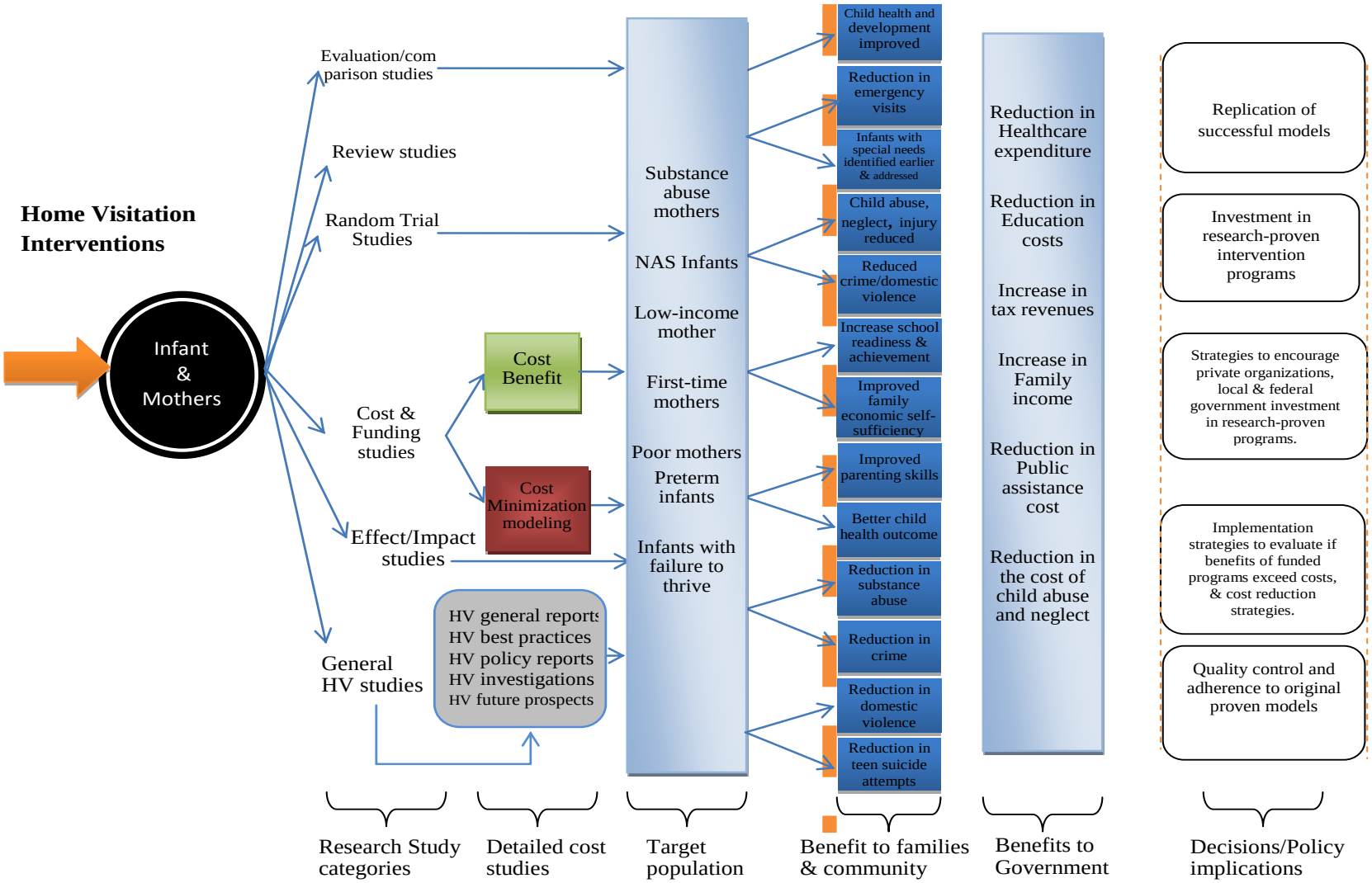

Figure 1 Current Study on the Home Visitation Paradigm

review, random trial, cost & funding, effect/impact and general HV studies. Detailed cost studies investigated are cost benefits and analysis studies. The target populations have been mainly substance abuse mothers, NAS infants, low-income mother, first-time mothers, poor mothers, preterm infants and infants with failure to thrive. Benefits of HV have been to both families and communities which include child health and development improvements, reduction in emergency visits, infants with special needs identified earlier and problems addressed, reduction in child abuse, neglect and injury, reduced crime/domestic violence, increased school readiness & achievement, improved family economic self-sufficiency, improved parenting skills, better child health outcome, reduction in substance abuse, reduction in crime, reduction in domestic violence and reduction in teen suicide attempts. Also HV has yielded numerous benefits to governments which include reduction in healthcare expenditure, reduction in education costs, increase in tax revenues, increase in family income, reduction in public assistance cost and reduction in the cost of child abuse and neglect among others. HV studies have contributed to the implementation of various government policies as well as decisions which include replication of successful models and investment in research-proven intervention program strategies to foster private, local and federal government investment in such research-proven programs. This has also led to implementation of various strategies to evaluate whether benefits of funded programs exceed costs, cost reduction strategies, quality control and adherence to original proven models.

Trends in HV interventions

Over the past 5 decades, HV has been an effective intervention scheme as supported by the extensive literature reviews. In this section several recent studies to identify research trends in the field are discussed. The red trend line in the plot of Figure 2 shows researchers' effort of OR home care publications by year from 1966 to 2014 which suggests that this field is still new and presents increasing interest to the OR community. It is worth knowing that no relevant OR home care studies were reported between 1966 and 1992. Also the studies being added to the field increased gradually in a wavering fashion until 2012. Only 4 and 3 relevant studies were reported in 2013 and 2014 respectively; but as this is a rapidly developing field with new literature being published continuously, additional literature may still be in preparation, in-press or under review. The various OR models and solution techniques that are available in home care literature include [71], [72] and [73] which address the balancing of workloads of the operators; [18], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84] and [85] all of which consider minimization of total travel time, distance and cost while respecting constraints related to route construction, scheduled hours, operator time windows, and skills requirements. Additional considerations include minimization of the total cost associated with overtime hours [19]; and [85], [84] and [20] which consider maximization of the

number of newly admitted patients based on resource availability constraints, minimum standard of service, variability of demand, transition rates among classes, and budget constraints.

From the non-mathematical perspective, HV studies have received significant attention in the areas of theoretical foundations, development of best practices and HV models, evaluation of different programs and their benefits among others. Other studies have estimated the cost of HV programs by using hospital/payer/insurance data in order to prove both its effectiveness and high cost. The blue trend line in Figure 2 shows the publications of infant HV literature by year from 1966 to 2014, and suggests that the evaluation of these programs increases in importance at specific points in time.

Based on the comprehensive literature search and as shown in Figure 2, research on HV programs may have started heavily around the 1960's and progressed through the years as its needs increased. Prior researchers, [97], [98] and [99], among others, have presented historical backgrounds of infant intervention programs that emanated in the 1960s. As seen in Figure 2, it can be inferred that research in the field increased gradually in a wavering manner from 1966 to 1990, took a sharp dive and picked up again around the end of 1991. It then showed a wavering growth up to 2001 from where it became undulating.

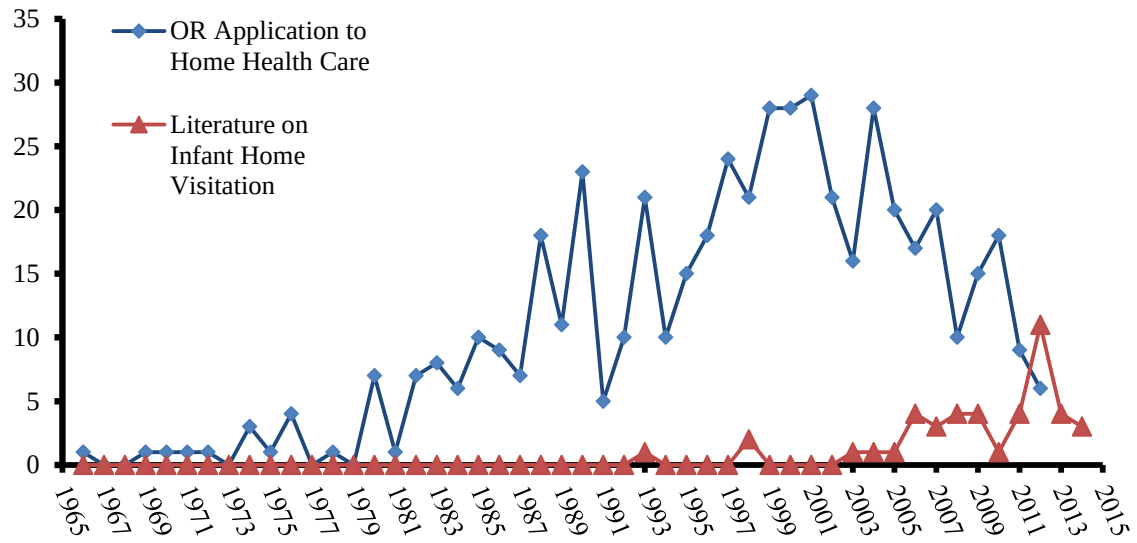

Figure 2 Accumulated Number of Relevant Publications from 1966 to 2014

By the years 2001 to 2014, most of the critical areas of HV studies had been covered with not much research in the field left to be done (except for some evaluations, comparisons and assessment of ongoing programs), leaving aspects of cost optimization studies partly untouched. Studies after 2001 were devoted to assessing the returns on investments, the effect on government expenditures, benefit cost of HV programs and different cost aspects with the realized HV's increasing cost [16], [17], [31], [63] [100], [101], [102] and

[103], etc. From the 1960s to the 1990s, most of the research studies seems to have focused on encouraging research into HV programs' development, its implementation as well as guidelines for implementation, testing and evaluation, and the selling of the program to many States in the U.S. and many other countries. Since 1993, HV programs have blossomed [104], watered by the flow of millions of public and private dollars [104]. Research on the importance of the early years of children's lives is on the increase [105], and shows that HV can offer unique benefits as a service strategy [106] based on preliminary positive research findings [70]. Over the last few years, there has been a renewed interest in the influence of early childhood, especially the first 3 years of a child's life, on health and development, educational attainment, and economic well-being [103]. This is possibly due to the variety of research recommendations by researchers in prior years. Public attention has been stimulated by television shows and stories in national news magazines. Governors and legislators have also been initiating programs to direct budgetary surpluses to services for young children [103]. In an immense effort to improve the outcomes of pregnancy and early child bearing among the poor, the federal government funded a number of health service demonstration programs for poor, young, pregnant women and their children in the 1960s and early 1970 [107-109]. In the late 1980s more than $4 million was awarded by the Health Resources and Services Administration (HRSA) to five States under an innovative program designed to help low-income persons avoid unnecessary hospitalization by receiving healthcare in their home [110].

In the 1990's, the U.S. advisory board on child abuse and neglect declared child maltreatment as a national emergency and recommended that a universal program of HV be developed for all new parents to eradicate this problem [111, 112]. This recommendation was based on evidence of past studies and also highlighted more research studies in this area to fortify the recommendation. A vast number of corroborated studies supported this recommendation. Among these were random trial studies by Hardy [113] and Olds et al. [114] that supported the efficacy of HV as a method of preventing maltreatment. Barth et al. [115], Gary et al. [116] and Siegal et al. [117] corroborated studies that hyped HV programs as a solution to prevention of child abuse and neglect. Around this same period and earlier, Olds and his team experimented different studies on HV and had shown evidence in their earlier reports that a comprehensive program of prenatal and infancy nurse HV improved the outcomes of pregnancy [60], reduced the rates of child abuse and neglect among high-risk families while the program was in operation, improved the life course development of the children's mothers [110], reduced the risk of intellectual delay associated with maternal smoking during pregnancy [118] and reduced government expenditures for low-income families[119], [120]. The most up to date study in the field is an ongoing research by Miller and Hendrie [121] with a focus on comparing the costs per family in randomized trials versus scale-up of the NFP program.

Categorization of Home Visitation and Intervention Studies

This dissertation presents HV literature by categories to serve as databank for all HV studies. By a thorough analysis of the various studies presented in 511 literature samples (see appendix), it is realized that prior HV studies have focused on specific subjects with specific aims at different times. The studies have addressed specific problems and needs that were prevailing at the time of the study. For instance, [60], [110], [122], [123] and [124] among others focused their study on random trial experiments in the late 1980's when HV models were needed, and research was needed to validate and justify the need for infant HVs. In another era, [104], [125-130] among others focused on evaluations of HVs to determine their effectiveness at specific times when the need arose. Also at different times when research was needed to ascertain the impact and long lasting effects of HV's, [10], [131], [117], [132], [95], [133], [134], [135] and others conducted studies in this area. Based on this discovery, this dissertation classifies prior research into six categories according to the focus of the study and research concentration; review, cost benefit, randomized trial experiments, impact/effect, evaluation/comparison, and general HV studies. Figure 3 shows the number of articles reviewed in each category by publication type. Table A.1 to Table A.6 in appendix A shows the taxonomies of these studies. It can be inferred from Figure 3 that there are more journal publications in all six categories than reports, books, conference proceedings, and dissertations. The descriptions of the six categories are presented in the sections that follow. It is noteworthy that none of the studies have focused on applying mathematical methods to cost reduction specifically in the infant HV process which this study had sought to investigate. Cost reductions with the use of paraprofessional was attempted in some studies but were not comparable to those that used nurses in terms of the benefits and outcomes of the programs [27]. A second observation is that no study has focused on maximizing HV's coverage with mathematical techniques within a specific deployment process for infants. OR and optimization techniques have however, been applied to adult HHC and HC, and can benefit infant care as well if considered. Optimization approaches and techniques are capable of solving large-scale instances, scheduling and routing problems effectively and may play a key role in the economic vitality of the healthcare industry for infant intervention programs. It was also observed that studies on evaluation of programs and their impacts or effects have spread through the years and will not end since this field is developing and keeps evolving, therefore governments and funding agencies need to know their successes in order to continue funding. The review and taxonomies identify which topics are being studied currently, and which should be investigated in the future. Based on the perspectives provided by this dissertation, a variety of fertile opportunities for research to contribute to postpartum infant HV and intervention programs are recommended. The categorizations are briefly explained in the sections that follow.

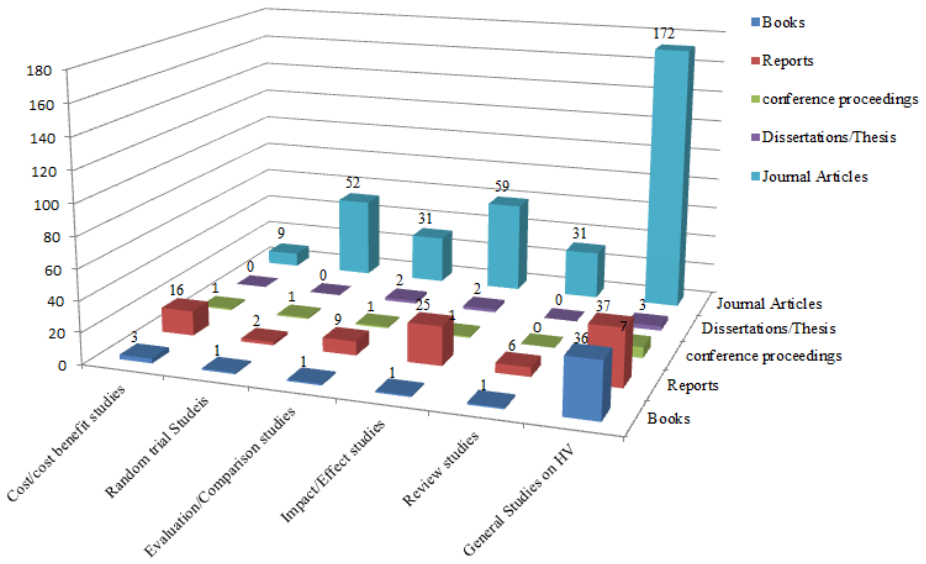

Figure 3 Categorization of Infant HV Literature

Review Studies

A number of research efforts have been devoted to conducting literature reviews on HV programs targeted at infant interventions. Studies in this category compile and analyze HV literature by using various methodologies; identify the weaknesses and strengths in studies, make recommendations, outline directions for future research as well as identify best practices for programs. Some reviews have focused on recommending evidenced based practical models and effective HV strategies by extracting pieces of information from comparative studies of various HV models. Methodologies that have been used in review studies include systematic reviews [65], longitudinal review study [66], meta-analysis [31], [68] and empirical review [69]. In review studies, researchers analyze selected programs with specific characteristics and then present suggestions and recommendations for best practices and future work. These studies select specific programs in the reviews based on defined criteria such as random trial studies that are targeted at a specific group of the population (eg. Hispanic mothers, African American mothers, first time mothers, etc). Also in review studies, researchers have identified program features and characteristics such as: description of the home visitors, program's objectives, sample size, research design, outcome measures and reported data [136] among others, and then compared and contrasted these features among several or selected programs. Replicability, long term effect, use of nurses or paraprofessionals and selection of target population has also been used to categorize and analyze HV programs in review studies. Some review studies have also categorized different selected programs under the service recipient, entry/exit point, frequency of visits, and duration of the program. HV experimental studies that focus on rigorous

methodologies like randomized trials and clinical trials [65], [70] among others have also been presented in this category. The majority of review studies have concluded positively on HV programs stating its contribution towards increased birth weight, improved prenatal care, improved maternal-infant interaction, and improved use of community resources [70], [136]. Based on the literature reviewed, it is noted that, well designed and implemented randomized trials of HV yield positive and greater effects as well as produce successful outcomes as noted by other studies. Review studies in the field will continue as it is necessary to aid in recommending untouched research areas, identification of fertile research directions as well as development of enhanced best practices. 31 journal articles, 6 reports and 1 book chapter are discussed in this dissertation (see Table A.1 in appendix A).

Cost and Benefit Analysis Studies

Cost, economic analysis and benefit studies have been reported by various literature elsewhere [50] [119], [137]. Extensive lists of these studies are reported in the appendix section (Table A.2). The cost of HV programs comprise nurse or paraprofessional pay, transportation expenses, home care supplies [138], administrative cost [113] , setup fees, training fees and other indirect expenses. Olds' [119] study seems to be the first to present HV program's cost/expenses in the equivalence of 1980 U.S. dollars based on a random trial study. Mainly, there are 3 categories of cost associated with the HV program; a. Direct cost associated with hiring nurse to participate in the program (eg. nurse salaries and fringe benefits,), b. Cost associated with nurse visiting patient/cost of services to which nurses linked families (eg. WIC nutritional supplements), and c. Transportation cost [119]. These costs have been the foundation for most researchers' study in which they have used economic calculations to convert the cost to different year dollars' to suit the year their studies is being conducted. Such studies include, Lee et al. [16], Gomby et al. [100], Glazner et al. [101], Aos et al. [17], [102] and Karoly et al. [63], [103]. The most up-to date study on cost benefit analysis is presented by Lee at al [16]. The 2012 report presents an extensive study on returns on investment for evidenced based HV programs in 2011 dollars. Barnett and Escobar [93] reiterates that economic analysis has been used to provide information about cost and to a lesser extent, the benefits of early intervention services, which helps to inform policy makers regarding the level of funding required to support a set of early intervention services. This also helps in deciding the types of desirable early intervention program, how governments should allocate funds and administer with the available resources in order to obtain the greatest benefits for children and their families [93]. Benefit-cost analysis involves the application of economic theory and primarily microeconomics to the problem of estimating the economic value of a program's effects. Barnett and Escobar [93] outline the steps of benefit-cost analysis for intervention program as follows; identify and estimate the resources used and the effects produced by

the program; translate resources and effects estimates into monetary measures of cost and benefits; aggregate those monetary estimates of costs and benefit to depict the net economic value of the program to society as a whole; describe the distributional consequences and finally, consider how the underlying assumptions and any other limitations of the analysis might affect the findings [93]. Researchers in the U.S. have determined cost savings by estimating government service costs and comparing to the various study groups with respect to the costs of Aid to Families with Dependent Children (AFDC), food stamps, Medicaid, child protective services, and foster care, as well as increases in government revenues generated by income taxes from women's participation in the work force [70]. Few studies have made significant efforts to contribute to reducing the cost of HV programs. For instance, in an attempt to solve the problem of cost reduction, different suggestions about using paraprofessional were proposed by Olds [139]. But Olds noted in his report: "could anyone be certain that paraprofessionals would bring the same skills and generate the same level of trust as registered nurses [139]?". In 1993, Olds put the paraprofessionals versus nurses' question to a rigorous scientific test in a Denver, Colorado experiment. The results, published in the journal of Pediatrics in 2002, confirmed Olds' suspicions [139], and this was later confirmed by other cost benefit analysis studies. Olds concluded that, the performance of the paraprofessional-visited group at the Denver study suggests that such a program may not be a wise expenditure of limited resources. While it is less expensive to deliver than the nurse-visitation program, it does not show promise for future recovery of program costs, as does the nurse-visitation program [101]. Based on the comprehensive literature review of the studies in this category and to the best of knowledge, no holistic approach using mathematical methods to minimize cost specifically on infant HV programs has been presented even though attempts have been made on HHC and HC in a different context. Future studies could be devoted to testing adults HHC/HC OR models (nurse scheduling, routing, operational planning and deployment) on infant HV programs, but may need to be modified to suite the unique needs, as well as developing OR models specifically for HV programs with their unique features as attempted in this study. This dissertation uses OR to model infant HV. OR employs mathematical equations and computer logics, etc., to forecast the consequences of particular decision choices without actually implementing them and presents the best or optimal choices [140-143]. OR applications in healthcare can lead to optimal resource allocation, improved revenue realization and reduction in operational expenses [144]. 9 journal articles, 1 conference paper, 16 reports, and 3 book chapters are reported under this category (see Table A.2 in Appendix A).

Randomized Controlled Trial Studies

In randomized controlled trial (RCT) studies, participants are assigned to treatment conditions at random. However, procedures are controlled to ensure that all participants in all study groups receive equal treatment

except for the factor that is unique to their group; the specific type of intervention they receive [145]. RCT's test whether an intervention works by comparing it to a controlled condition, usually either no intervention or an alternative intervention. RCT studies on HV also identify factors that influence the effects of the intervention and also tries to understand the processes through which an intervention influences change [146]. The "CONSORT" statement highlights that RCT's are conducted in 3 main ways; evidence creation; which is designing and conducting RCTs that generate data; evidence synthesizing; which is appraising and integrating RCT evidence to create a comprehensive understanding of the state of knowledge; and lastly evidence consuming; which is appraising articles produced by evidence creators and synthesizers in order to apply the knowledge in practice or teaching [147, 148]. RCT's are conducted to test whether an intervention or treatment works. It has been used in several studies to test whether HV interventions are effective. In the past 5 decades, researchers have conducted investigative and feasibility studies to test whether HV intervention services should be made universally available to all families in the United States, Great Britain, Canada and most of the developed countries. Among these studies RCT's investigates HV as an effective intervention for infants as well as the efficacy of HVs directed at teenage mothers, low income mothers, single and first time mothers. Through these studies, HV has been postulated to be a potent means of preventing maltreatment and abuse while enhancing growth and good health among others [21-24]. David Olds, popularly known as the father of HV programs, has probably conducted the most random trial studies on HV. In 1977, he began developing a nurse HV model to help young women and mothers take better care of themselves and their babies. He then developed the "Olds Model", first tested in Elmira, N.Y, 1977, which he keeps refining and has blossomed into the Nurse-Family Partnership (NFP), a nonprofit organization serving more than 20,000 mothers in 20 states across the United States [139]. The first RCT of comprehensive prenatal services provided the first evidence to show that the social and health contexts for child bearing among socially disadvantaged families can be improved, and finally concluded that nurse home-visitors are capable of improving women's use of community services, informal social support, and health habits [110]. Similarly Olds et al. [149] in 1986 tested a program of prenatal and infancy HV by nurses as a method of preventing a wide range of health and developmental problems in children born to "primiparas" who were either teenagers, unmarried, or of low socioeconomic status [149]. Again in 1988, Olds and his team tested a comprehensive and intensive program of prenatal and postnatal nurse HV aimed at improving the outcomes of pregnancy, early childrearing, and life-course development of women who were either teenaged, unmarried, or poor, and bearing their first child [110]. In conclusion, RCTs on the subject under consideration have been successful to this point. Through these experiments, HV programs have been refined and improved to serve many communities and the targeted population in a better way as well as yielded great benefits in different folds. This study recommends that more RCTs

should be conducted on HV programs that have not attained evidenced based status as well as new HV programs that are in the pipeline. This dissertation reports 52 journal articles, 1 conference paper, 2 reports and 1 book chapter of RCT studies (see Table A.3 in appendix A).

Impact/Effect Studies

This category considers studies that have been conducted to test and experiment the impact and effect of HV interventions on participants, the community, and governments as a whole. Impact/Effect studies have also looked at how successful and beneficial HV programs have been in enhancing the quality and safety of infant lives. Such studies test the effect or impact of early interventions on several components which comprise: intellectual and academic achievements [25], children's cognitive and affective development [26], cognitive and linguistic intervention, effect on child maltreatment, social development in children [27], school outcomes [28], mother child relationship, African American, Hispanic families, minorities, single-parent families, low-birth-weight premature infants [29], families of low socio-economic status [30], depressed mothers, and families dependent on public assistance [31]. Also some studies have focused on the impact on parental attitudes and behaviors, improving the interactions between mother and child, and the quality of child-care [31-34] improving prenatal and perinatal health, nutrition, safety and parenting, reducing the incidence of child abuse and neglect, improved child development, parent social-emotional support, parent education [35], decreased infant morbidity, decreased maternal school dropout [36], reduced drug substance use, emergency department visits and hospitalizations caused by injury and unintended subsequent pregnancies, increasing mothers' participation in the work force [32], and finally the impact of the programs on government cost savings. Impact and effect studies primarily targets specific groups of the population; disadvantaged and disabled children [9], at risk children's families and communities [10], adolescent mothers[11], low-income families, low-income single teen mothers, low birth-weight infants, premature infants [12], women at high risk for a variety of maternal and child health problems [13, 14] and impoverished children [15] among others. The impact and effect of HV programs can be short term or long term. Both are to the advantage of the infant, families, the communities and governments. Two studies concluded that certain subsets of participants may experience long-term positive outcomes on specific variables [59], [103]. Short term impacts/effects can be seen in HV's effect on child abuse and neglect and healthy growth, etc. Long term impacts/effects can be seen in HVs effect on education (earnings via high school graduation, earnings via test scores, K-12 grade repetition and special education), property loss from illicit drug disorder, healthcare (healthcare costs for disruptive behavior symptom, alcohol disorder, illicit drug disorder, depressive disorder) and public assistance [16]. 59 journal articles, 1 conference paper, 25 reports, 1 book chapter, and 2 dissertations are discussed in this dissertation. A taxonomy list of this

category is presented in Table A.4 in appendix A. Research on impact/effect studies needs to continue as the increasing need of the vulnerable population keeps growing. Most importantly, the impact/effects change over time and needs to be studied for continuous improvements. As time goes on, HV's positive impacts and effects may or may not continue, but ongoing research to assess these impacts and effects will help to realize them and to make necessary changes and improvements accordingly.

Evaluation/Comparison Studies

Literature on Evaluations and Comparison (EC) of HV programs have accumulated over the years and its market matured over the past few decades. EC studies analyze and compare intervention programs to ascertain their effectiveness, benefits, viability, program's efficacy and the positive or negative effects. Most importantly, EC studies examine careful designs of HV programs, evaluate empirical findings from previous research on HV programs, and high standards for field experimentation [52] and replication. Examples of programs that have exhibited positive results based on evaluations can be found in [13], [14], [60], [110] and [114]. Prior EC studies have also investigated whether the effects of programs are sustained [150] over time and at different locations. Some studies in this category have also evaluated the different applications and methodologies used for home interventions. For instance, a few studies have evaluated the use of nurses versus paraprofessionals to aid in cost reduction and concluded that studies that resulted in greater and positive effects were those that employed nurses [13], [14], [60], [110] and [114]. EC research has also aimed at investigative studies to determine well-designed and well implemented HV programs, and those that can be disseminated and replicated in different regions. Investigative studies classifies good HV programs as "evidenced based" (those based on rigorous experiments conducted, random trial experiment, and that have been successfully replicated, and yielded positive effects and benefits, etc.). For instance, evaluations study by Olds et al. [60], [110], [114], [122] suggested that for HV programs to be successful, they should have 3 requirements which were typical of the Elmira, Seattle, and Washington DC programs. The requirements identified by Olds include: a. Influences on maternal and child health should be viewed in terms of systems of material, social, behavioral, and psychological factors rather than single influences. b. HV should be designed to address the ecology of the family during pregnancy and the early childbearing years with nurse home visitors who establishes a therapeutic alliance with the families and who visit frequently and long enough to address the systems of factors that influence maternal and child outcomes. c. HV should be targeted on families at greater risk for maternal and child health problems by virtue of their poverty and lack of personal and social resources [32]. A 1998 study by the Council on Child and Adolescent Health (CCAH) emphasized the need for evaluation and safety studies that will examine careful designs of programs, give attention to empirical findings from previous research on HV programs,

and high standards for field experimentation [52]. Researchers have reiterated that public funding measures for HV programs should require both continuous evaluations and examination of outcome measures, and the ability to make midcourse corrections [58] [151]. Amidst the vast evaluation studies, evaluation studies must continue and focus on process improvements and control measures for HV programs to be effective in the changing world. 31 journal articles, 1 conference paper, 9 reports, 1 book chapter and 2 dissertations are discussed in this study (see Table A.6 in appendix A).

General Studies on Home Visitation

HV literatures which have general focus in the field are categorized under this section. These include general studies and findings on HV programs [152-154] and research that present theoretical foundations on the subject [155], HV models [156, 157] subjective studies, analytical studies on the issues of HV [158], studies focusing on HV implementation process, improvements and its effectiveness [159], the role of intervention programs, HV programs' enrollment strategies and characteristics [160, 161]. Included in this category, Wasik [158] among others have presented historical backgrounds of HV, staffing issues as well as implications for policymakers and funders [158]. The study reports tracing HV in the United States to Europe, especially Elizabethan England where visitors provided care to the poor in their own homes, and also nurses and non-nurses were encouraged to participate by Florence Nightingale [162, 163]. Research in this category also reiterate studies on experimentation of the variety of HV and intervention variables including timing of the intervention (prenatal vs. postnatal); intensity (weekly or more vs. monthly or less); duration (a year or more vs. less than a year); carefulness of the selection, training and supervision, continuing education of the home visitors; content of the intervention (specific educational content and/or emotional support); the overall framework of the intervention (child centered, family centered, ecologic); the research design and sample size [152]. Aspects like cultural considerations have also been covered. Overall, studies in this category have mainly concluded that intervention programs do have positive effects, and identified the potential for immediate and long-lasting benefits to the targeted populations. Studies in this category may be sub-divided into five groups; a) HV general reports**;** which are studies that present general information about HV, the advantages and disadvantages, challenges and issues with HV, results of HV surveys and implemented programs among others. b) HV best practices and strategies reports; which reports successful HV techniques based on comprehensive analysis of implemented programs. c) HV reports for policy makers; which focus on documenting and compiling evidences, benefits and positive effects of HVs for policy implementation. d) HV investigative reports; which accesses the possible benefits, successes and failures of HV programs as well as compare and contrast different HV programs and methodologies for possible outcomes. e) HV future prospects reports; which are devoted to analyzing,

forecasting and presenting how HV will impact and change the future of infants as well as present future directions. This dissertation reports 173 journal articles (which comprise 103 HV general reports, 42 HV best practices and strategies reports**,** 18 HV investigative studies, 6 HV reports for policy makers and 6 HV future prospects reports), 7 conference papers, 37 reports, 36 books/book chapters and 3 dissertations. Taxonomy of literature in this category is presented in Table A.6 in appendix 1A.

Summary: Discussion and Recommendations

Most studies report random trial studies, HV theory, evaluations of HV programs, its impacts/effects and the importance of HV interventions or cost/benefit of programs. It is clear that theoretical developments of mathematical models to minimize cost, increase coverage, optimize planning and operational efficiency for infant HVs are needed. The impact of cost spending on infant HVs affects government policies and budgets towards spending, and hence studies focusing on this may help to address related concerns. It is noteworthy that prior HV research has focused on experimentation and evaluation of programs. A second observation is that, no study optimizes infant HV deployment and implementation in terms of cost reduction. High cost of HV for infants cannot always be remedied by visiting only a selected critical few of the population, or cutting programs, as is being done with most programs. As mentioned in earlier sections, a critical feature of infant HV is that, they are funded by governments and public funds, and their effects are of importance to both the community and government, hence the need for cost optimization studies. On a Final note, the big question still stands unanswered; "OR approaches have been applied to adult care, but can these same models work for infant programs?" Identification of the unique features and deployment mechanism of infant HV programs in this study proves that adult care models may not work for infant models; the models may however be modified significantly to suit infant programs or better still, new OR models has to be developed for infant HVs.

Federal government initiatives such as "Head Start" serve almost one-half million preschool children (but only about one fifth of such children are eligible) [164]. Increasing fiscal restraint in the past 10 years led some health departments to abandon HV as it was considered to be too expensive [94]. Some States in the U.S. fund early intervention programs on the basis of program capacity or numbers of children enrolled, hence programs have no financial incentive to operate efficiently by providing maximum amount of services to the child and family given the resources available [93].The attention given to disadvantaged children has spawned a sprawling array of programs, all designed to enhance the lives of children and families and all vying for the same shrinking pool of public dollars [95]. The United States under-invests in early intervention programs because it fails to accommodate all children in poverty for even one year prior to kindergarten [93]. Virtually no study has dealt with cost minimization techniques and strategies for

infant visits using optimization approaches, and not long ago a few studies dealt with benefit cost analysis related to government spending on these programs. It is worth knowing that no mathematical models to maximize HV's quality of treatment and coverage have been published. One characteristic of HV program is that, the intervention strategies and models are similar but it targets an ever increasing population. Optimization models are needed to quantify and minimize implementation cost. It is expected that ongoing studies will develop optimization methodologies and techniques to address this, and also test optimization models for adult visits on infant HVs to ascertain its efficacy and to what extent they need to be modified to work with infant HVs.

OR application to HHC, HC and HV

Problem overview

OR application to HHC, HC and HV is popularly known as the home care or home healthcare scheduling problem (HCSP) which involves the scheduling and assignment of nurses to a number of visits in patients' homes, with the aim of minimizing cost, travel time, distances, and maximizing the overall service, etc. This problem is a generalization of the vehicle routing problem with time windows and with respect to a variety of constraints. A number of research efforts have been made towards solving this problem by several authors. Six of the most relevant ones are briefly summarized below. The remaining literature presents similar approaches and methodologies to the HCSP and are summarized in the section that follows.

Lanzarone et al. [165] addressed the resource assignment problem for HC systems by proposing a set of mathematical programming models to balance the workloads of the operators within specific categories. The model considered continuity and non-continuity of care constraint, operators' skills, and the geographical areas which patients and operators belong to. Based on the high variability of patient demands, the model developed assumes that patient demands are either deterministic or stochastic. Lanzarone defines continuity of care as a means that a patient is assigned to only one operator of each category, named the principal operator, who follows the entire patient's care pathway during his/her sojourn at the HC structure and preferably provides all of the visits pertinent to his/her category. The study analyzes the effects of patient demand variability on the assignment by comparing the solutions obtained in a deterministic or a stochastic demand context. Operators are divided into districts, based on their main skills and working territories. The HC service providers are divided into a certain number of districts and each operator belongs to a district according to his/her skills and the territory which he/she works in. The compatibility between the newly admitted patient and the operators belonging to district is defined based on territorial compatibility and operator skills versus patient care needs. Districts are defined before solving the

assignment problem, and the assignment-type decisions do not consider other operational decisions such as scheduling or routing of visits. Since the scheduling and routing of visits are not included, the interaction among the different categories of operators is not explicitly considered in the proposed model. Hence, the assignments are defined separately for each category of operators, and the model examines only one category at a time. This approach reflects the real condition of HC service providers having districts of limited territorial extensions, which are not modified during the assignments, and where the different categories of operators are managed and assigned independently. The assignment problem is solved either at a fixed frequency (e.g., day or week) or when a certain amount of newly admitted patients are reached. Assignments are made on a rolling time basis: each time the problem is solved, a new planning horizon is considered and the assignment problem is solved over this planning horizon. Models were run using OPL 5.1 (ILOG IBM, Sunnyvale, CA, USA). The percent gap between the integer solution, and the best node was imposed to be lower than 0.5%. The proposed model has been implemented in a software application currently in use by the analyzed HC service provider to assign patients to nurses.

Begur et al. [18] developed a spatial decision support system (SDSS) to address the HC problem. It integrates stand-alone PC-based geographic-information-system (GIS) software with scheduling heuristics and databases to form a user-friendly tool that saves the association travel time and schedule-preparation time (over $20,000 a year) and improves the balance of work among nurses. The study developed a module for the daily scheduling of operators' activities, which simultaneously assigns visits to operators and generates the sequence in which visits have to be provided. The planning period is five days, and no operative re-planning is required. The constraints consist of three types of restrictions: route construction, nurse time availability, and patient visitation requirements. The study considers a multi period vehicle routing problem (MVRP) as an integer linear programming problem with the characteristics of the Generalized Assignment problem. It addresses the assignment of customers, locations, or pickups, to different periods of the planning horizon; and the assignment of customers to vehicles (along with the visitation scheme) for each periods of the planning horizon. A Lagrangian relaxation based subgradient algorithm is developed for the Generalized Assignment problem, and adapts a heuristic approach that combines a set of procedures (e.g., k-optimal procedure, sweep algorithm, insertion procedures) to build daily operators' routes. The objective is to minimize the total travel time while respecting constraints related to route construction, operators' time windows, and skills requirements. The overall schedule planning process involves a hierarchy of several assignment decisions. First, a long range master schedule is developed that assigns patient visits to specific weekly time buckets during the planning horizon of sixteen weeks. Next, the visitations planned for a given week have to be allocated to a specific day of the week.

Then the patient visits scheduled for each day have to be assigned to the nurses and the order or route determined. The routing problem is solved based on Clark and Wright's (1964) heuristic [166]. Optimal primal solutions within 1% of the actual optimal values are obtained for the problem with up to 200 locations with 20 CPU seconds on the IBM 3090.

Cheng and Rich [16] addressed the daily scheduling problem as a multi-depot vehicle routing problem by formulating a mixed integer linear programming problem (MIP) with time windows and compatibility information. The objective was to minimize the total cost associated with the overtime hours assigned to full-time nurses and the hours given to part-time nurses. The problem in this study was to find an optimal schedule such that each nurse that is scheduled to work leaves from his or her home, visits a set of "feasible" patients within their time windows, takes a lunch break within the nurse's lunch time window, and returns home, all within the nurse's time window and within the known limit on the length of a shift. The set of nurses is made up of the disjoint union of full-time nurses and part-time nurses, and every nurse is required to visits at least one patient; and every patient must be visited exactly once. The problem is formulated as a MIP model and solved by two-phase heuristics; one using double-indexed variables and the other using triple-indexed variables. The first phase of the heuristic falls into the category of a parallel tour-building procedure since it typically builds several routes simultaneously and are generated using a randomized greedy algorithm. The second phase attempts to make improvements on the tours identified in phase one. Numerical results for up to four nurses and 10 patients are presented.

Bertels and Fahle [18] proposed a combination of linear programming, constraint programming, and heuristics to assign operators to visits and to optimally sort the visits assigned to each operator. The study describes the optimization models and methods used to solve a home health-care application in Germany by combining aspects of vehicle routing and staff rostering. The goal was to minimize the total transportation cost and maximize the satisfaction of both patients and operators, while considering a variety of soft constraints (e.g., patient-operator affinities and preferences for certain visits), however the study does not incorporate connected visits. The optimization is based on a combination of linear programming, constraint programming, and metaheuristics. The planning period is one day, and the solution time is limited to 10–15 minutes. The study develops the PARPAP software. They consider hard constraints like qualification requirements or work time limitations, and Soft constraints like patients preference for certain time intervals for being served, the right "chemistry" between patients and staff has to be ensured, as patients do not like frequent changes of nursing staff. The study applies tabu search (TS), simulated

annealing (SA), or constraint programming (CP), respectively, to assign staff to jobs. For optimizing an individual work-plan, the study uses a hybrid linear and CP module.

Eveborn et al. [74] [167] developed a decision support system where the scheduling problem is formulated as a set partitioning model and solved by a repeated matching algorithm. The objective was to develop visiting schedules for care providers that incorporate some restrictions. The soft objective is to minimize cost related to travel time, scheduled hours, preferences, etc., while respecting criteria such as time windows for visits, operators' skill requirements, and accomplishment of each visit by one operator. A number of restrictions are imposed on the staff routes where each visit has a time window and requires a set of skills which must be met by the staff member. Each staff member is given working areas, planned breaks and certain visits are grouped in such a way that the same staff member must do all visits, while certain visits also require multiple staff members. Allocation of sufficient travel time between visits and each client has one or more preferred staff members to make the visit. The decision support system LAP CARE aids the planners with scheduling, and the savings are considerable in terms of saved planning time and in the quality of the routes, as well as the measured quality for the clients. Each client has a list of contact persons, who are preferred staff members for the clients' visits. Using LAP CARE the staff can view what is expected and when visits are supposed to be done, making follow ups much easier. Finally, the study reports time savings of about 7% of the total working time and savings in travel time is about 20%.

Rasmussen et al. [84] solves the home care crew scheduling problem as a set partitioning problem with side constraints and develops an exact branch-and-price solution algorithm. Temporal dependencies are modeled as generalized precedence constraints and enforced through the branching. The study contributes by devising visit clustering schemes for the problem, and also enforcing generalized precedence constraints in the branching for real-life problems. The study considers visit preferences, visit priorities, visit cancellations, enforcement of temporal dependencies to cancelled visits, different working hours, different competences, and different means of transportation for the home carers. The main priority is to leave as few visits uncovered as possible. The visit clustering decreases run times significantly, and only gives a loss of quality for few instances. The study introduces a novel visit clustering approach based on the soft preference constraints. However, this study is restricted to only looking at the daily scheduling problem not the long-term plan.

Research Perspectives in this Field

In this section, perspectives of research on the problem of HHC, HC and HV scheduling, routing, human resource assignment and man power allocation problems are presented. Conclusions of these perspectives are provided and fertile research directions for this problem which are proposed to be addressed in this dissertation are presented. Table 1, Table 2 and Table 3 summarizes previous work done in the field. The most up to date summary of the state of art study in HC, HHC and HV scheduling, routing, human resource assignment and Man power allocation problem research are presented by Riazi et al. [168], Yalcindag et al. [169] and Mankowska et al. [170]. Despite the significant number of OR approaches, no case of modelling for multiple and long term planning horizon has been reported in the tables for this specific HV problem as considered in the proposed study for 1 to 3 years fixed period with weekly, bi-weekly and monthly visits based on model fidelity requirements. Other uniqueness of HV programs which have not been studied, but are tackled in this dissertation are: the program targeting 64 visits and in the ideal situation, visits occuring every other week through the child's 21st month (90 weeks) plus monthly visits in months 22-24 (90-103 weeks), except that visits are scheduled weekly for 4 weeks after program's enrollment and 6 weeks after birth. The home visits ideally begin by week 13 of pregnancy and must begin by week 28 [171]. The program has a total of 144 weeks of planning horizon. These have not been considered in prior studies, and modeling the approach imply the formulation of complex linear constraints using binary variables. Secondly, this dissertation considers the program's enrollment as a decision variable for every patient, maximizes the ideal enrolled patient and minimize the last due date enrollment of patients. Thirdly, other models in literature are oriented as vehicle routing problem based models. On the other hand, the study in this dissertation is not, but a visit planning model at the operational level, where coverage is a crucial objective, and funding is a constraint. To the best of our knowledge, no study has proposed a model capable of representing such a situation. Fourthly, and most importantly, this study addresses minimization of risk; thus, the maximization of the comprehensive nurse expertise; thus assignment of the right nurse with the right skill/training (in dealing with patients' needs: crime (C), health and drugs (HD), mental development and education (ME), and public assistance (PA)); nurse/NCP type (Registered nurse (RN), Certified nursing assistant (CNA), Licensed Practical nurse (LPN) or Nurse practitioner (NP));, and nurses' years of experience, matched to the right family with the specific need (C, HD, ME, PA). This has not been considered in prior studies. Also, it is worth knowing that prior studies have focused on HHC and HC which are mainly care for adult patients and not HV interventions which rather targets infants as an early intervention strategy.

It is noteworthy that HV is unique and different from HHC and HC. This study highlights the differences in these visitation programs in the sections that follows. HHC and HC aims at providing medical, paramedical, and social services to patients at their own domicile homes, to decrease patients' hospitalization rates, improve their quality of life, and reduce costs across the entire health care system [71], [172, 173]. On the contrary, HV aims at providing visitation and care for infants and their mothers during pregnancy and immediately after delivery discharge, to ensure healthy growth, guidance, early developmental delay detection, etc and prevent rehospitalization, death, neglect and abuse among others. An important characteristic of infant HV is that, they are funded by governments and public funds, and their effects concern both the community and the government. The nearest literature to this work are the studies by Lanzarone et al. [71] and Begur et al. [18]. On the contrary, this dissertation consider a fixed visit duration of 1 to 3 years, with different planning horizons for each patient, and considers additional variables. The study then defines and uses a number of unique and distinct features of infant HV which makes this study unique. To broaden the view of the literature surveyed in the field of OR applications to home care,

Table 1, Table 2, and Table 3 are presented. Table 1, Table 2 and Table 3, presents a taxonomy of surveyed HHC/HC/HV literature: by problem type, solution strategy, type of model, planning period, optimization criteria, approach and country in which the research was conducted. These are categorized according to published journal articles, books, conference papers and dissertations/thesis. Inferring from Table 1, Table 2 and Table 3; modeling methodologies applied in existing research include mathematical programming/MILP, stochastic linear programming, constraint programming/hybrid constraint programming, and heuristics related approaches. 80% of the research contributions in the field applied MILP modeling approaches. Four forms of problem types are identified; human resource assignment (HRA) or manpower allocation (MPA), Scheduling (S), Routing (R), and districting (D) related problems. About 70% of the research efforts are scheduling and routing related problems. The optimization criteria for almost all the research efforts included the minimization of cost, travel times and distances. Five types of approaches can be distinguished from Table 1, Table 2 and Table 3; Multi-activity combined timetabling and crew scheduling problem (MCTCSP), Man-power allocation problem with time windows and job-teaming constraints (MAPTWTC), Elementary shortest path problem with time windows (ESPPTW), Traveling salesman problem with time window (TSPTW) and Vehicle routing problem (VRP)/periodic vehicle routing problem (PVRPTW)/multi vehicle routing problem with time window (MVRPWT). Only about 20% consider the development of a decision support tool. All the literature surveyed considers either HHC or HC except one, Begur et al. [18] who considers both HC and some components of HV.

Summary:

The HHC, HC and HV problem has been addressed from different perspectives and with application of different techniques, optimization criteria and solution strategies. Begur et al. [18] is probably the first to present OR application to care at home, and since then the problem in this field has been gaining attention in the OR field. Despite the broad applications of OR in the healthcare industry, it seems that the first visible attempt to solve this specific problem was published about 22 years ago and remained stable for almost 5 years when Chen and Rich[19], and Deangelis [20] picked up and continued. Since the year 2000, OR experts have made tremendous efforts on the problem to date. The problem has been addressed in a broad range of random instances and also real life scenarios of different sizes, objectives and in various countries among which are Italy, Canada, Denmark, Sweden, Germany, Columbia, Belgium, Austria, France, USA, Spain, Switzerland, Singapore, United Kingdom, South Africa, Tunisia and China. Figure 4 depicts the contributions from the different countries.

OR methodologies have been applied to real life healthcare systems as well as with random instances. Feasible solutions, optimal or near optimal solutions have been obtained using mathematical approaches and heuristics, and in some instances, decision support tools developed. For real life cases considered in the U.S., the instances solved in the available literature appear to be small. It is observed that no modeling approaches for overall HV operational and planning levels are reported in the surveyed papers. Future research may be devoted to exploring these areas. The HV paradigm and problem is still an emerging new problem which calls for unexplored modeling and solution approaches. Future efforts may include the unique and real life features of HV such as enrollment as decision variable, the comprehensive nurse skill matrix (training, type of nurse and years of experience), multiple horizon and long term planning among others. In this dissertation, the developed model is different from the classical literature, due to the possibility of the set of patient classes that nurses can handle based on their skills/training, years of experience and nurse type, which is defined as a matrix for quality assignment. Moreover, the model introduced complicates the studies in literature by adding the unique features of the infant HV process described earlier as new constraints with consideration of long-term planning where a plan that spans a year to three year term is presented. The study also considers disruption management which occurs in instances where a nurse quits her job; in this situation, the solution is to provide a new, feasible plan in a timely manner with as few alterations to the original plan as possible. In many cases, a disruption only directly affects a smaller subset of the home carer's [96] and patients but in the problem considered, it may affect a larger subset as the caseload of nurses are larger for the entire planning horizon. Additionally, this dissertation considers that, patients on the other hand may drop out of the program; hence a solution is needed to adjust the nurse workload.

Table 1 A Taxonomy of HHC/HC Literature: By Problem Type, Modeling Feature, Solution Method, Type of Assignment, Tool and Planning Horizon: Journal Articles

Year	*Reference*	*Problem Type*	*Solution Strategy*	*Type of Model*	*Planning period*	*Optimization Criteria*	*Approach*	*Country*
2014	Mankowska et al. [170]	S & R	construction heuristics, Adaptive Variable Neighborhood Search (AVNS)	MILP	Daily	Minimize cost, travel time and tardiness	MTSPTW	Germany
2013	Allaoua et al. [174]	S & R	Meta heuristics	ILP	NS	Minimize travel time and cost	MTSPTW	France
2013	Cappanera and Scutella [175]	S & R	heuristics	ILP	Weekly	Minimize travel time and maximize the minimum operator utilization factor	VRP	Italy
2012	Lanzarone et al. [71]	HRA	Integer solution	SP & MP	1 day or week	Minimize utilization rate, travel time and cost	NA/NS	Italy
2012	Barrera et al. [73]	S & R	Heuristic procedure,	MP, MILP & LO	5 days	Maximize Coverage, Minimize workers scheduling	MCTCSP	Bogota, Columbia
2012	Rasmussen et al. [84]	S & R	Dynamic column generation, exact branch-and-price solution algorithm	MP	Daily	Maximize service level and minimize cost	VRPTWTD	Denmark
2012	Nickel et al. [176]	S & R	Meta heuristics, adaptive large neighborhood search (ALNS)	CP/MILP	Weekly	Minimize cost and travel time/distance and Maximize worker skill	VRP	Germany
2011	Trautsamwieser and Hirsch [79]	S & R	Meta-heuristic solution approach based on Variable Neighborhood Search	MP	Daily	Minimize travel time	NA/NS	Austria
2011	Bachouch et al. [177]	S & R	NS	ILP	Weekly	Minimize travel distance	NS	France
2009	Hertz and Lahrichi [72]	HRA	Tabu search heuristic.	MILP	Daily	Minimize visit load, caseload and travel load	NA/NS	Canada
2009	Chahed et al. [85]	S & R	Traveling salesman, exact solution method, branch and bound (B&B) algorithm	MP	NS	Minimize cost and travel time, maximize profits, coverage	NA/NS	France

Table 1 Continued

Year	*Reference*	*Problem Type*	*Solution Strategy*	*Type of Model*	*Planning period*	*Optimization Criteria*	*Approach*	*Country*
2009	Dohn et al. [178]	MPA	Branch-and-Price algorithm	MILP	Daily	Minimize cost	MAPTWTC/ ESPPTW	Denmark
2007	Akjiratikarl et al. [77]	S & R	Particle swarm optimization meta-heuristics.	MP	Daily	Minimize travel distance	VRPTW	United Kingdom
2006	Eveborn et al. [74]	S & R	Repeated matching algorithm (combination of optimization methods and heuristics.).	MP	NS	Minimize cost	NA/NS	Sweden
2006	Bertels and Fahle [75]	S & R	Tabu search (TS), simulated annealing (SA), and heuristics	LP & CP	1 day	Minimize travel cost and maximize satisfaction	TSP	Germany
2005	Li et al. [82]	MPA	Construction heuristics used with simulated annealing	MILP	NS	Minimize workers and travel time	MAPTWTC)	Singapore
2004	Lim et al. [179]	MPA	Tabu-embedded simulated annealing algorithm & a squeaky wheel optimization with local search algorithm	MILP	N/S	Minimize workers, travel distance and time	MAPTWTC	China
2003	Blais et al. [180]	D	Tabu Search	MP	NS	Minimize travel distance	NA/NS	Canada
1998	De Angelis [20]	HRD	NS	SLP	NS	Maximize new patients	NA/NS	italy
1998	Cheng and Rich [19]	S & R	Two-phase heuristics, branch and bound	MILP	Daily	Minimize cost	MVRPWT	USA
1993	Begur et al. [18]	S & R	Heuristic approach: k-optimal procedure, sweep algorithm, insertion procedures	MP	5 days & daily	Minimize travel time	VRP	USA

Table 2 A Taxonomy of HHC/HC Literature: By Problem Type, Modeling Feature, Solution Method, Type Of Assignment, Tool and Planning: Conference Papers

Year	*Reference*	*Problem Type*	*Solution Technique*	*Type of Model*	*Planning period*	*0ptimization Criteria*	*Approach*	*Country*
2014	Riazi et al. [168]	S & R	Heuristic gossip algorithm	MILP	N/S	Minimize travel time and customer dissatisfaction	VRPTW	Sweden
2014	Yalcindag et al. [169]	S & R	genetic algorithm	ILP	daily/weekly	Minimize travel time	TSP/VRP	Italy
2013	Gayraud et al. [181]	S & R	N/A	MILP	NS	Minimize cost and travel time/distance and Maximize worker skill	m-TSPTW	France
2013	Mutingi and Mbohwa [182]	S	genetic algorithm		NS	Minimize travel distance and cost	VRPTW	South Africa
2012	Cire and Hooker [183]	S & R	Heuristic search	CP		minimize cost	CP	USA
2012	Trabelsi et al. [184]	S & R	N/A	MILP	Daily	minimize cost	NA/NS	Tunisia
2012	Rendl et al. [185]	S	Variable neighborhood search, scatter search & simulated annealing hyper heuristic.	MILP	daily	Minimize cost, travel/work time and maximize nurse/patient satisfaction	VRPTW	Austria
2012	Yalcindag et al. [186]	S & R	NS	MILP	Weekly	Minimize travel distance and work hours	TSP	Italy
2011	Smet et al. [80]	S	Hyper heuristics	MP	4 weeks	minimization of travel cost and minimization of quality of care	VRPTW	Belgium
2011	Rendl et al. [187]	S	Hybrid meta-heuristic & variable neighborhood search	CP	NS	Minimize cost and travel time	VRP/TSPTW	Austria
2010	Misir et al. [81]	S	Hyper-heuristics	MP	4 weeks	minimize travel and Ide time	NA/NS	Belgium

Table 2 Continued

Year	*Reference*	*Problem Type*	*Solution Technique*	*Type of Model*	*Planning period*	*0ptimization Criteria*	*Approach*	*Country*
2009	Kergosien et al. [188]	R	N/A	ILP	N/S	Minimize cost and travel time	mTSPWT	France
2008	Bachouch et al. [78]	S	NS	MILP	NS	minimize travel distance	NA/NS	Switzerland
2008	Dohn et al. [189]	S	Exact solution approach, branch-and-price	MP	Daily	minimize cost	MAPTWTC / ESPPTW	Denmark Canada
2008	Elbenani et al. [190]	S & R	scatter search approach/meta heuristics/tabu search	ILP	NS	Minimize travel distance and work hours	VRPTW	
2008	Elbenani et al. [191]	S	Tabu search	ILP	NS	Minimize travel distance and work hours	MVRPTW	Canada
2007	Steeg and Schröder [192]	S	Large neighborhood search approach, Branch and bound search	HCP	NS	minimization of the number of visit	PVRPTW	Germany
2006	Borsani et al. [193]	S	NS	MILP	weekly	minimize number of visits, travel time and distances	NA	France

Table 3 A Taxonomy of HHC/HC Literature: By Problem Type, Modeling Feature, Solution Method, Type Of Assignment, Tool and Planning Horizon: Dissertations/Thesis

Year	*Author*	*Problem Type*	*HC/HHC / HV System*	*Solution Technique*	*Type of Model*	*Planning period*	*Optimization Criteria*	*Approach*	*Country*
2012	Hiermann [83]	S	HHC	Meta-heuristics variable neighborhood search, genetic algorithm	CP	1 day	Minimize travel time	CP	Austria
2012	Macdonald [194]	S & R	HHC	Meta-heuristic based on local search; Simulated Annealing	MILP	weekly	Minimize travel time and cost	VRP	Austria
2007	Lessel [195]	S & R	HC	Insertion heuristics, greedy restart heuristic, Tabu search technique	MILP	1 day	Minimize travel time and cost	TSPTW	Denmark
2006	Thomsen [196]	S & R	HC	Insertion heuristics, Tabu search technique	MILP	1 day	Minimize travel time and number of shared visits	VRPTW/VRPTWSV	Denmark

*[*NS-Not stated, NA-Not applicable, S- Scheduling problem, MPA-Man power allocation problem, R- Routing problem, D- Districting problem, MILP- mixed integer linear programming, HRD-human resources dimensioning, HRA-human resource assignment, MAPTWTC- man power allocation problem with time windows and job-teaming constraints, VRPTW/VRPTWSV-vehicle routing problem with time window and shared visits, TSPTW-traveling salesman problem with time window, VRPTWTD-vehicle routing problem with time window and temporal dependences, ESPPTW -elementary shortest path problem with time windows, VRP-vehicle routing problem, MVRPWT/ MD VRPTW -multi vehicle/depot routing problem with time window, PVRPTW- Periodic Vehicle Routing problem, CP-constraint programming, SP/SLP-Stochastic linear programming*].

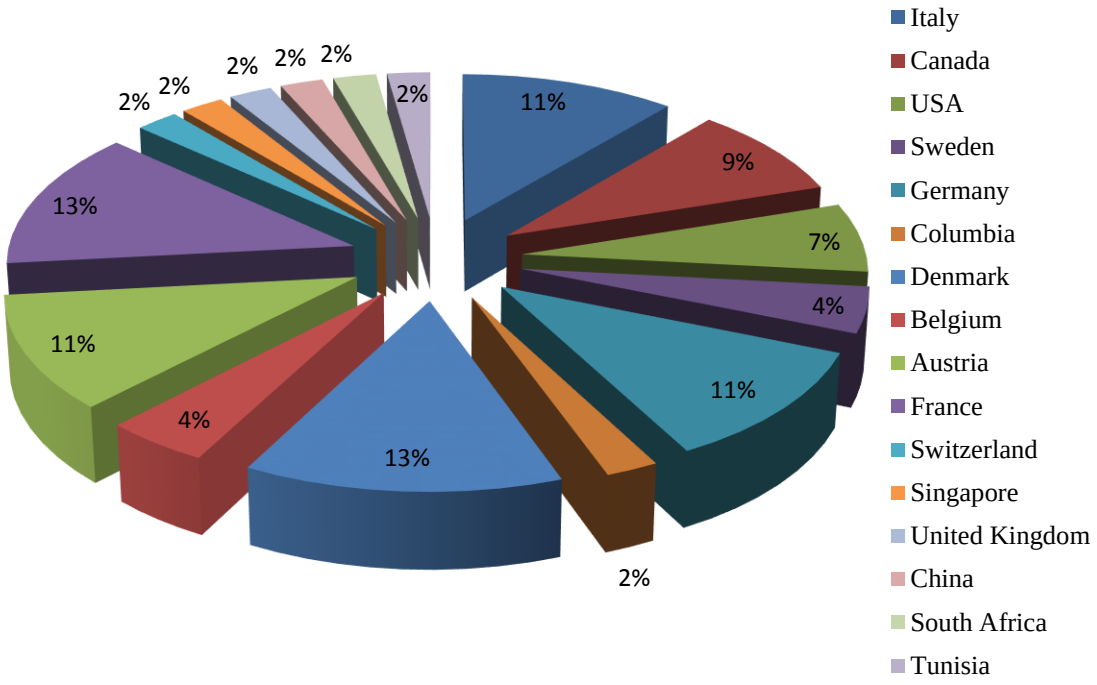

Figure 4: Countries reporting research contributions for the HHC and HC modeling

Conclusions

Home Healthcare, Home care, Home Visitation and Operations Research Approaches

As noted earlier OR has been successfully applied to adult HHC and HC from different perspectives but not infant HV. One of the objectives of this dissertation is to investigate the applicability of mathematical methodologies to infant HVs for effectiveness and cost efficiency, and then stimulate research interest in this field. By definition, OR employs a predictive modeling investigative paradigm, mathematical equations, computer logics and related tools to forecast the consequences of particular decision choices without actually implementing them which systematically searches for the best or optimal choices [140-143]. It's applications leads to host of benefits [144]. Users of the application need not have any background in mathematics or computer logic as they operate a decision support tool at the front end with mostly user friendly graphic user interfaces. These applications aid in overall operational planning (scheduling, routing and assignment of resources, etc.). An earlier study [197], which inspired this dissertation, presented a

simple application of OR to infant HV. A few other studies have also addressed the problem using OR by developing decision support systems with embedded mathematical programming models also noted in [197]. For example, Begur et al. [18] developed an integrated decision support (DSS) module using a heuristic approach for daily scheduling and routing HHC nurses targeted at adults. Similarly, Eveborn et al. [74], [167] developed the LAPS-CARE system, which uses OR for scheduling in order to eliminate manual planning. The tool was targeted at elderly care systems. Vehicle routing problem based solution approaches have also been proposed for the problem from an operational point of view. For instance, Bachouch et al. [177] dealt with the problem of routing nurses in HHC service systems. An integer linear programming model for deciding which human resource should be used and when to execute the service during the planning horizon to satisfy the care plan for each patient served was proposed. In another context, Barrera, Velasco, & Amaya [198] addressed the problem of improving the current operating conditions of a school visitation program delivered by the Bogota health department in Colombia.

Researchers objectives of OR application to healthcare have been successful in minimizing total travel time, number of shared and unlocked visits while respecting the patients' and operators' time windows [196], minimizing total distance traveled by nurses [199], balancing workloads of operators within specific categories [165] and minimizing cost, etc. It is identified that only a few studies have proposed mathematical models to optimize HHC and HC deployment and implementation in very particular contexts different than that of discharged newborns with first time mothers in a vulnerable situation [200] (e.g.: first time single mothers addicted to drugs and alcohol and the like). Infant HVs are unique in that their operation, planning and deployment are diverse. Clients are visited in their homes as in HHC and HC but the process and variables involved are different. After care for patients are classified either as HHC, HC, or HV. HHC and HC are somewhat related for the problem situations in the sense that they are both targeted at the elderly population and have a common operational strategy. Both are designed to provide medical, paramedical, and social services to patients at their own domicile [165, 201, 202]. On the contrary, Infant HV starts before and after hospital admission, and are designed to provide visits and care for both infants and their mothers. As a contribution, this study distinguishes HV with its unique features and characteristics from HHC and HC below;

a) HV visits are initiated before hospital admission (when a client knows she is pregnant), and continues after postpartum discharge, whiles in the case of HHCand HC, visits starts after hospital discharge.

b) HV clients are not necessarily ill or have health conditions, but targets every newborn and infants especially disadvantaged families, so visits and priority assignments are different from that of HHC and HC [203].
c) For HV, visits are normally not random but periodic and are for a specified duration. Families still conform to program and schedule even if the participants' condition changes as opposed to HC/HHC; which has many random events that affect the service delivery. The main randomness stems from unexpected changes in patient conditions, expressed as variations in the number, frequency, and duration of visits, which makes the activity of the HC service provider highly uncertain [165, 204].
d) Participants of HV do not determine their visit times and choice of visitor gender. They are scheduled by the program's office, as opposed to HC/HHC where patients prefer certain time intervals for being served and can make the choice of the gender of the operator.
e) Cost structure is same for each HV participant, and are funded by governments and public funds; therefore, their effects concern both the community and the government as opposed to HHC/HC where cost and cost structure is different for each patient based on their diagnosed sickness.
f) HVs participants' demand can easily be forecasted as most are enrolled based on eligibility criteria, through hospital databases. Hence the requirements and process for HV are predefined as opposed to HHC and HC [28], [205].

The few OR studies on HHC and HC for adult care have concentrated on just scheduling and routing, with no focus on operational planning of infant HV and its unique features. Cost and risk minimization, coverage and benefit maximization, as well as the quality of treatment on this subject, has not received the needed attention.

An important characteristic of HV is that, every infant most likely needs this service; which reflects the racial, cultural and ethnic diversity of the population; and the programs aim at early interventions in contrast with only care services. Future research should be devoted to experimenting OR approaches developed for HHC and HC to test the extent to which they will work with infant HV. Also, infant HV's may need new mathematical models valid for their unique features. Most importantly, HV is different from HHC/HC and must be treated as such, especially for infants. Finally, prior literature confirms that the impact of cost spending on HV programs is affecting government policies and budget towards spending. Studies focused on minimizing cost and risk, maximizing coverage and benefits might be able to address the situation. One issue of great concern with regards to HV's planning context is how to plan the follow up process to maintain program's fidelity. As federal governments and private organizations continue to fund research

and evaluations of HV's for infants, it is an opportune time to develop and formulate OR models for HV program's implementation.

CHAPTER III

MODELING THE INFANT HOME VISITATION DEPLOYMENT

This dissertation examines 26 infant home visitation programs (Appendix B, Table B. 1 and Table B.2), and compares their characteristics, monetary benefits, duration of the program, target populations, enrollment, graduation rates, eligibility criteria, intensity, aim and scope of the programs. The programs comprise 14 prenatal and postpartum HV programs for which visitations continue until the child is 3 years old (Appendix B, Table B. 1); and 12 programs for school going infants who are 3 years old and up (Appendix B, Table B.2). Cost benefit comparison of these programs are based on data and analysis presented by [206], [16], [61] and [63]. Characteristics and features of the programs are identified, and one program that best represents a comprehensive, standard and evidenced-based HV is selected for the modelling. The nurse family partnership program (NFP) is selected due to its high performance among the characteristics and features compared for a case study and model validation. The comparison and best program selection procedure is similar to the conclusions presented by [16], [61] and [63]. The NFP is a program designed to provide prenatal and infant home visitation for low-income, first–time mothers and children until child is 2 years old. The program has been proven through extensive research and has been judged to yield numerous positive outcomes and benefits. The program is managed by the NFP National Service Office (NSO) and has been replicated in many states in the U.S. as well as in many other countries-more than any other HV program. In collaboration with the NFP NSO, data was collected, as well as responses to questionnaires solicited which helped to facilitate the modeling of the real life deployment of the program's process mathematically.

This dissertation uses results of the study by [16] identifying issues that predominantly affect infants and their mothers in the target population, and the assumed benefits that can be achieved in the event that these issues are addressed. Lee et al. [16] presents an extensive calculation of monetary benefits of HV programs related to crime (C), healthcare and illicit drug abuse (HD), mental development and education (ME), and public assistance (PA) (see appendix C, Table C.1, Table C.2, Table C.3, Table C.4 and Table C. 5). In the model developed in this dissertation, it is assumed that families enrolled in HV may have one or multiple of these issues or needs related to C, HD, ME and PA; and hence NCP with training in these specific specializations would be hired to provide service to them. However in cases of multiple needs, the assignment priority is given to the most prevailing need out of the four needs. The best nurse to patient match is determined to be composed of 4 metrics: the right skill/training/expertise (C, HD, ME, and PA), nurse type (CNA, LPN, RN or NP), and nurses' years of experience, matched to the right patient with the specific need (C, HD, ME and PA). This is further explained and modeled in the sections that follow.

Figure 5 shows the detailed critical path for the general HV process which has commonalities among all 28 HV programs. The journey of each nurse starts the moment she leaves the NFP office or her home, and finishes after she has visited the corresponding patient and returns to her starting point to submit her report in order to satisfy the demand, and with respect to program's fidelity. From Figure 5, the system may consist of patients whose statuses (pregnant, new mother, or health condition) are known. The enrollment point for each patient is logged once they join the program. Direct care givers comprise family nurse practitioners, registered nurses, certified nursing assistants, licensed practical nurses and para-professionals in some cases. The care givers are specialized and also trained in a variety of care related issues that affects the target population. Also, depending on the size of the enrolled participants and available funds, care givers hired may be full-time, part-time or temporary. The overall personnel involved comprise supervisors/administrators, nurses and support or data entry persons.

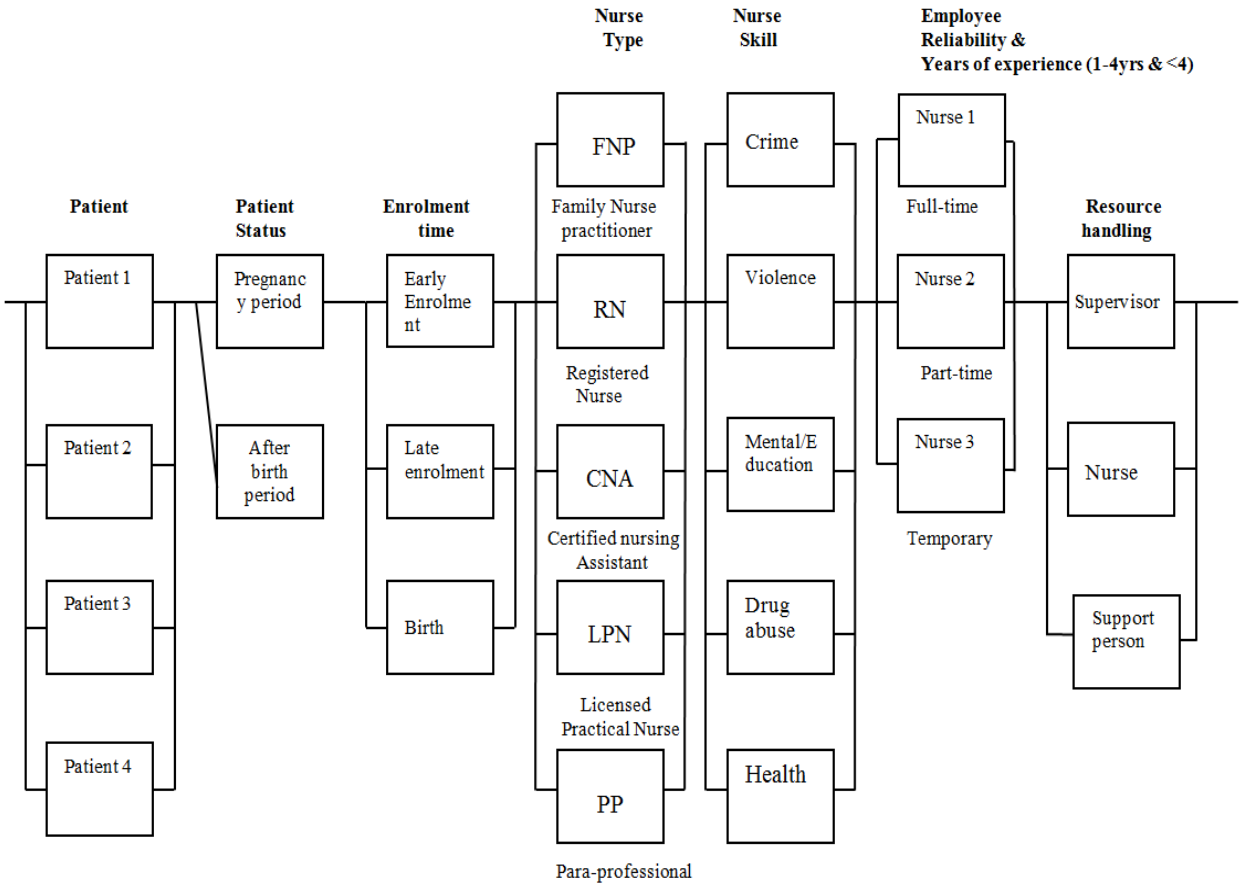

Figure 5 Detailed Critical Paths for General Home Visitation Process

Overall Conceptual Approach

The model developed in this dissertation considers the occurrence of important events at discrete points in time that are separate from each other. The time for 2 consecutive discrete points in the horizon planning period is the time it takes for one specific nurse visit to the next scheduled visit, which are weekly visits after birth for six weeks, 4 weekly visits after program's enrollment, and then visits every other week through the child's 21st month (90 weeks), plus monthly visits in months 22-24 (90-103 weeks), except that visits are scheduled weekly for 4 weeks after program enrollment and 6 weeks after birth; and the visits ideally begin by week 13 of pregnancy and must begin by week 28 [121]. The model's size is dependent on the number of time intervals of the horizon planning period being considered for each patient, which is similar to the total number of hired nurses to be scheduled throughout the visits, and the size of the target population. NCPs are hired, trained, assigned and scheduled for visits based on their skills/training, years of experience and nurse type/category for enhancement of quality of treatment and to reduce risk.

Modeling Paradigm

This dissertation proposes a mathematical model formulation for the HV process. The HV process is divided into segments and each segment is divided into groups of visits. The proposed mathematical formulation models the NFP HV deployment process which was introduced by David Olds [206] [70] through a series of random trial experiments at different HV sites. The visitation sequence of each group of visits upon the programs enrollment may not change over time until the patient's graduation. Based on this idea, the proposed modeling approach is represented in discrete points of time, for the journey of the groups of visits throughout the required visits and the different stages that makes up the duration of the program. Figure 6 depicts an illustration of the methodology with the NFP HV Program upon which the model in this research is developed. The NFP NSO has standards and regulations concerning nurses and patients with consideration of 18 model fidelity elements that sites must adhere to. Based on this, the study in this research propose the hiring requirements of nurses is composed of the nurse educational level, their years of experience in practice, and the nurses' skill or training. The NFP also has a requirement for the number of nurses depending on the number of enrolled patients. Inferring from Figure 6, the rules and regulations comprise hiring the most qualified nurse, nurses and supervisors caseload requirements, continuity of care where the same NCP takes care of the same patient throughout the program, consideration for disruption management, visit to patients in close proximity and different weeks of visit requirements. With respect to patients, time of enrollment, patient health need, health status and their geographic locations based on addresses are considered. The modeling approach used aims at representing the evolution of the HV process

during the entire horizon planning period by focusing on discrete points in time at which the state of the system might have changed through the horizon planning period.

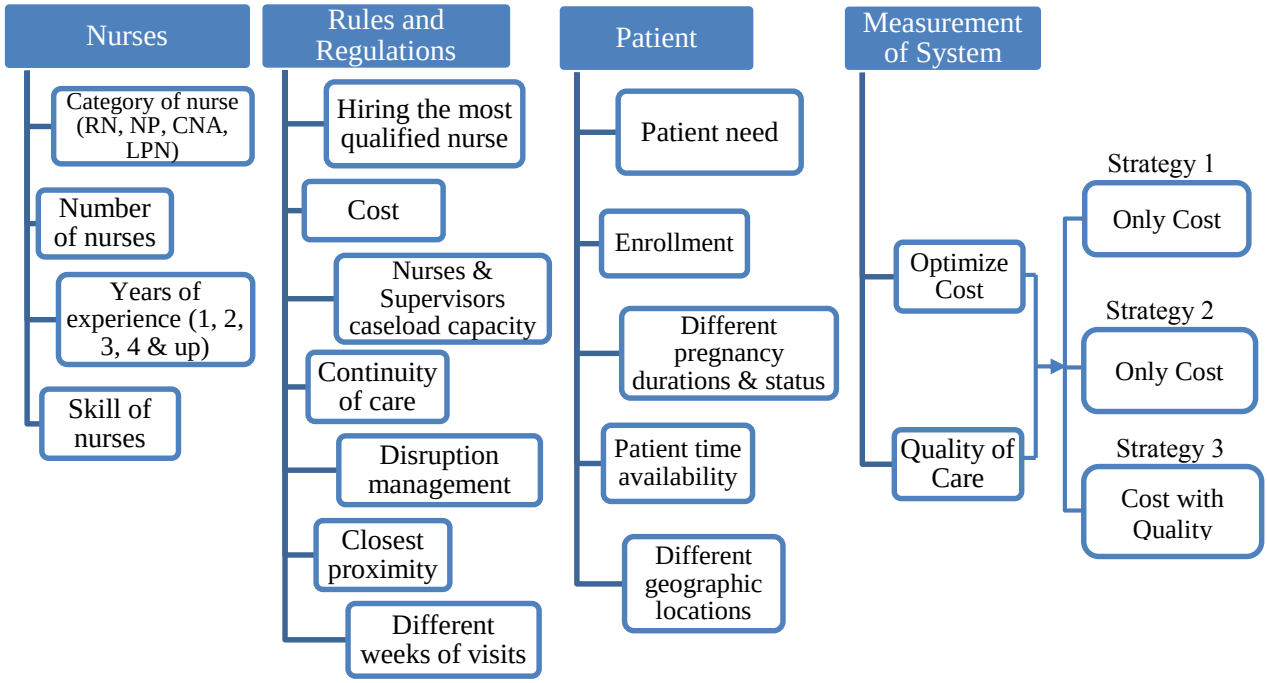

Figure 6 Methodology via illustrative scenario of Home Visitation Program

This change depends on whether at any given point in time, a nurse quits her job or is absent, or a patient drops out of the program. This impacts nurses' caseload and may demand hiring additional nurses or re-distributing the load evenly to adhere to the program's fidelity. In Figure 7, the conceptual framework of the HVP model is proposed and further explained in detail with the figures and tables that follow.

Figure 8 provides an illustration of the planning horizon for the NFP program which is being used to represent the standard HV system. This is a representation of what happens to a given patient in the program. P_1, $P_2 \ldots P_i$ represents the patient. The grey cells indicate that a visit takes place in that week. The observation periods for a patient have been divided in batches of 144 weeks. The program starts for a patient once she confirms she is pregnant, and then runs through to when she gives birth at week 40, after which it again continues until the child's second birthday.

As explained in the prior sections, the NFP targets 64 visits. In the ideal situation, the family's nurse visit every other week through the child's 21st month, plus monthly visits in months 22-24, except that visits are

scheduled weekly for 4 weeks after program enrollment and 6 weeks after birth. The home visits ideally begin by week 13 (early enrollment) of pregnancy and must begin by week 28 (late enrollment) [121].

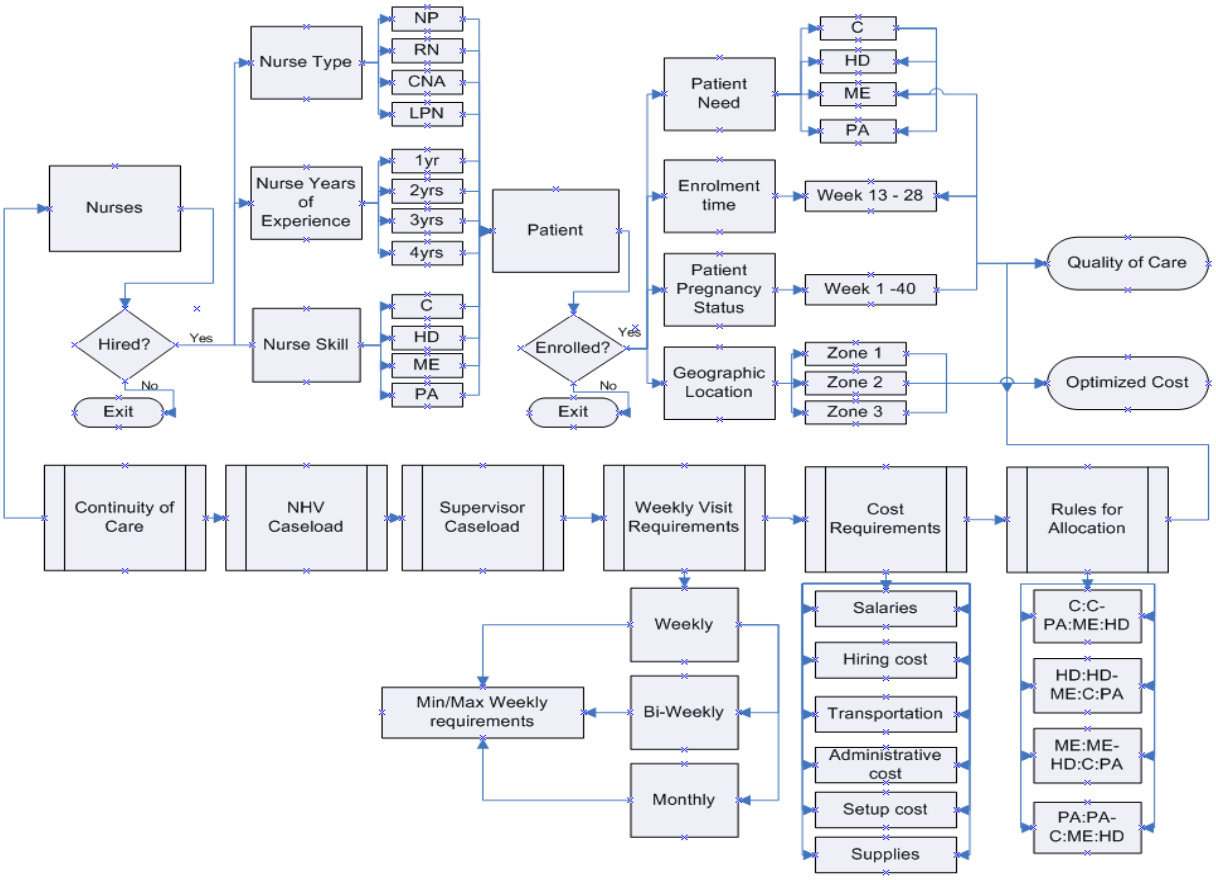

Figure 7 Conceptual Framework of HVP Model

The decisions taken in the HV deployment system correspond with the following 3 questions:

1. What is the specific enrollment time of each patient in the sequence to be visited through the horizon planning period?
2. What is the location at which each patient has to be visited in order to satisfy his or her demand?
3. What is the correct nurse-patient matching; where the correct nurse match is composed of 4 metrics: the right skill/training (C, HD, ME, PA), nurse type (RN, CNA, LPN or NP), nurses' of years of experience; matched with the right family that has a specific need (C, HD, ME, PA).

The proposed model must describe the evolution of this system through the entire horizon planning period given the assumptions made with adherence to the NFP's model fidelity elements [121, 207]. The model

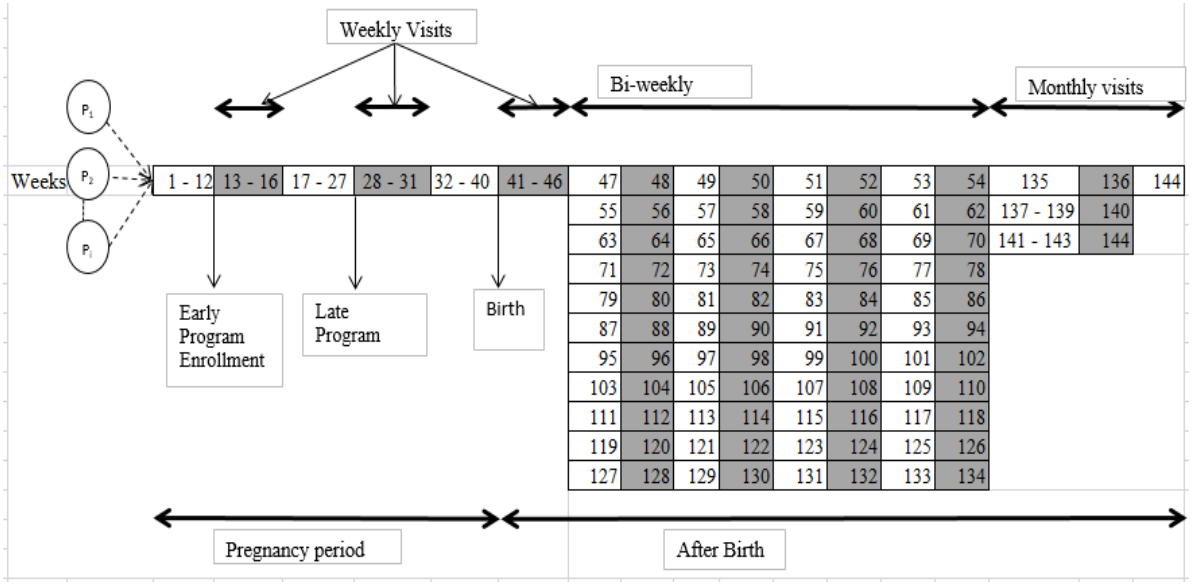

Figure 8 Representation of the HV Planning Horizon for a Given Patient

Also considers that, in reality, entry after week 13, late enrollment on 28th week, scheduling problems, families, dropout, nurse dropouts and early graduation dramatically affects visits [121]. Each nurse carries a target caseload of 25 families, and nurses maintain families in their caseloads even if they miss visits, only replacing them as they leave the program. A full-time nurse supervises up to 8 nurse home visitors (thus, a ratio of 1:8 and 1:4 supervisors to nurse ratios for 200 and 100 patient enrollments respectively). The supervisor provide clinical supervision with reflection, demonstrate integration of theories, and facilitate professional development through one-to-one clinical supervision, case conferences, team meetings and field supervision visits [121, 207]. At the NFP site, administrators, staffs and data entry/support persons are hired to help the programs' operations. The NFP NSO staffs help develop and fund the programs, train the nurses and supervisors, monitor implementation fidelity to 18 model program elements, and operate a centralized data system. The comprehensive program cost of a standard NFP HV comprises 5 components;

(a) Personnel Costs which include base salaries and fringe benefits which increase by 5% per year.

(b) Administrative cost which comprise office expenses (rent, maintenance, utilities), office supplies, client support materials, copies of forms/facilitators (B/W), postage, computers w/ software, computer network fees, cellular phones, cellular usage fees, medical & program supplies, professional development, mileage (20 trips/family/year).

(c) NFP services fees which are composed of start-up fee, nurse initial education tuition, supervisor initial education tuition, administrator orientation, nurse education materials, DANCE education, program support fee and nurse consultation fee.

(d) NFP travel costs (airfare/hotel/meals) which include travel: agency to administrator education, travel: agency to education unit 2, travel: agency to education unit 4, travel: agency to DANCE education and travel: supervisor to annual symposium.

(e) Additional materials and training costs which include NCAST materials, PIPE materials, ASQ materials, Edinburgh/PHQ-9 training and home IT assessment materials.

This dissertation makes three propositions and assumptions which aim at enhancing the quality of assignment and hence treatment. The first considers the hiring of nurses with different years of experience by assigning ranking scores or importance factors as shown in

Table 4. The highest and lowest scores are given to the highest and lowest years of experience respectively. This proposition is deemed valid based on the conclusion of [208], [209] and [210]'s study which investigates factors that contribute to nurse expertise. [208] states that clinical nursing expertise is central to quality patient care and concludes that when individual characteristics are controlled, the hospital context significantly influences clinical nursing expertise. A detailed study of the nurse expertise components related to nurse's years of experience and level of education as well as influence of expertise can be found in [208], [210] and [211]. Also [212] found that nurses with more experience reported performing more complex functions than those with less experience. Another study of five hospitals by [213] found that years of experience were associated with expertise. In a similar study, [214] examined the effect of the mean nurse experience level at the hospital level on nurse needlestick injuries; and concluded that a low mean experience level was associated with more near-miss needlestick incidents. In another related study, [215] found that the odds of high burnout, job dissatisfaction and poor-to-fair quality of care were twice as high in hospitals with 50% inexperienced nurses to be significant predictors of patient outcomes.

Secondly, the study considers that different types/categories of nurses are hired with different salary structures and then assigned ranking scores or importance factors as shown in Table 5. The different combinations of both scores are used to compute an importance factor which is the nurse specialty factor. A patient with a high critical health need is assigned a nurse with the highest score or importance factor, thus the most experienced nurse. For instance, the most experienced nurse may be a nurse practitioner (Master degree holder) and who has 4 and up years of working experience and is assigned the highest score. Similarly, this proposition is deemed valid based on the conclusion of

Table 4 Nurse Years of Experience Score Ranking

Nurse Years of Experience ID	Years (k)	Years of Nurses' Experience
1	Up to 1 year	0.20
2	More than 1 to 2 years	0.25
3	More than 2 to 4 years	0.26
4	More than 4 years	0.29

[208] and [210]'s study which presents investigation on factors that contribute to nurse expertise. As in nurses' years of experience, nurse education level influences clinical nursing function and hence central to quality patient care as presented in the study by [208]. Another study presented by [216] concludes that education influences expertise by providing theoretical and practical knowledge base that can be tested and refined in actual situations.

Table 5 Nurses' Category Score Ranking

Nurse Type ID	CatScore (k)	Score of nurse's category
1	Certified Nurse Practitioner (CNA)	0.20
2	Licensed practical Nurse (LPN)	0.25
3	Registered Nurse (RN)	0.26
4	Nurse Practitioner (NP)	0.29

Table 6 shows all the possible combinations of nurses' specialty importance factors which are obtained by multiplying all the possibilities of nurses' years of experience scores (Table 4) by nurses' category scores (Table 5). The first column, "Nurse Type ID" corresponds to the "Nurse Type name" in the second column. The third column is nurses' years of experience and the last column is the product of both score combinations', "importance factor". The highest importance factor represents the most qualified nurse with the most years of experience for each different set of combinations.

Table 6 Nurse Specialty Importance Factors

Nurse Type ID	Nurse Type Name	Years (k) Experience	Importance Factor
1	CNA	1	400
2	LPN	1	500
3	RN	1	520
4	NP	1	580
1	CNA	2	500
2	LPN	2	625
3	RN	2	650
4	NP	2	725
1	CNA	3	520
2	LPN	3	650
3	RN	3	676
4	NP	3	754
1	CNA	4	580
2	LPN	4	725
3	RN	4	754
4	NP	4	841

Thirdly, the study considers that families enrolled in the program have specific health needs related to C, HD, ME and PA; therefore nurses with an inter-professional training representing the Health Information Technology and Simulation (HITS) concept [217] may be hired based on their expertise and training in these 4 areas. A combination matrix of the patient need to nurse skill is presented as shown in Table 7**.**

Table 7 Patients Requirement and Nurse Skill Match

Skill Type ID	Skill Type	Patient Requirement ID	Patient Requirement	Combination Matrix
1	C	1	C	5000
2	HD	1	C	1000
3	ME	1	C	2000
4	PA	1	C	3000
1	C	2	HD	2000
2	HD	2	HD	5000
3	ME	2	HD	3000
4	PA	2	HD	1000
1	C	3	ME	2000
2	HD	3	ME	3000
3	ME	3	ME	5000
4	PA	3	ME	1000
1	C	4	PA	3000
2	HD	4	PA	1000
3	ME	4	PA	2000
4	PA	4	PA	5000

Inferring from Table 7, for instance, if a patient has need “C”, the model considers nurses’ with skill “C” having the highest combination matrix score and hence a perfect match. If there are no nurses with skill “C”, nurses’ skills are selected in the following order PA, ME and HD. If a patient has need HD, nurses with skill “HD” are first selected. If there are no available nurses with skill “HD”, the following priority order is used ME, C and PA. If a patient has need “ME”, the order of nurse skill selection is ME, HD, C and PA. Similarly, if a patient has need “PA”, the order of nurse skill selection is PA, C, ME and HD. The priority order of nurses skill selection is developed based on the analysis of historical nurses’ and patient’s data. The model assigns priority to critical health needs related to mental development and education which is associated with developmental delays, and also health and drug abuse related issues. In such cases the most qualified and experienced nurse is assigned.

Lastly, prior studies consider optimizing location and travelling distances in a different contexts. The model in this study groups patient locations into 3 zones based on proximity of their geographic locations, and aims at minimizing travelling distance cost, inter zone traveling cost and supervisor inter zone nurse managing cost. Table 8 shows the zone travelling costs established based on historical data.

Table 8 Inter Zone Travelling Cost

Neighborhood ID	Neighborhood Zone	Neighborhood ID	Neighborhood Zone	Travelling Cost
1	Zone1	1	Zone1	0
2	Zone2	1	Zone1	10
3	Zone3	1	Zone1	20
1	Zone1	2	Zone2	10
2	Zone2	2	Zone2	0
3	Zone3	2	Zone2	10
1	Zone1	3	Zone3	20
2	Zone2	3	Zone3	10
3	Zone3	3	Zone3	0

To better illustrate the proposed modeling concept, a medium to large size scenario for the problem is considered. In this case, an agency that wants to set up an NFP site contacts the NFP NSO office for approval, training and education. The agency then sets up the NFP site, acquires all the necessary resources and begins the hiring of nurses, administrators and support persons. A 200 family NFP site requires 8 nurses, 1 nurse supervisor, an administrator and a data entry/support person (Similarly, a 100 family NFP site requires 4 nurses, 1 nurse supervisor, an administrator and 1 data entry/support person).

The hiring of nurse home visitor involves the critical processes of selecting qualified staff with the required training and experience. Nurses' categories are RN, LPN, NP and CNA with different years of experience, and nurses have different specialty training in handling issues with C, HD, ME and PA. Each nurse is assigned a maximum caseload of 25 families. Nurses' salaries are either the same or based on their categories, and each nurse receives 26% fringe benefits based on their annual salaries. It is assumed that every nurse contributes a 100% effort toward the entire duration of the program and makes about 57 trips per family. The NFP site expends a variety of cost on office/training supplies and administrative cost which comprise both variable and fixed cost. Some additional costs involve travel mileage reimbursement. The visits are divided in three segments, weekly visits, bi-weekly visits and monthly visits. Figure 9 provides a representation for this scenario. From

Figure 9, families can enroll at the earliest during week 13 of the pregnancy period, and also at the latest during the 28th week. There are weekly visits for 4 weeks after an early enrollment or late enrollment; weekly visits after birth for 6 weeks; bi-weekly visit from the 47th to 134th week; and monthly visits from the 135th to the 144th week. The assignment of nurses to families and nurse visit scheduling are some of the most important concerns of this problem since these are determined by the families' health status and needs, as well as nurses' qualification, and families' geographic locations among others. Once nurses are assigned to families, they stay with the same family until the end of the horizon period when the family graduates. There are specific criteria to hire NCPs based on their experience and education. Additionally, the probability of staying in the program is considered to avoid disruption of management. There are also differences in the required frequency of visits for the patients based on the stage of the program they are at and a minimum amount of time between consecutive visits that are required for each patient. Enrollment in the NFP HV is on a rolling basis, hence families may enroll at any time (t). Each enrolled family has their unique planning horizon until they receive the total required visits. An example scenario for 3 families for different states of the system is represented in Figure 10, where each family enrolled, is visited and graduates at different times. These dynamic aspects of the system need to be very well represented by the proposed methodology since they constitute inherent and unique characteristics of this type of system.

Conclusions

A novel modeling approach has been introduced to plan the assignment of nurses to patients in a follow up program environment. The model considers the important operational aspects while seeking the minimization of the total cost of the program as a function of the salaries and costs associated with the visits

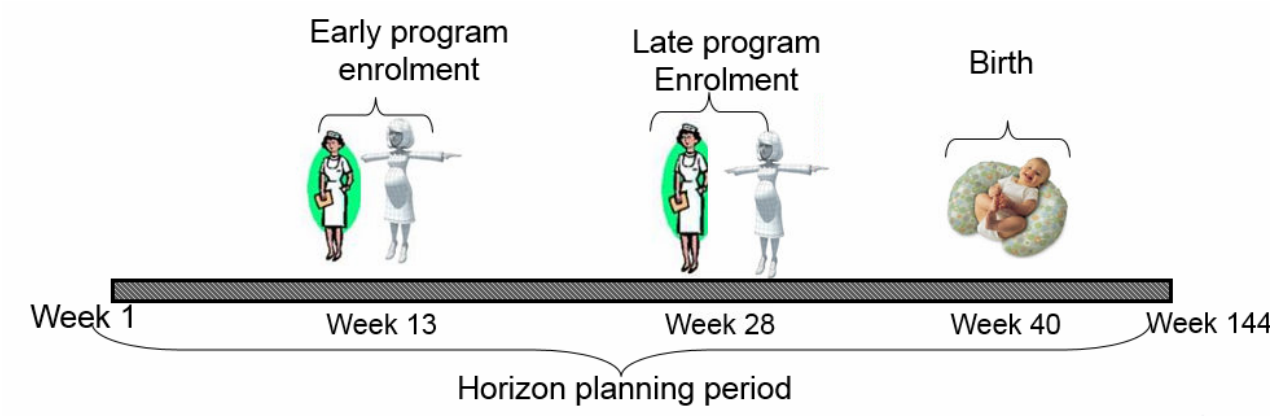

Figure 9 System Representation of Planning Horizon

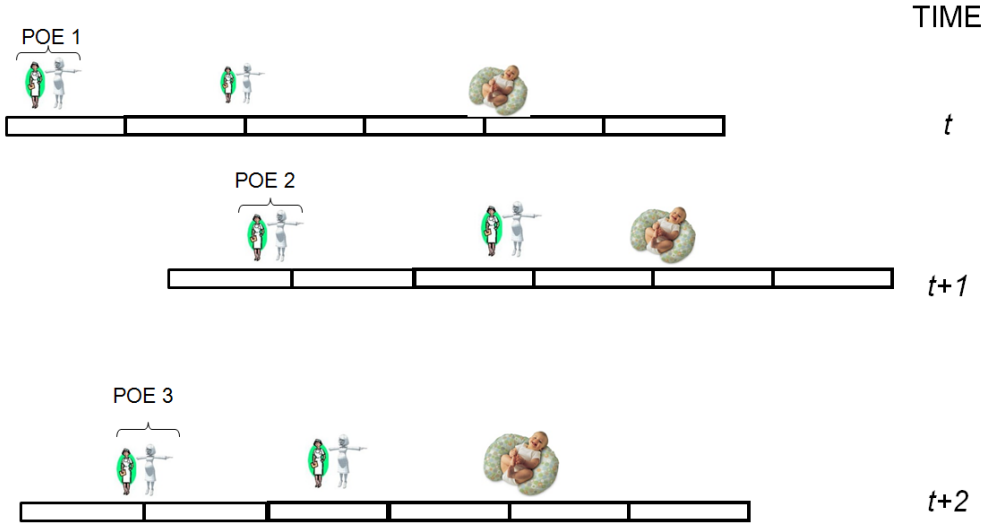

Figure 10 System Representation for different points of enrollments (POE) times, t **,** $t+1$ **and** $t+2$

to patients by the assigned nurses. The important dynamic features of the system are considered in the modeling process. The proposed modeling concept can represent the events that may change the state of the system, for instance rescheduling and reassignment of the nurses' caseload and also hiring of new nurses in the event that a nurse home visitor quits her job. It also considers the cases that families may drop out of the program as well. Nurse weekly capacities for visits are also accounted for with consideration of the visit pattern between 18 weeks of pregnancy and child's second birthday, and also depending on whether a nurse home visitor's caseload is predominantly pregnant women versus predominantly women with children in their second year. Finally, in the HVP process, geography makes a huge difference as it has a direct bearing

on the percentage of cost and nurses' time consumed by travel. The NFP NSO office estimates an average of about 20 to 50 miles per visit depending on the State the program is implemented. A closer look at HV's deployment shows that the distribution of travel distances in the U.S. varies from State to State. This is also considered in the modeling representation.

CHAPTER IV
MATHEMATICAL MODEL

A modeling approach, state of the HVP system and problem structure has been introduced in the previous chapter. The interpretation of each stage of the system and its requirements in the proposed model were explained and related with the real system. To reiterate, the main components of the system are replicated through the horizon planning period for as many times as an additional family is enrolled. In this chapter, the mathematical representation of the HV model as well as unique set of constraints necessary to model the dynamics of the real life system described in the previous chapter are presented. The system is shown to be effectively represented by a mixed-integer programming (MIP) model through the horizon planning period and the problem structure is explained. MIP is one of the many successful optimization techniques used to identify optimal or near-optimal solutions when faced with decision making. Most importantly, it is applicable when all the data needed to make decisions are available in making a single choice from a range of feasible options to achieve the best results.

Mathematical Model

This section provides the mathematical formulation for the HV deployment that represents the system of interest and its evolution through the horizon planning period. Assumptions made to model the system are first presented. This is followed by the optimization criteria and the model parameters. A definition of the decision variables is then presented and the objective function is stated. Lastly, the sets of constraints for the model are presented and explained in detail.

Assumptions

- There is a set of patients to be included in the HVP, which week of pregnancy (WoP) they are at is known and is less than or equal to 28 weeks at the beginning of the HPP.
- There is a set of nurses to choose from the nurses to be hired for the HVP.
- There is a horizon planning period (HPP), discretized by weeks that starts in week #1 and finishes in week #144
- Pregnancy period lasts 40 weeks
- Each nurse has a capacity to visit a given number of patients per week
- Early program enrollment can occur in week 13 and late program enrollment in week 28
- After birth, weekly visits are required for 6 weeks
- After week 6 of delivery, visits are required every two weeks until week 134
- After week 134, visits are required every four weeks until week 144

- All families receive the same number of visits, ideally, between 45 to 64 visits
- Each nurse serves the same family they are assigned throughout the whole planning horizon except for cases of disruption management.
- Each nurse caries a caseload of 25 families
- Each nurse has a specific skill/training, years of experience and education type.
- A program of 200 families requires 8 nurses, 1 nurse supervisor and 1 data entry/support person
- Visits are planned and scheduled so as to reduce travel time and cost (thus nurses are assigned to patients in the same neighborhood and not very far apart)
- A full-time nurse supervises up to 8 nurse home visitors

Optimization Criteria

Care for patient in the home may involve consideration of elements among which are transportation and treatment supplies costs, operating rules/policies of the host organization units, inventory considerations, customer service policies, model fidelity elements, and many other factors. One of the conclusions of the survey conducted for this problem was that, different optimization criteria have been considered for this problem. Considering research in this field, [71], [72] and [73] considers the balancing of workloads of the operators. In [18], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84] and [85], the minimization of total travel time, distance and cost while respecting constraints related to route construction, scheduled hours, operators' time windows, and skills requirements are considered. Cheng and Rich [19] consider minimizing the total cost associated with the overtime hours. De Angelis [20] considers maximizing the number of newly admitted patients based on resource availability constraints, a minimum standard of service, variability of demand, transition rates among classes, and budget constraints. [85] and [84] also considers maximization of the number of patients visited within nurse work time windows and minimization of the overall operation cost respectively as in the objective of this study. Other operational objectives considered in previously published literature on this subject aims to:

- *Minimize the number of workers to visit a set of customers whilst balancing workloads and demand.*
- *Maximize coverage*
- *Minimize the overall operation costs.*
- *Minimize uncovered visits*
- *Maximize worker visit preferences*
- *Minimize the total travelling distances, costs and time, also and waiting times*

- *Maximize the level of patient satisfaction*
- *Minimize the number of different vehicles that visit a given client.*

This dissertation defines the planning and performance of the system as a composite cost function where personnel costs and administrative cost are considered. Also, presented are extensions where NFP NSO services cost, NFP NSO travel cost and additional materials and training costs are considered. Further, computational experiments are provided for this problem. Most importantly, three optimization strategies are proposed. First, quality is optimized simultaneously with cost (S1). In the second strategy, only quality is optimized (S2) and finally, only cost is optimized (S3) for the third strategy. In the previous chapter, Figure 7 and Figure 8 provides the illustration of the basic component of the deployment approach and planning horizon respectively. In these figures, there is a set of families (patients) who are at different stages of their pregnancies (patient status). Families may enroll in the program at different times (enrollment time). Nurse participation and enrollment is based on the "Nurse Type", "Nurse Skill", "Years of experience" and employee reliability. Other resources involved include nurse supervisors, and data support persons (resource handling). The model is introduced by first defining the scalars, the sets and parameters. The decision variables, objective function and constraints of the model are then provided and explained in detail.

Model terminology:

HVP: Home visitation program

WoP: Week of pregnancy

HPP: Horizon planning period

Scalars:

P: Number of patients

N: Number of nurses

S: Number of supervisors

$NSmin$: Minimum number of nurses per supervisor

$NSmax$: Maximum number of nurses per supervisor

$FNmin$: Minimum number of patients per nurse

$FNmax$: Maximum number of patients per nurse

$NFPS/$CostSup: Cost of hiring a supervisor

β: $Cellular\ phone\ cost\ assigment\ to\ a\ nurse$

μ :Weight of nurses' years of experience of nurses

τ:	Weight of nurses' category
ϕ:	Weight of nurse to family need matching
CostNewNur:	Cost of hiring new nurses: Initial training - computer software - cellular phone
CostNewSup:	Cost of hiring new supervisors: Initial training - computer software
CostSup:	Salary and provisions for every supervisor both new and current ones
Z:	Residential zones for patient's location

Sets

$i = \{1,2, \dots, P\}$ Patients

$j = \{1,2, \dots ,40\}$ Week of pregnancy

$k = \{1,2, \dots, N\}$ Nurses

$l = \{1,2, \dots ,144\}$ Horizon planning period

$o = \{1,2, \dots, S\}$Supervisors

$t = \{C, HD, ME, PA\}$ Patients' needs

$\Psi = \{(j, l), (j + 1, l + 1), (j + 2, l + 2), \dots\}$ WoP of patient and week in the HPP

Subsets

NI (k, s)	Nurse's skill in need s
NewN (k)	New nurses
NewS (o)	New supervisors

$\boldsymbol{m}$: $\boldsymbol{set\ of\ cost\ related\ to\ personnel\ and\ administrative\ cost}$

$m = 1$: $Office\ supplies\ per\ nurse\ per\ year$

$m = 2$: $Cellular\ usage\ fees\ per\ nurse\ per\ year$

$m = 3$: $Professional\ development\ per\ nurse\ per\ year$

$m = 4$: $Nurse\ Home\ Visitor\ Salary\ per\ year$

$m = 5$: $Nurse\ Home\ Visitor\ fringe\ benefits\ per\ year$

Parameters

$u_{ij} = \begin{cases} 1, & patient\ i\ is\ at\ week\ j^{th} \text{ of pregnancy in week 1 of the HPP} \\ 0, & otherwise \end{cases}, j\epsilon[1,28]$

$\Gamma_{k,l}$: Number of visits that can be performed by nurse k in week l of HPP.

C_k /CostNur_k: Fixed cost associated with hiring nurse k

ρ_{ks}: Priority rating of the skill s by nurse k

ψ_k: Years of nurse's experience

$Qscore_k$: Score of nurse's category

FamZon (i, t, z): Family residential zone

Years (k): years of nurse's experience

CatScore (k): Score of nurse's category

α_{km}: $cost\ m\ assigment\ to\ nurse\ k$

α_k: $Total\ cost\ assigment\ to\ nurse\ k$

$$\alpha_k = (\alpha_{k1} + \alpha_{k2} + \alpha_{k3} + \alpha_{k4} + \alpha_{k5}) = \sum_{m=1}^{5} \alpha_{km}$$

$\boldsymbol{n}$: $\boldsymbol{set\ of\ families\ cost\ assigment\ related\ to\ support\ maerials}$

$n = 1$: $Client\ training\ and\ Support\ Materials\ per\ year$

$n = 2$: $Copies\ of forms\ \ /\ facilitators(b\ \&w)\ per\ year$

$n = 3$: $Medical\ and\ Program\ Supplies\ per\ year$

So we have;

γ_{in}: $cost\ n\ assigment\ to\ patient\ i$

γ_i: $Total\ cost\ assigment\ to\ patient\ i$

$$\gamma_i = (\gamma_{i1} + \gamma_{i2} + \gamma_{i3}) = \sum_{n=1}^{3} \gamma_{in}$$

Decision Variables

Eight sets of binary variables are proposed. Their value equal to one is used to indicate that the corresponding event occurs.

$$v_{ijlk} = \begin{cases} 1, & \text{patient } i \text{ enrolls HVP in her } j^{th} \text{ WoP during week } l \text{ HPP} \\ & \text{and is served by nurse k}, j\epsilon[13,28] \\ 0, & otherwise \end{cases}$$

$$w_k = \begin{cases} 1, & \text{nurse k is hired for the HVP} \\ 0, & otherwise \end{cases}$$

$$x_{ik} = \begin{cases} 1, & \text{nurse } k \text{ takes care of patient } i \\ 0, & otherwise \end{cases}$$

$$y_{ijkl} = \begin{cases} 1, & \text{patient } i \text{ is visited in her } j^{th} \text{ WoP by nurse } k \text{ in week } l \text{ of the HPP} \\ 0, & otherwise \end{cases} \quad j \in [13,144]$$

$$g_{ko} = \begin{cases} 1, & \text{nurse } k \text{ is assigned to supervisor } o \\ 0, & otherwise \end{cases}$$

$$h_o = \begin{cases} 1, & \text{supervisor } o \text{ is hired} \\ 0, & otherwise \end{cases}$$

$$\delta_{itks} = \begin{cases} 1 & \text{patient } i \text{ with need}, t \text{ is served by nurse } k \text{ with skill } s, (i,t) \in F \\ 0 & \text{Otherwise} \end{cases}$$

$$NZ_{k,s,z} = \begin{cases} 1 & \text{Nurse k with skill s has at least one patient to service in zone z} \\ 0 & \text{Otherwise} \end{cases}$$

Objective Function

$$Maximize\ Z_1 = \sum_k \left(\sum_i X_{ik} \right) * \psi_k + \phi \sum_{(i,t)\in F} \left(\sum_k \sum_s \delta_{itks}\ \rho_{ks} \right) + \tau * \sum_k w_k . Qscore_k\ \mu * \sum_k w_k . Years_k + \sum_{i=1}^{P} \sum_{j=1}^{40} \sum_{l=1}^{144} \sum_{k=1}^{N} v_{ijlk} \qquad [1]$$

$\mu + \tau + \phi = 1$→ Values for weighted values of quality components

$$Minimize\ Z_2 = \sum_{k=1}^{N} \sum_{ijl} (\alpha_k w_k\ y_{ijkl}) + \sum_{i=1}^{P} \sum_{j=1}^{40} \sum_{l=1}^{144} \sum_{k=1}^{N} (\gamma_i\ v_{ijlk}) + \text{CostNewNur} * \sum_{k \in \text{NewN}} w_k + \beta \left(\sum_{k=1}^{N} w_k * \text{CostNur}_k * \text{CostNewSup} \right) * \sum_{o \in \text{NewS}} h_o + \text{CostSup} + \sum_{k,s \in \text{NI}} \sum_z NZ_{k,s,z} * \text{CostNur}_k \qquad [2]$$

Constraints

$$NSmin \leq \sum_k g_{ko} \leq NSmax\ ;\ \forall o = 1,2, \dots N, \qquad [3]$$

$$w_k - \sum_{o} g_{ko} = 0;\ \forall k = 1,2,\dots,N \quad [4]$$

$$h_o - g_{ko} \geq 0;\ \forall k = 1,2,\dots N, o = 1,2,\dots,S \quad [5]$$

$$FNmin \leq \sum_{i} x_{ik} \leq\ FNmax;\ \forall k = 1,2,\dots,N \quad [6]$$

$$w_k - x_{ik} \geq 0;\ \forall\ i = 1,2\dots,P \quad k = 1,2,\dots,N \quad [7]$$

$$\sum_{i} x_{ik} = \sum_{(i,t)\in F} \sum_{s} \delta_{itks}\,; \quad \forall k = 1,2,\dots,N \quad [8]$$

$$\sum_{k} \sum_{s} \delta_{itks} \leq 1; \quad \forall\ (i,t) \in F \quad [9]$$

$$\sum\nolimits_{k,j,l:l:13\leq j+l-1\leq 28} v_{i,j+l-1,k,l} \leq 1;\ \forall\ i = 1,2,\dots,P \quad [10]$$

$$\sum_{(j,l)\in\Gamma} v_{ijkl} \leq 1, i = 1,2,\dots,P, k = 1,2,\dots,N \quad [11]$$

$$v_{ijkl} - w_k \leq 0;\ \forall i = 1,2,\dots,P, j = 1,2,\dots,28, k = 1,2,\dots,N, l = 1,2,\dots,144 \quad [12]$$

$$\sum_{(m,n):j<m<j+4,l<n<l+4} y_{imkn} - 4v_{ijkl} = 0;\ \forall i = 1,2,\dots,P, k = 1,2,\dots,N \quad [13]$$

$$\sum_{(j,l)\in\Psi,41\leq \mathrm{j}\leq 46} y_{i,j,k,l} - 6 \sum_{(j,l)\in\Psi,12\leq \mathrm{j}\leq 28} v_{ijkl} = 0;\ \forall\ i = 1,2,\dots,P, k = 1,2,\dots,N \quad [14]$$

$$y_{i,j,k,l} + y_{i,j+1,k,l+1} = 1;\ \forall i = 1,2,\dots,P, j = 47,\dots,134, k = 1,2,\dots,N, (j,l)\ \in \Psi \quad [15]$$

$$\sum_{i=1}^{P} \sum_{j:(j,l)\in\Psi} \left(v_{ijkl} + y_{ijkl}\right) \leq \Gamma_{k,l};\ \forall\ k = 1,2,\dots,N, l = 1,2,\dots,144 \quad [16]$$

$$\left(\sum_{\substack{(i,t)\\ \in F}} \delta_{(i,t,k,s)} * \mathrm{FamZon}_{(\mathrm{i,t,z})}\right) - NZ_{k,s,z} \leq\ 0; \quad \forall\ (k,s) \in NI, z \quad [17]$$

$$\sum_{i=1}^{P} \sum_{\mathrm{j}=13}^{23} \sum_{l=1}^{144} v_{i,j,k,l} \leq 25, \forall\ k = 1,2,\dots,N \quad [18]$$

$$\sum_{k:k\neq kk} s_{kk,k} \leq 8, \forall\ kk \qquad [19]$$

Equations 1 to 2 are the objective functions. Equation 1 seeks to maximize the quality of nurse to patient assignment and equation 2 seeks to minimize the overall deployment cost. Equation 3 is the capacity constraint controlling the maximum and minimum number of nurses assigned to each supervisor. Equation 4 is the set of constraint for assignment of supervisor, o to a hired nurse k. Equation 5 is the set of constraint for hiring of supervisors. Equation 6 is the set of constraints for minimum and maximum number of patients assigned to each nurse. Equation 7 is the set of constraints for the assignment of nurse, k to each specific family and not to exceed their capacities while maintaining continuity of care. Equation 8 is the set of constraints enforcing the quality of assignment of nurse expertise components. Equation 9 is the constraint enforcing every patient's need to be assigned to a nurses' skill. Equation 10 is the set of constraints for exact time in the horizon that patients enrolls based on program requirement, thus, patient can enroll at a specific time and not afterwards or before that time in the ideal situation. Equation 11 represents the scheduling of visits for any patient who enrolls at any time of the HPP depending on their condition and needs, and defines the starting condition for the next planning period. Equation 12 enforces that a nurse must be hired and assigned in order to take care patients who enroll at any time in the HPP. Equation 13 enforces weekly visits for 4 weeks after enrollment. Equation 14 enforces weekly visits for 6 weeks after birth. Equation 15 is the set of constraints for patients' bi-weekly visit assignment from the 47th to 134th week; based on WoP of the patient and week in the HPP. Equation 16 is the set of constraints controlling the number of visits that can be performed by a given nurse, every week considering the full HPP with its weekly, bi-weekly and monthly visits; equation 17 is the set of constraints enforcing patients' location zones to every nurse in order to optimize travel distance and time. Equation 18 enforces a caseload of 25 patients or less to every nurse, and equation 19 is the constraint enforcing every 8 nurses to be supervised by 1 supervisor.

Data Computation

The purpose of this section is to describe the data obtained from real life situation as well as from results of interviews used for the model's computation and validation. Real data was acquired from the NFP NSO and used for the model's computation and validation. The data includes historical and current data of cost information, maximum and minimum number of visit requirements, NFP's model fidelity requirements and regulations, travel distances and cost, as well as data on the home visitation pattern. Also preliminary

information into the analysis and understanding of the real life home visitation process was obtained from a hospital in the southwest part of the U.S. A list of interview questions used in the process can be found in Appendix D. In the current NFP HVP process, some required data was not available since it was not included in the organization's data collection process. This data includes nursing skills components with respect to patient needs and nurses' years of experience. Also, data that included patients' and nurses' protected health information (PHI) could not be obtained due to institutional privacy regulations. These data include patients' and nurses' details, addresses (used in determining neighborhoods/zones), demographic information, patients' pregnancy durations and status, and patient needs. In the current NFP HVP process, only registered nurses are hired, therefore only one salary structure of $74,455 (including fringe benefits) for nurses, and $93,300 for nurse supervisors were available. Also, travel cost per mileage reimbursement to nurses was at a rate of $0.565/mile is used by the NFP.

For data which were not available, randomly data were generated based on the historical data, survey data and information available in literature, and used. Sample data for some instances of the computational experiments are provided in appendix E (Table E.1, Table E.2 and Table E.3). Table E.1 in the appendix contains data for patients. "ID" is the identification number randomly generated for patients, "Preg_WeekAtEnrollment" is the exact duration of patients' pregnancy which is generated randomly. "Enroll_Week_WallCalendar" is the specific week a patient enrolls in the program. This data is randomly generated and defined to be between early and late enrollment weeks; thus week 13 and week 28 with about 5% of the data going beyond late enrollment. "Patient Zone" is the assigned zone of patients locations based on their addresses in the same geographic locations. Three zones are generated randomly for patients that are enrolled in the program. "Patient Needs" are the specific needs of patients. This data is randomly generated using a distribution as shown in Figure 11. The distribution of patient needs is based on the studies presented by [16], [61], [63], [102] and [206] which analyzes the cost benefit of home visitation programs based on patients' needs.

Table E.2 in the appendix contains data for hired nurses. "ID" is the identification number randomly generated for hired nurses. "Hiring_Cost" is the sum of costs related to the hiring of a nurse to participate in the program. This is the sum of the administrative cost, NFP travel cost, computer and software cost, and the cost of cellular phone assignment to nurses and training cost per nurse. The column named "Salary" is the annual salary of hired nurses (including fringe benefits). "Max_Visit" is the maximum weekly visits a nurse can perform. "Nurse Skill" is the expertise of the nurse which is generated randomly based on the needs of patients. "Nurse Type" is the education level of the hired nurse. This data is generated randomly with distribution shown in Figure 12 which is based on the number of available nurse type graduates as of

2013 published by the U.S. Bureau of labor statistics [218] and the National Center for Health Workforce Analysis [219].

The column named "Years (k)" is the years of experience of hired nurses which are randomly generated between 1 to 4 years. "Nurse Zone" in the last column is the nurses' zone assignment. Travel distances to patient's locations are computed by generating random travel distances for acceptable mileage travel limits based on historical information gathered from the survey and interview data, and also historical data collected, and then normalized between 0 to 100 (see Table E.3).

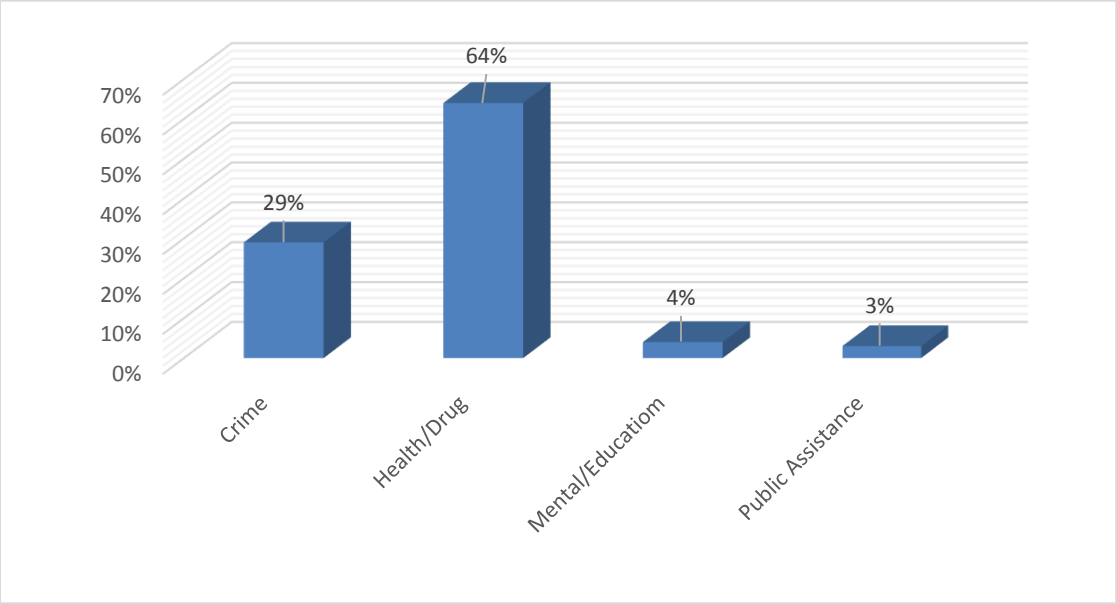

Figure 11 Distribution of Patient Needs

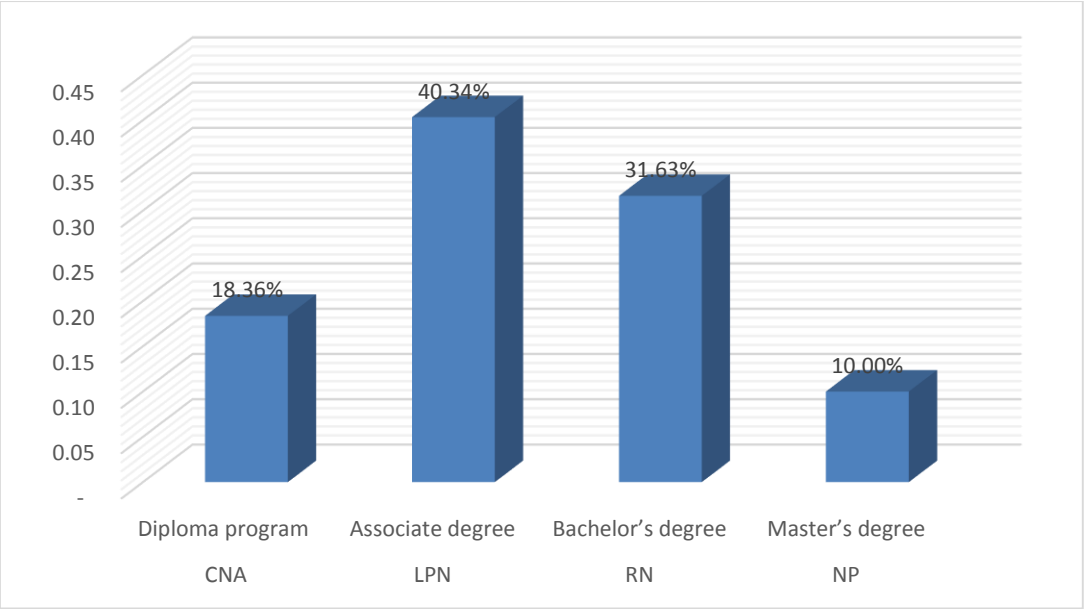

Figure 12 Distribution of Nurse Types/Categories

CHAPTER V

SOLUTION AND COMPUTATIONAL RESULTS

This chapter presents the computational experiments for the solution to the model as well as the obtained results. The purpose of the numerical experiment is to solve the problem under consideration for the NFP HV and use the results to validate the model developed. The model's performance in terms of computational time, solution quality and robustness in relation to the problem being studied is also analyzed. The first objective function maximizes the quality of assignment and the second minimizes the total operational cost. The three strategies proposed are then presented and the model tested with a set of real data instances of different sizes. The size of the model was determined by the number of nurses(N), the number of patients(P) , the number of supervisors (S) and the number of discrete points in time in the horizon planning period (T) for the HV. 50 instances of the problem were included in the set of computational experiments with N, P and S, but 18 of the instances of the problem ranging from mid-size to larger size were chosen to be reported in this study. The instances correspond to different scenarios of a system with an initial instance of 1 nurse, 25 patients, and 1 supervisor for 144 weeks of horizon planning period. The variation is in the number of patients, which increase the number of nurses and subsequently the number of supervisors. The model is built on a personal computer and solved by a server with Intel Xeon 2.26 Ghz processor and 12.0 GB RAM. The IBM ILOG CPLEX optimization studio is used to solve the MIP model. The computational time was upper bounded by 3600 seconds limit within the solver for each of the instances which is based on the minimum amount of time used in solving the home health care scheduling problem as reported in literature. Additionally, the relative gap is set to be 1%, therefore the model's instances are terminated when a feasible solution was within 1% of the optimal solution.

In the first solution, quality is optimized simultaneously with cost and is called strategy One (S1).

Table 9 shows the results of the performance of the computational experiments for the 18 instances considered for S1. Five important aspects of the results are reported; the number of constraints and variables, objective values, computational time and optimality gap. The first column of the table shows the instances for the problem where there are 25 patients, 2 nurses and 1 supervisor. The second and third columns represents the total number of constraints and variables respectively. The optimal objective function value reported for each case is the best objective value obtained when the program terminated. This is reported in the fourth Column for each instance. The fifth column represents the MIP relative optimality gap. The computational time (in seconds) is the time it takes for the objective value to be obtained, thus, the time either at which the optimal solution is found or after which the solution does not improve. This is represented in the last column.

The first, sixth and seventeenth instances of the problem were solved to optimality. In the remaining cases, near optimal solutions were obtained. Consequently, there were two types of result for the problem as far as the objective function is concerned: Optimal or a near optimal solution within MIP relative optimality gap. The MIP model is efficient in solving the assignment and scheduling problem, however the number of variables of the model increases as the size of the instances increase. For instance, in the largest instance considered, 400P-16S-2S, there are 1,094,038 constraints and 1,085,524 variables which subsequently increased the solution time.

Table 9 Computational Results for 18 Instances of the problem Considered : Optimizing quality with Cost (S1)

Instance	Total Constraint	Number of Variable	Best Objective Function Value	MIP Relative Gap	Computational Time (s)
25P-1N-1S	4554	4356	135866.295	0.0000%	0.23
50P-2N-1S	17804	17359	76899.07077	0.0100%	65.68
60P-3N-1S	31909	31212	96511.21558	0.0098%	162.85
75P-3N-1S	39754	39012	47601.67974	0.0100%	133.63
85P-4N-1S	59949	58920	104893.8721	0.0037%	158.78
100P-4N-1S	70404	69315	59394.36	0.0000%	1.45
120P-5N-1S	104374	103073	10149720.4	0.0083%	69.72
135P-6N-1S	139855	138210	20094353.64	0.0027%	79.83
150P-6N-1S	155530	153795	20007252.49	0.0005%	6.27
168P-7N-1S	203368	201218	20092858.05	0.0041%	150.84
175P-7N-1S	211901	209702	20080624.76	0.0046%	27.25
180P-8N-1S	249112	246559	20105590.62	0.0037%	560.04
190P-8N-1S	263042	260409	20087037.87	0.0059%	40.62
200P-8N-1S	276972	274259	19971803.16	0.0100%	12.18
250P-10N-2S	426254	422403	60212796.01	0.0023%	97.52
300P-12N-2S	615904	610683	60040254.34	0.0024%	271.46
350P-14N-2S	835482	828719	79990917.19	0.0000%	86.36
400P-16-2S	1094038	1085524	80298097.57	0.0025%	896.26

Figure 13 depicts a plot of the computational times (seconds) for 18 instances of the problem considered. The results obtained from the computational experiments suggest that a near optimal feasible solution can be obtained in a computational time of less than one hour. The average computational time of all the instances considered is 156.72 seconds.

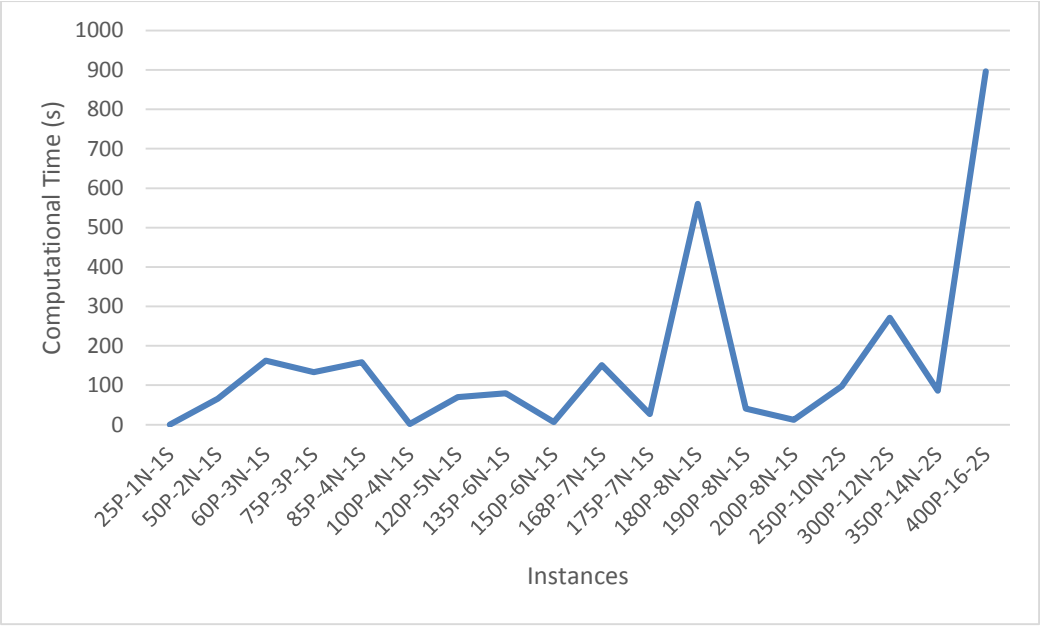

Figure 13 Computational Times (seconds) for 18 Instances of the Problem Considered

Exploration of Strategy Two (S2) and Strategy Three (S3)

To further explore the model, two different schemes were also investigated based on the importance of the objective functions: in strategy two (S2), the objective was to maximize only quality by adding up all the assignments and scheduled visits performed by nurses to patients during the horizon planning period. In strategy three (S3), the objective was to minimize only costs by adding up the total cost of the HV deployment process for one full year of the horizon planning period. Table 10 provides a summary of the computational results for both schemes. Table 10 compares the best objective values obtained and the computational times for S2 and S3. The MIP relative gaps are also reported. The best objective values for S3 are significantly lower than that of S2 as the objective only focused on minimizing only cost. For instance, in the first instance, the total cost of the S2 is 12% more than that of S3. This pattern is similar for all the 18 instances of the problem considered. Figure 14 shows a comparison of the computational times for S1, S2 and S3. The computational times for optimizing S1 are significantly lower when compared with both S2 and S2.

Table 10 Computational Results for Optimization of Strategy Two (S2) and Strategy Three (S3)

Optimizing Quality				Optimizing Cost		
Instance	Non Optimized Cost	MIP Relative GAP	Computational Time (s)	Optimized Cost	MIP Relative GAP	Computational Time (s)
25P-1N-1S	$ 210,109.30	0.0000%	20.51	$ 185,831.30	0.0000%	35.51
50P-2N-1S	$ 319,122.74	0.0001%	84.86	$ 276,452.74	0.0000%	90.36
60P-3N-1S	$ 408,510.63	0.0083%	231.71	$ 357,850.63	0.0109%	227.71
75P-3N-1S	$ 419,913.42	0.0027%	219.49	$ 381,956.42	0.0111%	205.99
85P-4N-1S	$ 512,143.79	0.0005%	261.64	$ 465,130.79	0.0235%	238.64
100P-4N-1S	$ 525,211.36	0.0027%	231.39	$ 469,295.36	0.0011%	198.89
120P-5N-1S	$ 647,532.20	0.0098%	206.58	$ 557,521.20	0.0095%	164.58
135P-6N-1S	$ 762,535.84	0.0100%	233.69	$ 662,513.84	1.0020%	182.19
150P-6N-1S	$ 739,332.50	0.0037%	268.19	$ 650,352.50	0.0500%	207.19
168P-7N-1S	$ 881,653.46	0.0049%	338.7	$ 793,893.46	0.0052%	268.2
175P-7N-1S	$ 875,789.76	0.0030%	232.11	$ 769,878.76	0.2530%	152.11
180P-8N-1S	$ 989,310.20	0.0083%	781.9	$ 848,280.20	1.1437%	692.4
190P-8N-1S	$ 987,804.66	0.0003%	279.48	$ 878,851.66	1.6200%	180.48
200P-8N-1S	$ 937,904.75	0.0005%	268.04	$ 813,919.75	1.7900%	159.54
250P-10N-2S	$ 1,307,969.45	0.0005%	370.38	$ 1,200,918.45	2.0500%	252.38
300P-12N-2S	$ 1,453,377.64	0.0041%	420.86	$ 1,299,871.64	2.1100%	325.32
350P-14N-2S	$ 1,694,870.53	0.0046%	393.22	$ 1,474,361.53	1.3600%	256.22
400P-16-2S	$ 2,189,861.58	0.0337%	1173.86	$ 1,869,839.58	2.6300%	1027.36

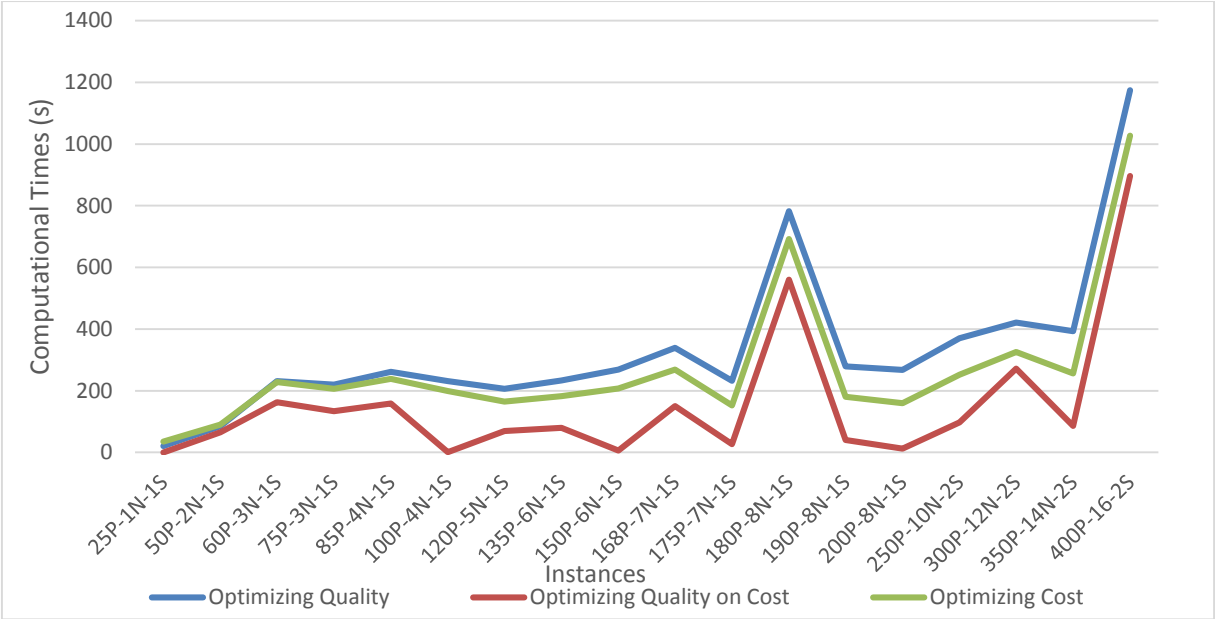

Figure 14 Computational Times (seconds) for S1, S2, and S3

CHAPTER VI

ANALYSIS OF RESULTS AND MODEL VALIDATION

The purpose of this chapter is to analyze the results of the model's computation and validate it with real data currently being used by the NFP HV. For simplicity the results of strategy one is explained in this section, and explanation for all three strategies presented in the model validation section.

Lastly, a sensitivity analysis is conducted on nurses' years of experience in working in the field to the variation of nurse to patient quality match and costs of care. This aids in studying the influence of the nurse working experience on the scheduling and patient match decision. Table 11 provides a summary of the instances of strategy one with the percentage of quality assignments obtained, the average visit per patient, the optimized cost of the plan generated for each instance as well as optimality gaps.

Table 11 Results of Quality Match and Optimized Cost for 18 Instances of S1

Instance	% of Quality Match	Average Visit Per Patient	Optimized Cost	MIP Relative Gap
25P-1N-1S	92%	50.80	$ 209,886.30	0.0000%
50P-2N-1S	82%	51.72	$ 316,452.74	0.0100%
60P-3N-1S	78%	55.07	$ 407,850.63	0.0098%
75P-3N-1S	67%	49.33	$ 421,956.42	0.0100%
85P-4N-1S	66%	52.95	$ 515,157.79	0.0037%
100P-4N-1S	57%	50.41	$ 507,235.36	0.0000%
120P-5N-1S	57%	51.55	$ 657,536.20	0.0083%
135P-6N-1S	42%	52.98	$ 752,508.84	0.0027%
150P-6N-1S	38%	51.42	$ 710,352.50	0.0005%
168P-7N-1S	36%	52.89	$ 893,663.46	0.0041%
175P-7N-1S	33%	52.12	$ 900,780.76	0.0046%
180P-8N-1S	33%	52.78	$ 989,280.20	0.0037%
190P-8N-1S	44%	52.35	$ 1,003,804.66	0.0059%
200P-8N-1S	30%	50.81	$ 903,904.75	0.0100%
250P-10N-2S	24%	51.89	$ 1,357,969.45	0.0023%
300P-12N-2S	19%	50.52	$ 1,373,363.64	0.0024%
350P-14N-2S	15%	50.83	$ 1,574,870.53	0.0000%
400P-16-2S	15%	52.14	$ 2,069,861.58	0.0025%

The results of the 18 instances ranging from 25 to 400 patients shows that the percentage of quality match decreases as the instances increase. A quality match is when we have the right nurse with the preferred skill, right education level and most years of experience matched with the right patient need. The average

visit per patient for all the 18 instances is 52 visits. As expected, the optimized total cost increases with the increase in instances except for instances 100P-4N-1S, 150P-6N-1S and 200P-8N-1S that drops slightly. This is due to the distances related to the patients geographic locations assigned to the nurses, which results in a decrease in the travel cost and hence the total cost.

Figure 15 portrays the observed behavior of the cost and the result of optimizing the total deployment cost while maintaining the quality of matching at its maximum level (S1). The larger the instance, the more significant the impact was on cost savings. As seen in the plot, significant cost savings are obtained when compared with the actual NFP operating cost.

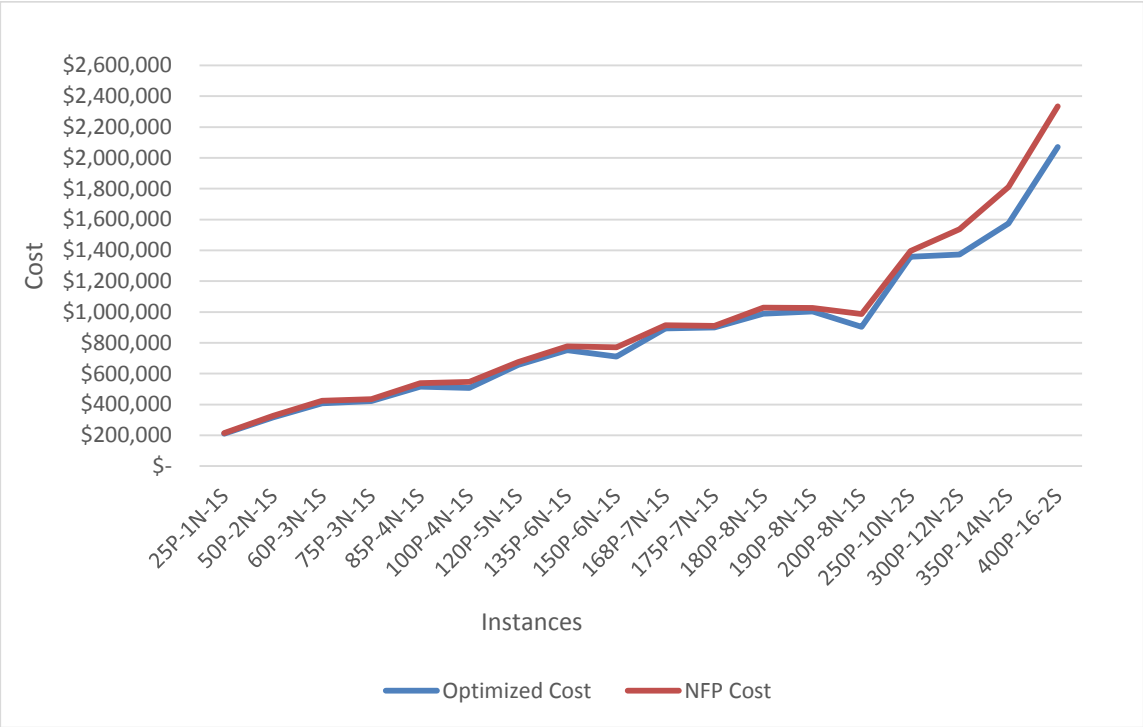

Figure 15 Observed Behavior of Optimized Cost

Table 12 reports a sample output for 10 patients for an instance of 100P-4N-1S. Patient ID's are the identifications of the different patients, nurse ID's are the identifications of the nurses assigned to the patients. The column called compatibility is binary and 1 means that the patient-nurse match is compatible, and hence a quality match counted under the column "quality". The last column shows the optimized transportation cost for the entire planning horizon per patient based on their geographic locations and zone allocations.

Table 12 Sample Output of Key Performance Indicators

Patient ID	Nurse ID	Compatibility	Quality	Transportation Cost
1	1	1	1	348.04
2	1	1	1	701.73
3	1	1	1	305.1
4	1	1	1	1245.825
5	1	1	1	1093.275
6	1	1	1	610.2
7	1	1	1	381.375
8	1	1	1	610.2
9	1	1	1	686.475
10	1	1	1	381.375

Table 13 shows a sample schedule and assignment output for instance 100P-4N-1S and represents the 10 patient's wall calendar. The first row is the weeks in the horizon planning period. The first column shows the list of patient 1 to patient 10; and for example, the first row is interpreted as; patient 1 who resides in zone 1 with need related to "crime" (C), is served by nurse with ID 1 who is skilled in handling issues related to "C", is a certified nursing assistant (CNA) and has one year of experience. This patient enrolled in the first week of the horizon planning period and from the data input it is known that this patient is 15 weeks pregnant.

Table 13 Patient Wall Calendar Schedule and Nurse Assignments

Patient ID	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Model Validation

This section describes the model's validation and evaluation of its effectiveness. The developed model is applied to a real life HV deployment process with data from the NFP NSO in an effort to estimate the cost savings, benefits and quality of assignment that would result from the adoption of the proposed planning model. Results of the models computation are compared with the historical data and current operating budget of the NFP process for 18 instances. The cost savings as well as percentage of quality matching for each instance is calculated and shown in Table 14 for S1. For this comparison, 8 components of the cost are used which comprise supervisor and nurse home visitor salaries, computer and software cost, cost of cellular phone and phone usage per nurse, medical and program supplies per nurse, professional development cost per nurse, cost of travel mileage per nurse (considering an average of 20 trips per family per year at a cost of $0.565 per mile), nurse and supervisor initial education tuition, nurse education materials, and the cost of travel to education unit. Cost related to data entry/support persons and administrators, computer network fees, NFP set up fees and educational materials are not included.

Table 14 Results of Strategy One (S1) and NFP Cost for 18 Instances

Instance	% of Quality Match	Optimized Cost	NFP Cost	Cost Savings
25P-1N-1S	92%	$ 209,886.30	$ 215,078.12	2.47%
50P-2N-1S	82%	$ 316,452.74	$ 326,909.36	3.30%
60P-3N-1S	78%	$ 407,850.63	$ 425,224.90	4.26%
75P-3N-1S	67%	$ 421,956.42	$ 435,305.40	3.16%
85P-4N-1S	66%	$ 515,157.79	$ 537,955.98	4.43%
100P-4N-1S	57%	$ 507,235.36	$ 546,571.64	7.76%
120P-5N-1S	57%	$ 657,536.20	$ 675,759.68	2.77%
135P-6N-1S	42%	$ 752,508.84	$ 776,440.08	3.18%
150P-6N-1S	38%	$ 710,352.50	$ 771,134.39	8.56%
168P-7N-1S	36%	$ 893,663.46	$ 914,221.38	2.30%
175P-7N-1S	33%	$ 900,780.76	$ 910,795.81	1.11%
180P-8N-1S	33%	$ 989,280.20	$ 1,029,365.90	4.05%
190P-8N-1S	44%	$ 1,003,804.66	$ 1,027,208.74	2.33%
200P-8N-1S	30%	$ 903,904.75	$ 987,368.82	9.23%
250P-10N-2S	24%	$ 1,357,969.45	$ 1,395,966.79	2.80%
300P-12N-2S	19%	$ 1,373,363.64	$ 1,536,153.90	11.85%
350P-14N-2S	15%	$ 1,574,870.53	$ 1,810,154.94	14.94%
400P-16-2S	15%	$ 2,069,861.58	$ 2,335,122.80	12.82%

Figure 16 depicts a comparison of the optimized cost of the plan generated for each instance with the actual cost of the NFP HV for the 18 instances used. Significant cost savings can be realized for all the instances, proving the effectiveness of the model in saving cost and at the same time enhancing the quality of treatment with the maximization of quality of patient-nurse matching.

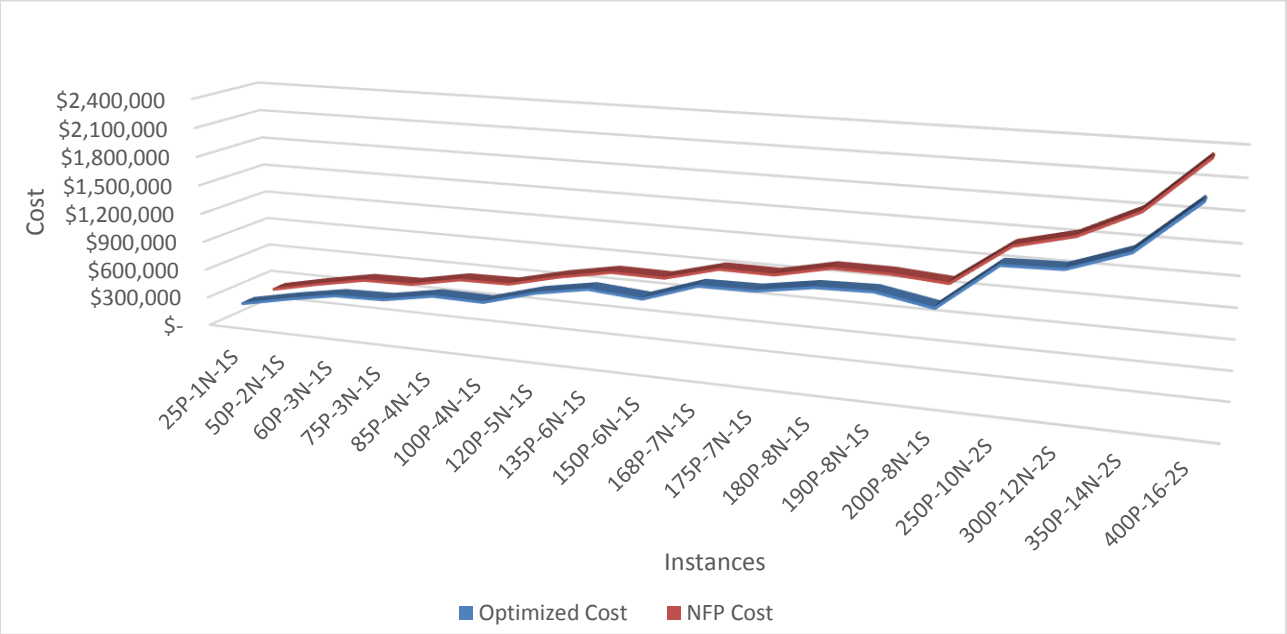

Figure 16 Comparison of Optimized Cost with NFP Cost

This dissertation also compares the results of S2 and S3 with the NFP cost, and finally presents a comparison for all three strategies in the validation process in an attempt to confirm the model's effectiveness. Table 15 reports the results of S2 with the NFP cost and the realized cost savings as well as percentage of quality patient to nurse match. Cost savings between 1% and 13% are obtained for the different instances. Also high percentage of nurse patient quality match are realized in S2 since the objective focused on maximizing quality matching between nurses and patients.

Table 16 reports the results of S3 with the NFP cost and the realized cost savings as well as percentage of quality patient to nurse match. Cost savings between 12% and 20% are obtained for the different instances. Compared to S2, S3 had lower percentage (s) of nurse patient quality match except for the first two instances which had only one and two nurses.

Figure 17 illustrates the comparison of percentage of patient-nurse quality match for all schemes. "S2" yielded higher number of patient-nurse quality match for all the instances considered. "S3" had the lowest

Table 15 Comparison of Strategy Two (S2) with NFP Cost

Instance	% of Quality Match	Non-Optimized Cost	NFP Cost	Cost Savings
25P-1N-1S	92.00%	$ 210,109.30	$ 215,078.12	2.31%
50P-2N-1S	80.00%	$ 319,122.74	$ 326,909.36	2.38%
60P-3N-1S	88.33%	$ 408,510.63	$ 425,224.90	3.93%
75P-3N-1S	81.33%	$ 419,913.42	$ 435,305.40	3.54%
85P-4N-1S	85.88%	$ 512,143.79	$ 537,955.98	4.80%
100P-4N-1S	88.00%	$ 525,211.36	$ 546,571.64	3.91%
120P-5N-1S	80.83%	$ 647,532.20	$ 675,759.68	4.18%
135P-6N-1S	91.11%	$ 762,535.84	$ 776,440.08	1.79%
150P-6N-1S	96.67%	$ 739,332.50	$ 771,134.39	4.12%
168P-7N-1S	92.26%	$ 881,653.46	$ 914,221.38	3.56%
175P-7N-1S	96.57%	$ 875,789.76	$ 910,795.81	3.84%
180P-8N-1S	95.00%	$ 989,310.20	$ 1,029,365.90	3.89%
190P-8N-1S	94.74%	$ 987,804.66	$ 1,027,208.74	3.84%
200P-8N-1S	92.00%	$ 937,904.75	$ 987,368.82	5.01%
250P-10N-2S	82.00%	$ 1,307,969.45	$ 1,395,966.79	6.30%
300P-12N-2S	86.33%	$ 1,453,377.64	$ 1,536,153.90	5.39%
350P-14N-2S	83.43%	$ 1,694,870.53	$ 1,810,154.94	6.37%
400P-16-2S	82.25%	$ 2,189,861.58	$ 2,335,122.80	6.22%

Table 16 Comparison of Strategy Three (S3) with NFP Cost

Instance	% of Quality Match	Optimized Cost	NFP Cost	Cost Savings
25P-1N-1S	92%	$ 185,831.30	$ 215,078.12	14%
50P-2N-1S	58%	$ 276,452.74	$ 326,909.36	15%
60P-3N-1S	18%	$ 357,850.63	$ 425,224.90	16%
75P-3N-1S	25%	$ 381,956.42	$ 435,305.40	12%
85P-4N-1S	26%	$ 465,130.79	$ 537,955.98	14%
100P-4N-1S	20%	$ 469,295.36	$ 546,571.64	14%
120P-5N-1S	19%	$ 557,521.20	$ 675,759.68	17%
135P-6N-1S	18%	$ 662,513.84	$ 776,440.08	15%
150P-6N-1S	21%	$ 650,352.50	$ 771,134.39	16%
168P-7N-1S	11%	$ 793,893.46	$ 914,221.38	13%
175P-7N-1S	15%	$ 769,878.76	$ 910,795.81	15%
180P-8N-1S	13%	$ 848,280.20	$ 1,029,365.90	18%
190P-8N-1S	15%	$ 878,851.66	$ 1,027,208.74	14%
200P-8N-1S	15%	$ 813,919.75	$ 987,368.82	18%
250P-10N-2S	10%	$ 1,200,918.45	$ 1,395,966.79	14%
300P-12N-2S	17%	$ 1,299,871.64	$ 1,536,153.90	15%
350P-14N-2S	21%	$ 1,474,361.53	$ 1,810,154.94	19%
400P-16-2S	26%	$ 1,869,839.58	$ 2,335,122.80	20%

number of patient-nurse quality match for all the instances. Optimizing quality with cost resulted in percentages of quality match values that were between the results obtained for S2 and S3. Figure 18 illustrates the comparison of cost for the instances considered under the different schemes. For all the instances, the NFP cost was higher when compared with the model's results. In essence, cost savings were obtained for "S1", "S2" and "S3". The largest savings were obtained for "S3", however this dissertation recommends optimizing quality with cost simultaneously as this balances between the cost and quality metrics.

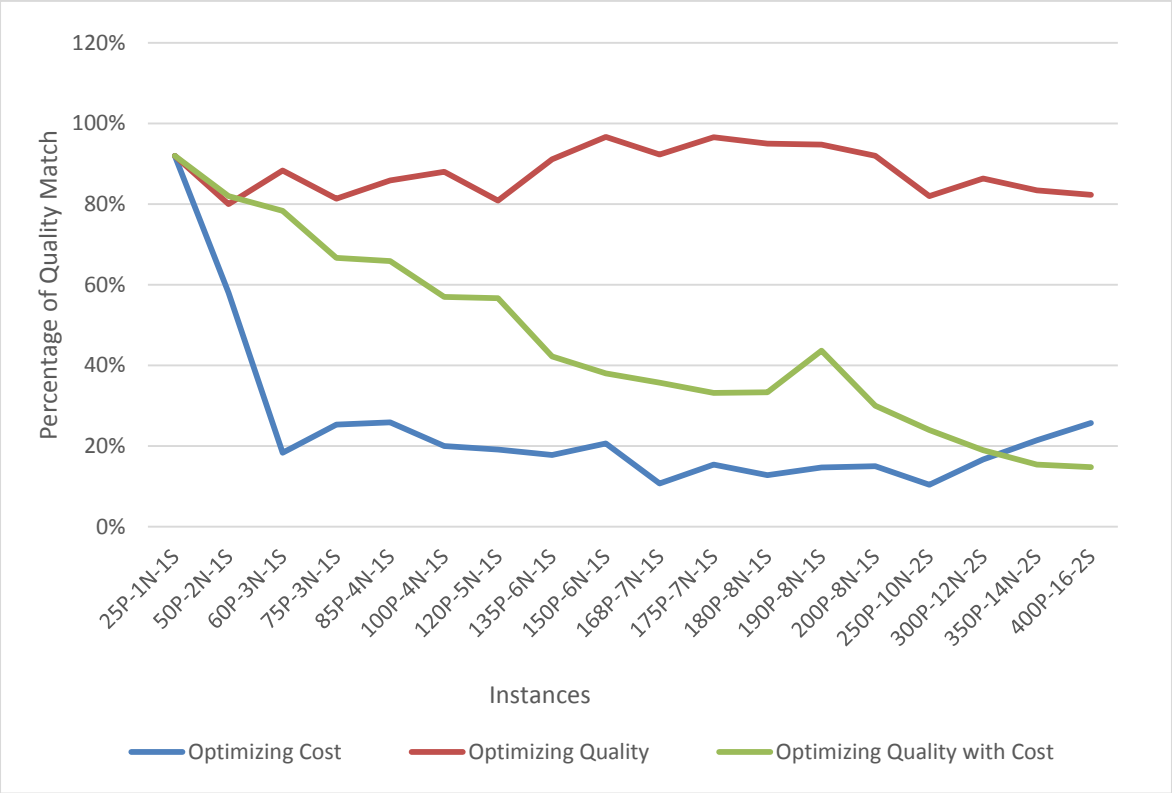

Figure 17 Percentage of Patient-Nurse Quality Match: S1, S2 and S3

The developed model has been successfully validated and could facilitate the planning process of follow up programs by helping to highlight the best course of action when assigning nurses to patients. Most importantly, the model improves the quality of treatment of infants in their homes after discharge from the hospital, by maximizing the assignment of the right nurse with the right skill; nurse type (CNA, LPN, RN or NP)); and years of experience, to the right patient with specific needs (C, HD, ME, PA), hence reducing

the risk of treatment. Application of the model also benefits from significant cost savings as explained in the previous sections.

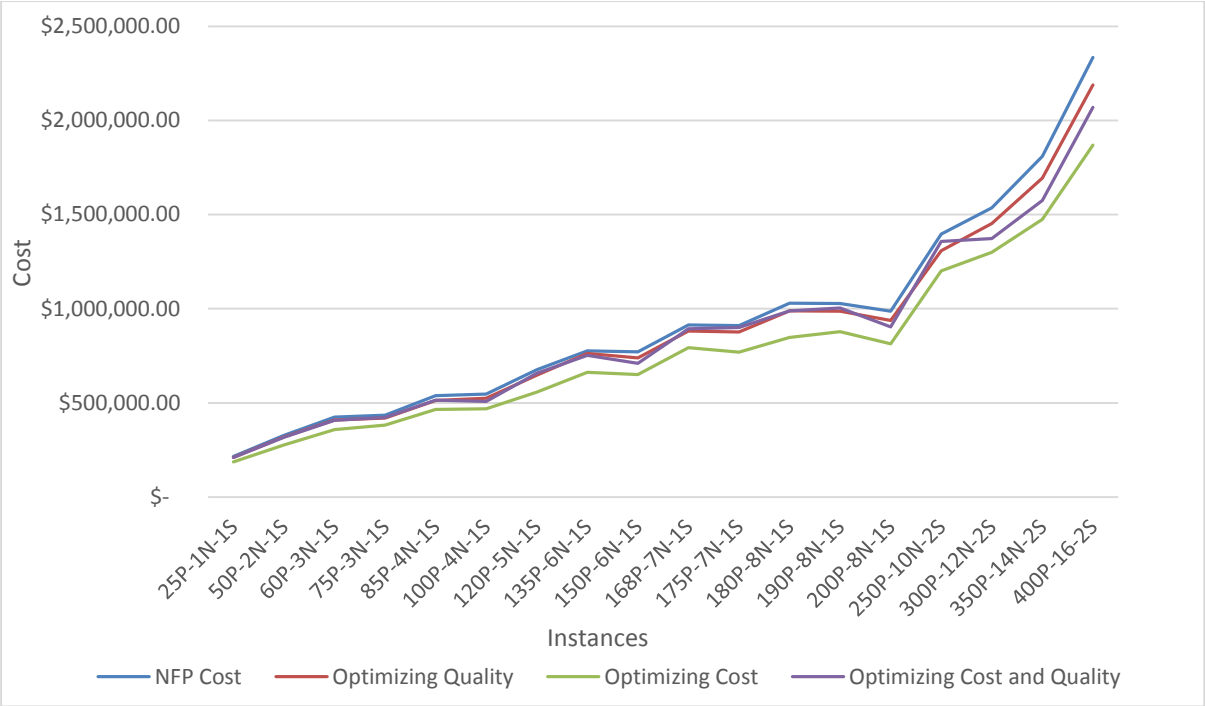

Figure 18 Comparison of Cost: S1, S2, S3 and NFP Cost

Sensitivity Analysis

The solution to the HV model presents the schedule, assignment match, and the sequence in which the visits will occur with reference to the horizon planning period. The model also specifies the number of patients assigned to each nurse and the estimated cost of care based on the solution and decisions presented. The type of nurses' education is critical to care and cannot be compromised, however, the quality of nurse to patient match and cost could vary based on the years of experience of nurses; therefore, experiments are performed on the sensitivity of quality match and cost to the assumed variations. The sensitivity analysis is conducted on each of the 18 instances of strategy one where quality is optimized with cost. In the first experiment, the model is simulated by giving the highest score to 3 years of experience followed by 4 years, 2 years and then 1 year of experience. This yields a combination matrix of nurse education and years of experience for the model to select the highest score which represents the most experienced nurse in caring for a particular patient need. The percentage of quality match and cost that results are then noted for each experiment. In the second experiment, the model is simulated by giving the highest score to 2 years of

experience followed by 4 years, 3 years and then 1 year of experience. The third experiment assigns the highest score to 1 year of experience followed by 2 years, 4 years and then 3 years of experience.

Table 17 and Table 18 presents the results of the sensitivity analysis. Table 17 presents the results of sensitivity analysis on nurse to patient quality match. The first columns of the table shows a list of the 18 instances considered. The second, third and fourth columns are the differences in percentage of nurse to patient quality match when experiments 1, 2 and 3 are compared with the results of S1 respectively. For all the experiments considered, there were no changes in quality realized in the first 6 instances. This is due to the fact that the number of nurses and patients available are fewer in these cases. Thus there are 1 to 4 nurses available, and that at least one highly qualified nurse type and required skill are represented in each case of the nurses available. For experiment 1, a decrease in quality is realized for all the instances from -1.75% to -28.92%, except for instance 175P-7N-1S which had no change in quality match, and instance 200P-8N-1S which had a slight increase of 1.67% in quality. Similarly, in experiment 2, a decrease in quality is realized for all the instances from -3.33% to -32.53%, except for instance150P-6N-1S which had no change in quality match, and instances 135P-6N-1S and 175P-7N-1S which had slight increases in quality of 1.26% and 3.45% respectively. In experiment 3, a decrease in quality is realized for all the instances from -1.67% to -31.33%, except for instances 175P-7N-1S and 200P-8N-1S which had slight increases of 1.72% and 2.33 % in quality respectively. It is interesting to note that the quality of nurse to patient matches were significantly reduced for almost all the instances of the 3 experiments considered, which signifies the importance of years of experience of nurses in the assignment for quality of care. The experiment shows that years of experience impact quality significantly in the care process.

Table 18 presents the results of sensitivity analysis on cost savings. The first columns of the table shows a list of the 18 instances considered. The second, third and fourth columns are the differences in percentage of cost savings when experiments 1, 2 and 3 are compared with the results of S1 respectively. For experiment 1, a decreased cost is realized for all the instances between -0.01% to -14.65%, except for instances 50P-2N-1S and 120P-5N-1S which had no change in cost, and instances 60P-3N-1S, 100P-4N-1S and 150P-6N-1S which had their cost increased slightly between 0.01% and 0.03%. Similarly, in experiment 2, a decreased cost is realized for all the instances from -0.01% to -15.37%, except for instances 50P-2N-1S, 100P-4N-1S and 150P-6N-1S which had their cost increased slightly between 0.01% and 0.05%.

In experiment 3, a decreased cost is realized for all the instances from -0.02% to -13.30%, except for instances 50P-2N-1S, 60P-3N-1S, 100P-4N-1S, 120P-5N-1S and 150P-6N-1S which had their cost increased slightly between 0.01% and 0.07%. It is worth noting that both instances 100P-4N-1S and 150P-

6N-1S had their cost increase slightly in each of the 3 experiments considered. The experiment also shows that years of experience has an impact on cost for different scenarios of the care process.

In the experiments conducted, the increase or decrease in quality and cost are due to the type of patient classes available in each instance, and also due to the geographic locations of patients being distant from an assigned nurses' zone; hence a nurse assignment being violated because the health needs of such patients are not critical whereas any available nurse could care for their needs to avoid higher qualified nurses traveling out of their zone. This contributes in confirming the studies by [208], [210] and [211].

Table 17 Sensitivity Analysis on Quality Match

Instances	Experiment 1	Experiment 2	Experiment 3
25P-1N-1S	0	0	0
50P-2N-1S	0	0	0
60P-3N-1S	0	0	0
75P-3P-1S	0	0	0
85P-4N-1S	0	0	0
100P-4N-1S	0	0	0
120P-5N-1S	-23.53%	-20.59%	-26.47%
135P-6N-1S	-1.75%	1.26%	-10.53%
150P-6N-1S	-3.51%	0.00%	-5.26%
168P-7N-1S	-3.33%	-6.67%	-3.33%
175P-7N-1S	0.00%	3.45%	1.72%
180P-8N-1S	-5.00%	-5.00%	-1.67%
190P-8N-1S	-28.92%	-32.53%	-31.33%
200P-8N-1S	1.67%	-3.33%	5.00%
250P-10N-2S	-8.33%	-8.33%	-6.67%
300P-12N-2S	-18.35%	-11.32%	-3.51%
350P-14N-2S	-16.25%	-17.85%	3.70%
400P-16-2S	-23.90%	-21.68%	-8.47%

Table 18 Sensitivity Analysis on Cost Savings

Instance	Experiment 1	Experiment 2	Experiment 3
25P-1N-1S	-0.01%	-0.03%	-0.02%
50P-2N-1S	0.00%	0.05%	0.07%
60P-3N-1S	0.01%	-0.07%	0.03%
75P-3P-1S	-0.03%	-0.03%	-0.03%
85P-4N-1S	-0.03%	-0.03%	-0.04%
100P-4N-1S	0.03%	0.03%	0.01%
120P-5N-1S	0.00%	-0.08%	0.01%
135P-6N-1S	-0.11%	-0.08%	-0.09%
150P-6N-1S	0.03%	0.01%	0.01%
168P-7N-1S	-0.10%	-0.10%	-0.10%
175P-7N-1S	-0.03%	-0.03%	-0.06%
180P-8N-1S	-0.11%	-0.07%	-0.06%
190P-8N-1S	-0.11%	-0.09%	-0.09%
200P-8N-1S	-13.30%	-13.08%	-13.30%
250P-10N-2S	-4.55%	-8.36%	-3.00%
300P-12N-2S	-14.65%	-14.30%	-5.00%
350P-14N-2S	-5.09%	-15.37%	-2.89%
400P-16-2S	-7.59%	-11.65%	-5.52%

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the dissertation, followed by conclusions and finally recommendations for future research directions on this field.

Summary

This dissertation presents a novel development of an optimal model for infant home visitation programs. Three topic areas are addressed: a comprehensive study and literature review to build a complete taxonomy and databank for infant HV programs by classifications; a study and literature review on OR applications to HHC, HC and HV; and finally, the development of a novel HVP model. In accomplishing these goals, firstly, a literature review for the state of the art study on HHC, HC and HV, and also OR applications to these have been presented with emphasis on care provided to patients in their domicile homes by nurses. The dissertation then highlighted relevant contributions for this problem as well as identified various gaps in these studies. A conceptual framework of the infant HV paradigm is proposed. Finally, a novel mixed integer programming approach is introduced to model the problem which explores a variety of instances and model's solution characteristics. The model is tested on 18 instances and validated with the NFP HV program for its effectiveness in saving cost and enhancement of treatment.

Conclusions

HV has been accepted as a promising strategy for infant intervention after birth in many developed countries and continues to gain increasing recognition in the health sector. HV is a type of service-delivery model that can be used to provide many different kinds of interventions to target participants. This suggests that it can be modeled mathematically to yield a host of benefits. Several research efforts are required to contribute to this field, and OR applications could play a pivotal role in the modeling process which incorporate cost components and all targeted population as well as other complexities in an optimal way. Real life scenarios and instances of the problem presented in literature are smaller as compared to the presented study. In the HV scenarios, larger subsets of the population are involved and to be served by groups of nurses considering various crucial program's fidelity elements. Modeling and optimizing such situations calls for larger computational times and extra sets of variables yielding complex formulations. This presents the potential to predict how key performance indicators and relevant parameters affect the healthcare system's performance and economic viability in the field. Overall, such research efforts are of great interest to researchers, health professionals, policy-makers who allocate resources, and to the general public who provide those resources through the taxes they pay. This dissertation has presented an extensive and broad

review of infant HV and OR application to HHC, HC and HV focusing on relevant research in the field. Several aims are achieved which include; investigating whether mathematical methodologies have been applied to specifically infant HV for effectiveness and cost efficiency, identification of the differences between adult HHC/HC and infant HV, exploring and analyzing relevant state of-the-art OR application literature on home care programs, stimulating research interest in this field, presenting a novel modeling solution to the problem, validating the model as well as identifying fertile avenues for future research.

Future Research Directions in this Field

The HV paradigm and problem is still an emerging new problem which calls for several unexplored modeling and solution approaches. Future research will be devoted to developing a graphic user interphase (GUI) or web user interphase (WebUI) decision support tool based on the model to aid in planning, scheduling and assignment. Additionally, the GUI or WebUI would integrate Google map to show patient's geographic locations in demarcated zones and aid in realizing the sequence of daily scheduled visits. This would also comprises a data-management system and key performance analysis system in the results upon running the model. Secondly, future efforts may include several unique and real life features of HV such as adding more requirements and qualifications to the nurse skill matrix combination to enhance care for patients. More efforts could also be devoted to exploring different solution approaches to disruption management affecting larger subsets for quicker solution times and optimality. The model in this research study was mainly developed using the Nurse Family Partnership program's (NFP) deployment process which proved to be the best infant home visiting program noted by its successes, replicability, and being the strongest evidence-based program, among others. Future research efforts present great opportunities in testing the models and methodologies with other HV programs such as the Healthy families America, Even start, Early Start, Parents as Teachers and the Comprehensive Child Development Program, among others which have major similarities with the NFP. The model also presents future prospects for testing on programs for school-going infants such as the Perry Preschool Program, Chicago Child-Parent Centers' program and Abecedarian Early Childhood Intervention, among others. Moreover, the current version of the model represents the NFP HV program which has strict regulations and model fidelity elements that NFP sites must adhere to, hence the implementation of several hard constraints. Future studies will focus on implementation of various soft constraints and relaxation of the model's restrictions to test other HV programs. Lastly, future research may be devoted to experimenting and testing the approach developed for infant HV in this study, and to test the extent to which it will work for adult HHC and HC.

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APPENDIX

A. Taxonomy and Categories of Infant Home Visitation Programs

Section A of the appendix contains a databank for HV studies classified into six categories according to the focus of study and research concentration, namely; review (Table A.1), cost benefit analysis (Table A.2), randomized trial experiments (Table A.3), effect/impact (Table A.4), evaluation/comparison (Table A. 5, and general HV studies (Table A.6).

Table A.1 Taxonomy of Review studies/Papers

Type of Study	Publication Type	year	Researcher (s)	Reference
Review Studies	**Journal**	1982	Simeonsson et al. (1982)	Simeonsson RJ, Cooper DH, Schemer AP. A review and analysis of the effectiveness of early intervention programs. Pediatrics. 1982;69:635-641
		1985	White and Casto (1985)	White, K., and Casto, G. An integrative review of early intervention efficacy studies with at-risk children: Implications for the handicapped. Analysis and Intervention in Developmental Disabilities (1985) 5:7–31.
		1985	Combs et al. (1985)	Combs-Orme T, Reis J, Ward LD. Effectiveness of home visits by public health nurses in maternal and child health: an empirical review. Public Health Rep 1985;100:490-9.
		1988	Heinicke et al. (1988)	Heinicke C, Beckwith L, Thompson A. Early intervention in the family system: a framework and review. Infant Mentl Health J. 1988;9:111-14
		1990	Chapman et al. (1990)	Jean Chapman, Earl Siegel and Alan Cross, Home Visitors and Child Health: Analysis of Selected Programs, 1990;85;1059 Pediatrics. http://pediatrics.aappublications.org/content/85/6/1059
		1993	Olds and Kitzman (1993)	Olds, D.L. & Kitzman, H. (1993) Review of research on home visiting for pregnant women and parents of young children. The Future of Children, 3(3), 53-92.
		1996	Robert et al. (1996)	Roberts, I., Kramer, M.S., & Suissa, S. (1996). Does home visiting prevent childhood injury? A systematic review of randomized controlled trials. BMJ, 312, 29-33. Available at http://www.bmj.com/cgi/content/full/312/7022/29.
		1996	Ciliska et al. (1996)	Ciliska, D., Hayward, S., Mitchell, A., Thomas, H., Dobbins,M. and Underwood, J. 1996: A systematic overview of the effectiveness of home visiting as a delivery strategy for public health nursing interventions. Canadian Journal of Public Health 87, 193–98.
		1997	Byrd (1997)	Byrd, M. E. (1997). A typology of the potential outcomes of maternal-child home visits: a literature analysis. Public Health Nursing 14: 3-11.

Table A.1 Continued

Type of Study	Publication Type	year	Researcher (s)	Reference
Review Studies	**Journal**	1999	Robinson (1999)	Robinson, J. 1999. Domiciliary health visiting: a systematic review. Community Practitioner 72, 15–18.
		2000	Elkan et al. (2000)	Elkan, R., Kendrick, D., Hewitt, M., Robinson JJA., et al. (2000). The effectiveness of domiciliary health visiting: A systematic review of international studies and a selective review of the British literature. Health Technology Assessment, 4(13).
		2000	MacLeod and Nelson (2000)	MacLeod, J., & Nelson, G. (2000) Programs for the promotion of family wellness and the prevention of child maltreatment: A meta-analytic review. Child Abuse & Neglect, 24(9), 1127-1149.
		2000	Kendrick et al. (2000)	Kendrick, D., Elkan, R., Hewitt, M., Dewey, M., et al. (2000) Does home visiting improve parenting and the quality of the home environment? A systematic review and meta-analysis. Arch Dis Child, 82, 443-451.
		2000	Kendrick et al. (2000).	Kendrick, D., Hewitt, M., Dewey, M., Elkan, R., et al. (2000). The effect of home visiting programmes on uptake of childhood immunization: A systematic review and meta-analysis. Journal of Public Health Medicine, 22(1), 90-98.
		2000	McNaughton (2000)	McNaughton, D. B. (2000). A synthesis of qualitative home visiting research. Public Health Nursing 17 (6): 405-14.
		2001	Ciliska et al. (2001)	Ciliska, D., Mastrilli, P., Ploeg, J., Hayward, S., et al. (2001). The effectiveness of home visiting as a delivery strategy for public health nursing interventions to clients in the prenatal and postnatal period: A systematic review. Primary Health Care Research and Development, 2(1), 41-54. from web: http://journals.cambridge.org/download.php?file=%2FPHC%2FPHC2_01%2FS1463423601000068a.pdf&code=9ad72785950062775367dab8427fc72d
		2003	Nelson et al. (2003)	Nelson, G., Westhues, A., & MacLeod, J. (2003). A meta-analysis of longitudinal research on preschool prevention programs for children. Prevention & Treatment,Volume 6, Article 31, posted December 18, 2003. Available at http://journals.apa.org/prevention/volume6/pre0060031a.html.
		2003	Bakermans-Kranenburg et al. (2003)	Bakermans-Kranenburg, M. J., van Ijzendoorn, M. H., & Juffer, F. (2003). Less is more: Meta-analyses of sensitivity and attachment interventions in early childhood. Psychological Bulletin, 129, 195-215.

Table A.1 Continued

Type of Study	Publication Type	year	Researcher (s)	Reference
Review Studies	**Journal**	2004	Sweet and Appelbaum (2004)	Sweet, M.A., & Appelbaum, M.I. (2004) Is home visiting an effective strategy? A meta-analytic review of home visiting programs for families with young children. Child Development, 75(5), 1435-1456.
		2004	Hodnett and Roberts (2004).	Hodnett, E.D., & Roberts, I. (2004). Home-based social support for socially disadvantaged mothers (Cochrane Review). In: The Cochrane Library, Issue 3, 2004. Oxford.
		2004	Sikorski et al. (2004)	Sikorski, J., Renfrew, M.S., Pindoria, S., & Wade, A. (2004). Support for breastfeeding mothers (Cochrane Review). In: The Cochrane Library, Issue 3, 2004. Oxford.
		2004	Brown et al. (2004)	Brown, S., Small, R., Faber, B., et al. (2004) Early postnatal discharge from hospital for healthy mothers and term infants (Cochrane Review). In: The Cochrane Library, Issue, 3, 2004. Oxford: Update Software.
		2004	Levitt et al (2004)	Cheryl Levitt, MBBCh, CCFP, FCFP, Elizabeth Shaw, MD, CCFP, FCFP, Sharon Wong, RD, MSc, Janusz Kaczorowski, PhD, Russ Springate, MD, CCFP, John Sellors, MD, CCFP, MSc, Murray Enkin, MD, and the McMaster University Postpartum Research Group*, Systematic Review of the Literature on Postpartum Care: Methodology and Literature Search Results, Birth 31:3 September 2004.
		2004	McNaughton (2004)	McNaughton, D. B. (2004). Nurse home visits to maternal-child clients: A review of intervention research. Public Health Nursing, 21, 207-219.
		2005	Bilukha et al. (2005)	Bilukha, Oleg, et al. "The Effectiveness of Early Childhood Home Visitation in Preventing Violence: A Systematic Review." American Journal of Preventive Medicine, 2005: 11-39.
		2006	Shaw et al. (2005)	Systematic review of the literature on postpartum care: effectiveness of postpartum support to improve maternal parenting, mental health, quality of life, and physical health. Shaw E, Levitt C, Wong S, Kaczorowski J; McMaster University Postpartum Research Group. Birth. 2006 Sep; 33(3):210-20. Review.
		2007	Macdonald et al. (2007)	Home-based support for disadvantaged teenage mothers. Macdonald G, Bennett C, Dennis J, Coren E, Patterson J, Astin M, Abbott J. Cochrane Database Syst Rev. 2008 Jan 23;(1):CD006723. Review.
		2007	Harding et al. (2007)	Kathryn Harding and others, “Healthy Families America Effectiveness: A Comprehensive Review of Outcomes,” Journal of Prevention and Intervention in the Community 34 (2007): 149–79.

Table A.1 Continued

Type of Study	Publication Type	year	Researcher (s)	Reference
Review Studies	**Journal**	2009	Reynolds et al. (2009)	Arthur J. Reynolds, Lindsay C. Mathieson and James W. Topitzes, Do Early Childhood Interventions Prevent Child Maltreatment? : A Review of Research, Child Maltreat 2009 14: 182 originally published online 24 February 2009, DOI: 10.1177/1077559508326223
		2010	Nievar et al. (2010)	M. A. Nievar, L. A. Van Egeren, and S. Pollard, A Meta-Analysis Of Home Visiting Programs: Moderators Of Improvements In Maternal Behavior Infant Mental Health Journal, Vol. 31(5), 499–520 (2010)
		2011	Issel et al. (2011)	Issel, M.L., et al., A review of prenatal home-visiting effectiveness for improving birth outcomes. Journal of Obstetric, Gynecologic and Neonatal Nursing, 2011. 40: p. 157-165.
	Reports	1974	Bronfenbrenner(1974)	Bronfenbrenner, Urie, A Report on Longitudinal Programs: Vol. 2. Is Early Intervention Effective? Washington, D.C.: U.S. Government Printing Office, DHEW Publication Number OHD 74–24, 1974.
		1999	Wade et al. (1999)	Wade, K., Cava, M., Douglas, C., Feldman, L. et al. (March 1999). A systematic review of the effectiveness of peer/paraprofessional 1:1 interventions targeted toward mothers (parents) of 0-6 year old children in promoting positive maternal (parental) 50 and/or child health/developmental outcomes. Effective Public Health Practice Project. Ontario Public Health Research, Education & Development Program. http://www.ephpp.ca/PDF/1999_Peer%20Para%201-1.pdf
		2004	Bull et al. (2004)	Bull, J., McCormick, G., Swann, C., Mulvihill, C. (February 2004). Ante- and postnatal home-visiting programmes: a review of reviews. Health Development Agency, National Health Service. http://194.83.94.67/uhtbin/cgisirsi.exe/1112044798/0/520/EBBD_Home_pdf_ft
		2005	Gomby (2005)	Gomby, Deanna S. Home Visitation in 2005: Outcomes for Children and Parents. Working Paper, Sunnyvale: Committee for Economic Develoment; Invest in Kids Working Group, 2005.
		2007	LPC Consulting Associates, Inc. (2007)	LPC Consulting Associates, Inc., Home Visitation Best Practices: A Review Of The Literature ,,Submitted to: Birth and Beyond ,May 2007
		2010	Brooks (2010)	Brooks, Jade. A Comparative Analysis of Statewide Programs and Initatives to Improve Perinatal and Maternal Health. Huntington: Center for Business and Economic Research, 2010.
	Books	1990	Farran(1990).	Farran, D. C (1990). Effects of Intervention with disadvantaged and disabled children: A decade review. In S. J Meisels & J. P. Shonkoff (Eds.), Handbook of Early Childhood Intervention (pp. 501-539). New York: Cambridge Press.

Table A.2 Taxonomy of Cost/cost benefit analysis studies

Type of Study	Publication Type	year	Researcher(s)	Reference
Cost and Benefit Analysis Studies	**Journals**			
		1988	Barnett (1988)	Barnett, W.S. Economic analysis as a tool for early intervention research. Journal of the Division of Early Childhood (1988) 12,4:376-83.
		1989	Affleck et al. (1989)	Affleck, G., Tennen, H., Rowe, J., et al. (1989). Effects of formal support on mothers' adaptation to the hospital-to-home transition of high-risk infants: The benefits and costs of helping. Child Development, 60(2), 488-501.
		1993	Olds et al. (1993)	Olds, D.L., Henderson, C.R., Phelps, C., et al. (1993) Effect of prenatal and infancy nurse home visitation on government spending. Medical Care, 31(2), 155-174.
		1993	Barnett (1993)	Barnett, W. Steven, "Benefit-Cost Analysis of Preschool Education: Findings from a 25-Year Follow-Up," American Journal of Orthopsychiatry, Vol. 63, No. 4, 1993, pp. 500–508.
		1993	Barnett (1993)	Barnett WS. Economic evaluation of home visiting programs. The Future of Children. 1993;33:93-112
		1995	Vistnes and Hamilton (1995)	Vistnes, J. P., & Hamilton, V. (1995). The time and monetary costs of outpatient care for children. The American Economic Review, 85, 117–121.
		2004	Paul et al. (2004)	Ian M. Paul, MD, MSc*‡; Troy A. Phillips, MHA§; Mark D. Widome, MD, MPH*; and Christopher S. Hollenbeak, PhD,Cost-Effectiveness of Postnatal Home Nursing Visits for Prevention of Hospital Care for Jaundice and Dehydration, Pediatrics 2004;114:1015–1022; doi:10.1542/peds.2003-0766-L
		2009	Marcela et al. (2009)	Marcela Aracena, Mariane Krause, Carola Pérez, María Jesús Méndez, Loreto Salvatierra, Mauricio Soto, Tomás Pantoja, Sandra Navarro, Alejandra Salinas, A Cost-Effectiveness Evaluation Of A Home Visit Program For Adolescent Mothers, Journal Of Health Psychology, 2009 , Vol 14(7) 878–887, Doi: 10.1177/1359105309340988
		2010	Olds et al. (2010)	Olds DL, Kitzman HJ, Cole RE, Hanks CA, Arcoleo KJ, Anson EA, Luckey DW, Knudtson MD, Henderson CR Jr, Bondy J, Stevenson AJ.,Enduring effects of prenatal and infancy home visiting by nurses on maternal life course and government spending: follow-up of a randomized trial among children at age 12 years. Arch Pediatr Adolesc Med. 2010 May;164(5):419-24.
	Reports	1996	Greenwood et al. (1996)	Greenwood, Peter W., Karyn E. Model, C. Peter Rydell, and James Chiesa, Diverting Children from a Life of Crime: Measuring Costs and Benefits, Santa Monica, Calif.: RAND, MR-699-UCB/RC/F, 1996.

Table A.2 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Cost and Benefit Analysis Studies	**Reports**	1997	Paul et al. (1997)	Ian M. Paul, MD, MSc; Troy A. Phillips, MHA; Mark D. Widome, MD, MPH; and Christopher S. Hollenbeak, PhD, Cost-Effectiveness of Postnatal Home Nursing Visits for Prevention of Hospital Care for Jaundice and Dehydration Figueroa E. California State Assembly. Assembly Bill No. 38: Chapter 389. Newborns' and Mothers' Act of 1997. August 26, 1997
		1998	Karoly et al. (1998)	Karoly, L.A., Greenwood, P.W., Everingham, S.S., Hoube, J., Kilburn, M.R., Rydell, C.P., et al. (1998). Investing in our children: What we know and don't know about the costs and benefits of early childhood interventions. Santa Monica, CA: The RAND Corporation.
		1998	Division of Science. (1998)	Division of Science. "Maternal and Child Health Services Economics in MCH." In A Review of Descriptive Costs Studies and Economic Evaluations of MCH Interventions. MCH Bureau, HRSA, 1998.
		2000	Montgomery et al. (2000)	Montgomery, D., Phillips, G., Merickel, A. (September 29, 2000). Home visiting programs: Varying costs and elusive effects. Report submitted to The David and Lucile Packard Foundation. Palo Alto, CA: American Institutes for Research.
		2001	Aos S et al. (2001)	Aos S, Phipps P, Barnoski R, Leib R. (2001). The comparative costs and benefits of programs to reduce crime. Version 4.0. Washington State Institute for Public Policy, May, 2001.
		2001	Karoly et al. (2001)	Karoly, Lynn A., M. Rebecca Kilburn, James H. Bigelow, Jonathan P. Caulkins, and Jill Cannon, Assessing Costs and Benefits of Early Childhood Intervention Programs: Overview and Application to the Starting Early Starting Smart Program, Santa Monica, Calif.: RAND Corporation, MR-1336-CFP, 2001.
		2002	VanLandeghe m (2002)	VanLandeghem, Karen. The Benefits and Financing of Home Visiting Programs, Issue Brief. Washington, DC: National Governer's Association Center for Best Practices, 2002.
		2004	Glazner et al. (2004)	Glazner, J., Bondy, J., Luckey, D., & Olds, D. Effect of the Nurse Family Partnership on government expenditures for vulnerable first-time mothers and their children in Elmira, New York, Memphis, Tennessee, and Denver, Colorado. Final Report to the Administration for Children and Families. www.acf.hhs.gov/programs/opre/welfare_employ/economic_analysis/reports/effect_nursefam/effect_nursefam.pdf
		2004	Aos et al. (2004)	Aos, S., Lieb, R., Mayfield, J., Miller, M., Pennucci, A. (2004). Benefits and costs of prevention and early intervention programs for youth. Olympia: Washington State Institute for Public Policy.Olympia, WA, 2004. www.wsipp.wa.gov/rptfiles/04-07-3901.pdf. Accessed 03/22/2012.

Table A.2 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Cost and Benefit	**Reports**	2005	Kent et al. (2005)	Kent, Calvin et al. The Economic Impact of Early Child Development Programs in West Virginia. Huntington: Center for Business and Economic Research, 2005.
Analysis Studies		2005	Karoly et al. (2005)	Karoly LA, Kilburn RM, Cannon JS. Early Childhood Interventions Proven Results, Future Promises. The RAND Corporation. Santa Monica, CA, 2005. www.rand.org/pubs/monographs/MG341/. Accessed 03/22/2012.
		2007	Isaacs (2007)	Isaacs, JB. Cost-effective Investments in Children.Budgeting for National Priorities, Washington, DC: Brookings Institution; 2007 http://www.brookings.edu/~/media/research/files/papers/2007/1/01childrenfamilies%20isaacs/01childrenfamilies_isaacs.pdf
		2008	Lee et al. (2008)	Stephanie Lee, Steve Aos, and Marna Miller. (2008). Evidence-based programs to prevent children from entering and remaining in the child welfare system: Benefits and costs for Washington. Olympia: Washington State Institute for Public Policy, Document No. 08-07-3901.
		2009	Bartik and Upjohn (2009)	Bartik, T. J., & W. E. Upjohn Institute for Employment Research. (2009). Distributional effects of early childhood programs and business incentives and their implications for policy. Upjohn Institute staff working paper no. 09-151. Kalamazoo, MI: W. E. Upjohn Institute.
		2012	Lee et al. (2012)	Lee, S., Aos, S., Drake, E., Pennucci, A., Miller, M., & Anderson, L. (2012). Return on investment: Evidence-based options to improve statewide outcomes, April 2012 (Document No. 12-04-1201). Olympia: Washington State Institute for Public Policy.
	Conference proceedings	2009	Boonstra (2009)	Boonstra H. Home visiting for at-risk families: a primer on a major Obama administration initiative. Guttmacher Policy Rev. 2009; 12(3):11–15.
	Books	1990	Barnett and Escobar (1990)	Barnett, W. Steven, and Collette M. Escobar, "Economic Costs and Benefits of Early Intervention," Handbook of Early Childhood Intervention, Samuel J. Meisels and Jack P. Shonkoff, eds., New York: Cambridge University Press, 1990, pp. 560–582.
		1992	Harkavy and Bond (1992)	Harkavy, O., and Bond, J.T. Program operations: Time allocation and cost analysis. In Fair start for children: Lessons learned from seven demonstration projects. M. Larner, R. Halpern,and O. Harkavy, eds. New Haven, CT: Yale University Press, 1992, pp. 198-217.
		2002	Masse and Barnett (2002)	Masse, Leonard N., and W. Steven Barnett, "A Benefit-Cost Analysis of the Abecedarian Early Childhood Intervention," in Henry M. Levin and Patrick J. McEwan, eds., Cost-Effectiveness and Educational Policy, Larchmont, N.Y.: Eye on Education, Inc., 2002, pp. 157–173.

Table A.3 Taxonomy of Randomized Trial Studies

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	1986	Olds et al. (1986)	Olds, D. L., Henderson Jr., C. R., Tatelbaum, R., & Chamberlin, R. (1986). Improving the delivery of prenatal care and outcomes of pregnancy: A randomized trial of nurse home visitation. Pediatrics, 77(1), 16-28.
		1986	Olds et al. (1986)	Olds, David L., Charles R. Henderson, Jr., Robert Chamberlin, and Robert Tatelbaum, "Preventing Child Abuse and Neglect: A Randomized Trial of Nurse Home Visitation," Pediatrics, Vol. 78, No. 1, 1986, pp. 65–78.
		1986	Brooten et al. (1986)	Brooten, D., Kumar, S., Brown, L. P., Butts, P., Finkler, S. A., Bakewell-Sachs, S., Gibbons, A. and Delivoria-Papdopoulos, M. 1986: A randomized clinical trial of early hospital discharge and home follow-up of very-low-birth-weight infants. New England Journal of Medicine 315, 934–39.
		1988	Olds et al. (1988)	D L Olds, C R Henderson, Jr, R Tatelbaum, R Chamberlin,Improving the Life-Course Development of Socially Disadvantaged Mothers: A Randomized Trial of Nurse Home Visitation," American Journal of Public Health, Vol. 78, No. 11, 1988, pp. 1436–1445.
		1990	Wasik et al. (1990)	Wasik, B.H., Ramey, C.T., Bryant, D.M., & Sparling, J.J. A longitudinal study of two early intervention strategies: Project CARE. Child Development (1990) 61: 1682-96
		1990	Infant Health and Development Program (1990)	Infant Health and Development Program (1990). Enhancing the outcomes of low-birth weight, premature infants: A multisite, randomized trial: The Infant Health and Development Program. Journal of the American Medical Association, 263(22), 3035-3042.
		1991	Bryce et al. (1991)	Bryce, R.L., Stanley, F.J., and Gamer, J.B. Randomized controlled trial of antenatal social support to prevent preterm birth. British Journal of Obstetrics and Gynaecology (1991) 98:1001-1008.
		1992	McLaughlin et al. (1992)	McLaughlin, F.J., Altemeier, W.A., Christensen, M.J., Sherrod, K.B., Dietrich, M.S., & Stern, D.T. (1992). Randomized trial of comprehensive prenatal care for low-income women: Effect on infant birth weight. Pediatrics, 89(1), 128-132.
		1993	Casiro et al. (1993)	Casiro, O.G., McKenzie, M.E., McFadyen, L., Shapiro, C., et al. (1993) Earlier discharge with community-based intervention for low birth weight infants: a randomized trial. Pediatrics, 92(1), 128-134;
		1993	Johnson et al (1993)	Johnson Z, Howell F, Molloy B. Community mother's programme: a randomized controlled trial of non-professional intervention in parenting. BMJ 1993;306:1449-52.
		1994	Marcenko and Spence (1994)	Marcenko MO, Spence M. Home visitation services for at-risk pregnant and postpartum women: a randomized trial. Am J7 Orthopsychiatny 1994; 64:468-78.

Table A.3 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	1995	Black et al. (1995)	Maureen M. Black, Howard Dubowitz, Jacqueline Hutcheson, Julie Berenson-Howard and Raymond H. Starr, Jr, A Randomized Clinical Trial of Home Intervention for Children With Failure to Thrive, Pediatrics, 1995;95;807, http://pediatrics.aappublications.org/content/95/6/807
		1997	Olds et al. (1997).	Olds, D.L., Eckenrode, J., Henderson, C.R., et al. (1997). Long-term effects of home visitation on maternal life course and child abuse and neglect: Fifteen-year follow-up of a randomized trial. JAMA, 278(8), 637-643.
		1997	Kitzman et al. (1997)	Kitzman, H., Olds, D.L., Henderson, Jr., C.R., Hanks, C., Cole, R., Tatelbaum, R., et al. (1997). Effects of prenatal and infancy home visitation by nurses on pregnancy outcomes, childhood injuries, and repeated childbearing: A randomized controlled trial. The Journal of the American Medical Association, 278, 644-652.
		1997	York et al. (1997)	York, R., Brown, L. P., Samuels, P., Finkler, S. A., Jacobsen, B., Persely, C. A., Swank, A. and Robbins, D. 1997: A randomized trial of early discharge and nurse specialist transitional follow-up care of high-risk childbearing women. Nursing Research 46, 254–61.
		1998	Schuster et al. (1998)	Mark A. Schuster, MD, PhD. David L. Wood, MD, MPH; Naihua Duan, PhD; Rebecca M. Mazel, MA; Cathy D. Sherbourne, PhD; and Neal Halfon, MD, MPHi, Utilization of Well-child Care Services for African-American Infants in a Low-income Community: Results of a Randomized, Controlled Case Management/Home Visitation Intervention, PEDIATRICS Vol. 101 No. 6 June 1998
		1998	Bolam et al. (1998)	Bolam, A., Manandhar, D.S., Shrestha, P., Ellis, M., & Costello, A.M. (1998). The effects of postnatal health education for mothers on infant care and family planning practices in Nepal: A randomized controlled trial. British Medical Journal, 316(7134), 805-811.
		1998	Robinson et al. (1998)	Robinson, M., Israel, C., Parker, D., Lawrence, E., Smith, J., Dolby, S., Ring, W., Russell, G., Briscoe, J., Berry, J., House, A., Sawyer, J., Fry, K., Mercier, C., Hobday, A., Emond, A., Ravenhill, D. and Marlow, N. 1998: Randomized trial of parental support for families with very preterm children. Archives of Disease in Childhood: Fetal and Neonatal Edition 79, F4–F11.
		1998	Olds et al. (1998)	David Olds, Charles Henderson, Jr., Harriet Kitzman, John Eckenrode, Robert Cole, Robert Tatelbaum, The Promise Of Home Visitation: Results Of Two Randomized Trials, Journal Of Community Psychology, Vol. 26, No. 1, 5–21 (1998)

Table A.3 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	1999	Raynor et al (1999)	Raynor, P., Rudolf, M.C.J., Cooper, K., et al. (1999) A randomized controlled trial of specialist health visitor intervention for failure to thrive. Arch Dis Child, 80, 500-506.
		1999	Korfmacher et al. (1999)	Korfmacher, J., O'Brien, R., Hiatt, S., & Olds, D. (1999) Differences in program implementation between nurses and paraprofessionals providing home visits during pregnancy and infancy: A randomized trial. American Journal of Public Health, 89(12), 1847-1851.
		1999	Armstrong et al. (1999)	A randomized, controlled trial of nurse home visiting to vulnerable families with newborns. Armstrong KL, Fraser JA, Dadds MR, Morris J. J Paediatr Child Health. 1999 Jun;35(3):237-44.
		2000	Lieu et al (2000)	Tracy A. Lieu, MD, MPH; Paula A. Braveman, MD, MPH; Gabriel J. Escobar, MD; Allen F. Fischer, MD; Nancy G. Jensvold, MPH; and Angela M. Capra, MA, A Randomized Comparison of Home and Clinic Follow-Up Visits After Early Postpartum Hospital Discharge, PEDIATRICS Vol. 105 No. 5 May 2000: 1058–1065
		2000	Kitzman et al. (2000)	Enduring effects of nurse home visitation on maternal life course: a 3-year follow-up of a randomized trial. Kitzman H, Olds DL, Sidora K, Henderson CR Jr, Hanks C, Cole R, Luckey DW, Bondy J, Cole K, Glazner J. JAMA. 2000 Apr 19; 283(15):1983-9.
		2000	Fraser et al. (2000)	Home visiting intervention for vulnerable families with newborns: follow-up results of a randomized controlled trial. Fraser JA, Armstrong KL, Morris JP, Dadds MR. Child Abuse Negl. 2000 Nov; 24(11):1399-429.
		2001	Escobar et al. (2001)	Escobar, G.J., Braveman, P.A., Ackerson, L., et al. (2001). A randomized comparison of home visits and hospital-based group follow-up visits after early postpartum discharge. Pediatrics, 108, 719-727
		2001	Brooten et al. (2001)	Brooten D, Youngblut JM, Brown L, Finkler SA, Neff DF, Madigan E., A randomized trial of nurse specialist home care for women with high-risk pregnancies: outcomes and costs. Am J Manag Care. 2001 Aug;7(8):793-803. Erratum in: Am J Manag Care 2001 Sep;7(9):855.
		2001	Constantino et al. (2001)	Constantino JN, Hasemi, N, Solis E, Alon T, Haley S, McClure S, Nordlicht N, Constantino MA, Elmen J, Carlson VK. Supplementation of urban home visitation with a series of group meetings for parents and infants: results of a "real world" randomized, controlled trial. Child Abuse and Neglect 2001; 25(12):1571-1581.

Table A.3 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	2002	Tsitoura et al. (2002).	Tsitoura, S., Nestoridou, K., Botis, P., et al. (2002). Randomized trial to prevent sensitization to mite allergens in toddlers and preschoolers by allergen reduction and education. Arch Pediatr Adolesc Med, 156, 1021-1027.
		2002	Olds et al. (2002)	Olds, D.L., Robinson, J., O'Brien, R., Luckey, D.W., et al. (2002) Home visiting by paraprofessionals and by nurses: A randomized, controlled trial. Pediatrics, 110(3), 486-496.
		2002	Olds (2002)	Olds, D.L. (2002) Prenatal and infancy home visiting by nurses: From randomized trials to community replication. Prevention Science, 3(3), 153-172.
		2002	Barnet et al. (2002).	Barnet, B., Duggan, A.K., Devoe, M., et al. (2002). The effect of volunteer home visitation for adolescent mothers on parenting and mental health outcomes: A randomized trial. Arch Pediatr Adolesc Med, 156, 1216-1222.
		2002	Gagnon et al (2002)	Gagnon AJ, Dougherty G, Jimenez V, Leduc N., Pediatrics. 2002 Jun; 109(6):1074-80. Randomized trial of postpartum care after hospital discharge.
		2002	Gielen et al. (2002)	Effects of improved access to safety counseling, products, and home visits on parents' safety practices: results of a randomized trial. Gielen AC, McDonald EM, Wilson ME, Hwang WT, Serwint JR, Andrews JS, Wang MC. Arch Pediatr Adolesc Med. 2002 Jan;156(1):33-40.
		2003	Gardner et al (2003)	Gardner, J.M., Walker, S.P. Powell, C.A. et al. (2003). A randomized controlled trial of a home-visiting intervention on cognition and behavior in term low birth weight infants. Journal of Pediatrics, 143, 634-639.
		2004	Duggan et al. (2004)	Duggan, A., McFarlane, E., Fuddy, L., Burrell, L, et al. (2004) Randomized trial of a statewide home visiting program: impact in preventing child abuse and neglect. Child Abuse & Neglect, 28, 597-622.
		2004	Duggan et al. (2004).	Duggan, A., Fuddy, L., Burrell, L., Higman, S.M., et al. (2004). Randomized trial of a statewide home visiting program: impact in reducing parental risk factors. Child Abuse & Neglect, 28, 623-643.
		2004	Olds et al. (2004)	Olds, D. L., Robinson, J., Pettitt, L., Luckey, D. W., Holmberg, J., Ng, R. K., et al. (2004). Effects of home visits by paraprofessionals and by nurses: Age 4 follow-up results of a randomized trial. Pediatrics, 114(6), 1560–1568.

Table A.3 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	2004	Anisfeld et al. (2004)	Anisfeld, E., Sandy, J. & Gutterman, N. (2004). Best beginnings: A randomized controlled trial of a paraprofessional home visiting program. Retrieved April 2007 from http://www.healthyfamiliesamerica.org/downloads/eval_NY_bb_2004.pdf
		2004	Boulvain et al. (2004)	Home-based versus hospital-based postnatal care: a randomised trial. Boulvain M, Perneger TV, Othenin-Girard V, Petrou S, Berner M, Irion O. BJOG. 2004 Aug;111(8):807-13.
		2005	Klinnert et al. (2005)	Klinnert, M.D., Liu, A.H., Pearson, M.R., et al. (2005). Short-term impact of a randomized multifaceted intervention for wheezing infants in low-income families. Arch Pediatr Adolesc Med, 159, 75-82.
		2005	Bonuck et al. (2005)	Karen A. Bonuck, Michelle Trombley, Katherine Freeman, and Diane McKee, MD‡,Randomized, Controlled Trial of a Prenatal and Postnatal Lactation Consultant Intervention on Duration and Intensity of Breastfeeding up to 12 Months
		2005	MacMillian et al. (2005)	MacMillian, H. L., Thomas, B., H., Jamieson, E., Walsh, C. A., Boyle, M. H., & Shannon, H. S. (2005). Effectiveness of home visitation by public-health nurses in prevention of the recurrence of child physical abuse and neglect: A randomized controlled trail. Lancet, 365, 1786-1793.
		2006	Barlow et al. (2006)	Barlow A, Varipatis-Baker E, Speakman K, Ginsburg G, Friberg I, Goklish N, Cowboy B, Fields P, Hastings R, Pan W, Reid R, Santosham M, Walkup J. Home-visiting intervention to improve child care among American Indian adolescent mothers: a randomized trial. ,Arch Pediatr Adolesc Med. 2006 Nov;160(11):1101-7.
		2006	Fergusson et al. (2006)	David M. Fergusson and others, “Randomized Trial of the Early Start Program of Home Visitation: Parent and Family Outcomes,” Pediatrics 117 (2006): 781–86.
		2007	Barlow et al. (2007)	Barlow, J., Davis, H., McIntosh, E., Jarrett, P., Mockford, C., & Stewart-Brown, S. (2007). Role of home visiting in improving parenting and health in families at risk of abuse and neglect: Results of a multicenter randomized controlled trial and economic evaluation. Archives of Disease in Childhood, 92, 229-233.
		2008	Doesum et al. (2008)	Karin T. M. van Doesum and others, “A Randomized Controlled Trial of Home-Visiting Intervention Aimed at Preventing Relationship Problems in Depressed Mothers and Their Infants,” Child Development 79 (2008): 547–61.

Table A.3 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Random Trial Studies	**Journals**	2008	DuMont et al. (2008)	Kimberly DuMont and others, "Healthy Families New York (HFNY) Randomized Trial: Effects on Early Child Abuse and Neglect," Child Abuse and Neglect 32 (2008): 295–315.
		2009	Lee et al. (2009)	Lee, Eunju, Susan D Mitchell-Herzfeld, Anna A Lowenfels, Rose Greene, Vajeera Dorabawila, and Kimberly A DuMonth. "Reducing Low Birth Weight through Home Visitation: A Randomized Controlled Trial." American Journal of Preventative Medicine, 2009: 154-160.
		2009	Walkup et al. (2009)	Walkup JT, Barlow A, Mullany BC, Pan W, Goklish N, Hasting R, Cowboy B, Fields P, Baker EV, Speakman K, Ginsburg G, Reid R. J, Randomized controlled trial of a paraprofessional-delivered in-home intervention for young reservation-based American Indian mothers. Am Acad Child Adolesc Psychiatry. 2009 Jun; 48(6):591-601.
		2010	Kitzman et al. (2010)	Kitzman HJ, Olds DL, Cole RE, Hanks CA, Anson EA, Arcoleo KJ, Luckey DW, Knudtson MD, Henderson CR Jr, Holmberg JR. Enduring effects of prenatal and infancy home visiting by nurses on children: follow-up of a randomized trial among children at age 12 years. Arch Pediatr Adolesc Med. 2010 May; 164(5):412-8.
		2011	Tandon et al. (2011)	Tandon, S. D., Mendelson, T., Kemp, K., Leis, J., Perry, D. (2011). Preventing perinatal depression in low-income home visiting clients: A randomized controlled trial. Journal of Consulting and Clinical Psychology, 79, 707-712
	Reports	1996	Center on Child Abuse Prevention Research (1996)	Center on Child Abuse Prevention Research, National Committee to Prevent Child Abuse (1996). Intensive home visitation: A randomized trial, follow up and risk assessment study of Hawaii's Healthy Start Program. Chicago IL: National Center on Child Abuse and Neglect.
		2003	Quinlivan et al. (2003)	Quinlivan, J. A., Box, H., & Evans, S. F. (2003). Postnatal home visits in teenage mothers: A randomized controlled trial. The Lancet, 361, 893-900.
	Books	1990	Gross (1990)	Gross, R. T. (1990). A multisite randomized intervention trial for premature, low birth weight infants: The Infant Health and Development Program. In D. E. Rogers & E. Ginsberg (Eds.), Improving the life chances of children at risk (pp. 146-160). San Francisco: Westview.
	Conference proceedings	1999	Gagnon et al. (1999)	Gagnon AJ, Dougherty GE, Jimenez V, Leduc N. A randomized trial of postpartum care following hospital discharge. In: Pediatric Academic Societies' 1999 Annual Meeting. San Francisco, CA: Lippincott Williams & Wilkins; 1999:102A

Table A.4 Taxonomy of Effect/ Impact of Home visitation studies

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	1976	Haus and Thompson (1976)	Haus, B.F., and Thompson, S. The effect of nursing intervention on a program of behavior modification by parents in the home. JPN and Mental Health Services (1976) 14:9-16.
		1980	Larson (1980)	Larson, C.P. Efficacy of prenatal and postpartum home visits on child health and development. Pediatrics (1980) 66:191-97.
		1980	Siegel et al. (1980)	Siegel E, Bauman KE, Schaefer ES, Saunders MM, Ingram D. Hospital and home support during infancy: impact on maternal attachment, child abuse and neglect and health care utilization. Pediatrics 1980; 66:183–90.
		1980	arson (1980)	Larson CP. Efficacy of prenatal and postpartum home visits on child health and development. Pediatrics 1980; 66:191–7.
		1982	Cappleman et al. (1982)	Cappleman, M. W., Thompson, R. J., DeRemer-Sullivan, P. A., King, A. A., & Sturm, J. M. (1982). Effectiveness of a home based early intervention program with infants of adolescent mothers. Child Psychiatry and Human Development, 13, 55-64.
		1982	Burkett (1982)	Burkett, C.W. (1982). Effects of frequency of home visits on achievement of preschool students in a home-based early childhood education program. Journal of Educational Research, 76(1), 41-44.
		1983	Barkauskas (1983)	Barkauskas, V. H. (1983). Effectiveness of public health nurse home visits to primiparous mothers and their infants. American Journal of Public Health, 73, 573-580.
		1984	Madden et al. (1984).	Madden J., O'Hara, H., & Levenstein, P. (1984). Home again: Effects of the Mother-Child Home Program on mother and child. Child Development, 55, 636-647.
		1985	Seitz et al.(1985)	Seitz, V., Rosenbaum, L.K., & Apfel, N.H. (1985). Effects of family support intervention: A ten year follow-up. Child Development, 56, 376 391.
		1985	ombs-Orme et al. (1985)	Combs-Orme T, Reis J, Ward LD. Effectiveness of home visits by public health nurses in maternal and child health: an empirical review. Public Health Rep 1985;100:490–9
		1985	Casto and White (1985)	Casto, G., & White, K. R. (1985). The efficacy of early intervention programs with environmentally at-risk infants. Journal of Children in Contemporary Society, 17, 37-50.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	1986	Casto and Mastropieri(1986)	Casto, G., & Mastropieri, M. (1986). The efficacy of early intervention programs: A meta-analysis. Exceptional Children, 52, 417-424.
		1988	Resnick et al (1988)	Resnick, M.B., Armstrong, S., and Carter, R.L. Developmental intervention program for high-risk premature infants: Effects on development and parent-infant interactions. Developmental and Behavior Pediatrics (1988) 9:73-78.
		1988	Stone et al. (1988)	Stone, W.L., Bendell, R.D., & Field, T.M. (1988). The impact of socioeconomic status on teenage mothers and children who received early intervention. Journal of Applied Developmental Psychology, 9, 391-408.
		1989	Leonard et al. (1989)	Leonard BJ, Scott SA, Sootsman J. A home-monitoring program for parents of premature infants: a comparative study of the psychological effects. Dev Behav Pediatr. 1989;10:92–97
		1989	Dawson et al. (1989)	Dawson, P., van Doominck, W.J., & Robinson, J.L. (1989). Effects of home-based, informed social support on child health. Developmental Behavioral Pediatrics, 10, 63-67.
		1990	Achenbach et al. (1990)	Achenbach, T. M., Phares, V., Howell, C. T., Rauh, V. A. and Nurcombe, B. 1990: Seven-year outcome of the Vermont Intervention Program for Low-Birthweight Infants. Child Development 61, 1672–81.
		1990	Dawson et al. (1990)	Dawson, P., Robinson, J.L., Butterfield, P.M., et al. Supporting new parents through home visits: Effects on mother-infant interaction. Topics in Early Childhood Special Education (1990) 10:29-44.
		1992	Brooks-Gunn et al. (1992)	*Brooks-Gunn, J., Liaw, F, & Klebanov, P. K. (1992). Effects of early intervention on cognitive function of low birth weight preterm infants. Journal of Pediatrics, 120, 350-359.
		1994	Campbell et al. (1994)	Campbell, Frances A., and Craig T. Ramey, "Effects of Early Intervention on Intellectual and Academic Achievement: A Follow-Up Study of Children from Low-Income Families," Child Development, Vol. 65(2, Spec. No.), 1994, pp. 684–689.
		1994	Black et al. (1994)	Black MM, Nair P, Kight C, Wachtel R, Roby P, Schler M. Parenting and early development among children of drug abusing mothers: effects of home intervention. Pediatrics 1994; 94:440-8.
		1994	Reynolds (1994)	Reynolds, Arthur J., "Effects of a Preschool Plus Follow-On Intervention for Children at Risk," Developmental Psychology, Vol. 30(6), 1994, pp. 787–804.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	1994	Bradley et al. (1994)	Robert H. Bradley and others, "Impact of the Infant Health and Development (IHDP) on the Home Environments of Infants Born Prematurely and with Low Birthweight," Journal of Educational Psychology 86 (1994): 531–41
		1995	Olds et al. (1995)	Olds, D.L., Henderson, C.R., Kitzman, H. & Cole, R. (1995). Effects of prenatal and infancy nurse home visitation on surveillance of child maltreatment. Pediatrics, 95, 365-372.
		1995	Gomby et al. (1995)	Gomby, D. S., M. B. Larner, C. S. Stevenson, et al., "Long-Term Outcomes of Early Childhood Programs: Analysis and Recommendations, "The Future of Children, Vol. 5, Winter 1995, pp. 6–24.
		1995	Oda et al. (1995)	Oda, D. S., Heilbron, D. C., & Taylor, H. J. (1995). A preventative child health program: The effect of telephone and home visits by public health nurses. American Journal of Public Health, 85, 54-85.
		1995	Olds et al. (1995)	Olds DL, Kitzman HJ, Cole RE. Effect of home visitation by nurses on caregiving and matemal life course. Arch Pediatr Adolesc Med 1995; 149:76.
		1995	Yoshikawa (1995)	Yoshikawa, H., "Long-Term Effects of Early Childhood Programs on Social Outcomes and Delinquency," The Future of Children, Vol. 5, Winter 1995, pp. 51–75.
		1996	Aronen and Kurkela (1996)	Aronen, E.T.K., S. A., Long-term effects of an early home-based intervention. Journal of the American Academy of Child & Adolescent Psychiatry, 1996. 35(12): p. 1665-72.
		1996	Riksen-Walraven et al. (1996)	*Riksen-Walraven, J., Meij, M., Th, J., & Hubbard, F. L. (1996). Intervention in lower-class Surinam-Dutch families: Effects on mothers and infants. International Journal of Behavioral Development, 19, 739-756.
		1996	Luster et al. (1996)	Luster, T., Perlstadt, H., McKinney, M., Sims, K., & Juang, L. (1996). The effects of a family support program and other factors on the home environments provided by adolescent mothers. Family Relations, 45, 255-264
		1997	Lisa et al (1997)	Lisa M. Pettitt, and Dennis Luckey, "Long-Term Effects of Home Visitation on Maternal Life Course and Child Abuse and Neglect: Fifteen-Year Follow-Up of a Randomized Trial," Journal of the American Medical Association, Vol. 278, No. 8, 1997, pp. 637–643.
		1997	McCarton et al. (1997)	McCarton, Cecelia M., Jeanne Brooks-Gunn, Ina F. Wallace, et al., "Results at Age 8 Years of Early Intervention for Low-Birth-Weight Premature Infants, The Infant Health and Development Program," Journal of the American Medical Association, Vol. 277(2), 1997, pp. 126–132.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	1997	Reynolds et al. (1997)	Reynolds, Arthur J., Emily Mann, Wendy Miedel, and Paul Smokowski, "The State of Early Childhood Intervention: Effectiveness, Myths and Realities, New Directions," Focus, Vol. 19(1), Summer/Fall 1997.
		1998	Olds et al. (1998).	Olds, D., Henderson, C.R., Cole, R., et al. (1998). Long-term effects of nurse home visitation on children's criminal and antisocial behavior: 15-year follow-up of a randomized controlled trial. JAMA, 280(14), 1238-1244.
		2000	Koniak-Griffin et al (2000)	Koniak-Griffin D, Anderson NL, Verzemnieks I, Brecht ML. ,A public health nursing early intervention program for adolescent mothers: outcomes from pregnancy through 6 weeks postpartum. Nurs Res. 2000 May-Jun; 49(3):130-8.
		2000	Schuler et al. (2000)	Schuler, M. E., Nair, P., & Black, M. M. (2000). Mother-infant interaction: Effects of a home intervention and ongoing maternal drug use. Journal of Clinical Child Psychology, 29, 424-431.
		2001	Kagitcibasi et al. (2001)	Kagitcibasi, C., Sunar, D., & Bekman, S. (2001). Long-term effects of early intervention: Turkish low-income mothers and children. Journal of Applied Developmental Psychology, 22, 333-361.
		2002	Bradley and Gilkey (2002)	Bradley, R.H., & Gilkey, B., (2002). The impact of the Home Instructional Program for Preschool Youngsters (HIPPY) on school performance in 3rd and 6th grades. Early Education and Development, 13(3), 302-311
		2002	MacArthur et al. (2002)	MacArthur C, Winter HR, and Bick DE, et al. Effects of redesigned community postnatal care on women's health 4 months after birth: A cluster randomized controlled trial. Lancet 2002; 359:378–385.
		2002	Garces et l. (2002)	Garces, Eliana, Duncan Thomas, and Janet Currie. 2002. "Longer-Term Effects of Head Start." The American Economic Review 92, no. 44: 999–1012.
		2003	Koniak-Griffin et al (2003)	Koniak-Griffin D, Verzemnieks IL, Anderson NL, Brecht ML, Lesser J, Kim S, Turner-Pluta C., (2003), Nurse visitation for adolescent mothers: two-year infant health and maternal outcomes. Nurs Res. 2003 Mar-Apr; 52(2):127-36.
		2004	Geerart et al. (2004)	Geerart, L., Van den Noortgate, W., Grietens, H., & Onghena, P. (2004). The effects of early prevention programs for families with young children at risk for physical child abuse and neglect: A meta-analysis. Child Maltreatment, 9(3), 277-291.
		2004	Olds et al. (2004)	Olds, D.L., Kitzman, H., Cole, R. et al. Effects of nurse home-visiting on maternal life course and child development: Age 6 follow-up results of a randomized trial. Pediatrics, 114, 1550-1559.(2004)

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	2004	Meara et al. (2004)	Ellen Meara, PhD*‡; Uma R. Kotagal, MBBS, MS§ ¶; Harry D. Atherton, BSEE, MS§; and Tracy A. Lieu, MD, MPH,Impact of Early Newborn Discharge Legislation and Early Follow-up Visits on Infant Outcomes in a State Medicaid Population
		2004	Zercher and Spiker(2004)	Zercher, C., and D. Spiker. "Home Visiting Programs and their Impact on Young Children." In Encyclopedia on Early Childhood Development. Centre of Excellence for Early Childhood Development, 2004.
		2004	Donelan-McCall and Olds (2004)	Nancy Donelan-McCall & David Olds, Prenatal/postnatal home visiting programs and their impact on the social and emotional development of young children (0–5) September 2012 (Rev. ed.), (Published online July 2004) (Revised September 2012) ,In Encyclopedia on Early Childhood Development
		2004	Gaylor and Spiker (2004)	Erika Gaylor & Donna Spiker, Home visiting programs and their impact on young children's school readiness, September 2012 (Rev. ed.),SRI International, Center for Education and Human Services, USA, (Published online August 2004) (Revised September 2012) In Encyclopedia on Early Childhood Development.
		2005	Bakermans-Kranenburg et al. (2005)	Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., & Bradley, R. H. (2005). Those who have, receive: The Matthew Effect in early childhood intervention in the home environment. Review of Educational Research, 75, 1-26.
		2005	Love (2005)	John M. Love and others, "The Effectiveness of Early Head Start for 3-Year-Old Children and Their Parents: Lessons for Policy and Programs," Developmental Psychology 41 (2005): 885–901.
		2006	Daro (2006)	Daro, D. "Prenatal/Postnatal Home Visiting Programs and their Impact on Young Children's Psychosocial Development (0-5): Commentary on Olds, Kitzman, Zercher and Spiker." In Encyclopedia on Early Childhood Development. 2006.
		2007	Olds et al. (2007)	David L. Olds, Harriet Kitzman, Carole Hanks, Robert Cole, Elizabeth Anson, Kimberly Sidora Arcoleo, Dennis W. Luckey, PhDe, Charles R. Henderson, Jrf, John Holmberg, PsyDa, Robin A. Tutt, BAa, Amanda J. Stevenson, BSe, Jessica Bondy, MHAe, Effects of Nurse Home Visiting on Maternal and Child Functioning: Age-9 Follow-up of a Randomized Trial
		2007	Barnet et al. (2007).	Barnet B, Liu J, DeVoe M, Alperovitz-Bichell K, Duggan AK., Home visiting for adolescent mothers: effects on parenting, maternal life course, and primary care linkage. Ann Fam Med. 2007 May-Jun; 5(3):224-32.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Impact Effect Studies	**Journals**	2007	Caldera et al. (2007)	Caldera D, Burrell L, Rodriguez K, Crowne SS, Rohde C, Duggan A. Impact of a statewide home visiting program on parenting and on child health and development. Child Abuse Negl. 2007 Aug; 31(8):829-52. Epub 2007 Sep 5.
		2007	Duggan et al. (2007)	Duggan, A., Caldera, D., Rodriguez, K., Burrell, L., Rohde, C., & Crowne, S. S. (2007). Impact of a statewide home visiting program to prevent child abuse. Child Abuse & Neglect, 31, 801-827.
		2007	Chazen-Cohen et al. (2007)	Rachel Chazen-Cohen and others, "It Takes Time: Impacts of Early Head Start That Lead to Reductions in Maternal Depression Two Years Later," Infant Mental Health Journal 28 (2007): 151–70.
		2009	Duggan et al (2009)	Duggan, A., Berlin, L., Cassidy, J., Burrell, L., & Tandon, S. (2009). Examining maternal depression and attachment insecurity as moderators of the impacts of home visiting for at-risk mothers and infants. Journal of Consulting Clinical Psychology, 77, 788-799.
		2010	Eckenrode et al. (2010)	Eckenrode, J., et al., Long-term effects of prenatal and infancy nurse home visitation on the life course of youths: 19-year follow-up of a randomized trial. Arch Pediatr Adolesc Med, 2010. 164(1): p. 9-15.
		2010	Beeber et al. (2010)	Beeber, L. S., Holditch-Davis, D., Perreira, K., Schwartz, T., Lewis, V., Blanchard, H., Canuso, R., & Goldman, B. D. (2010). Short-term in-home intervention reduces depressive symptoms in early head start Latina mothers of infants and toddlers. Research in Nursing & Health, 33, 60-76.
	Reports	1985	McKey et al. (1985)	McKey, Ruth Hubbell, Larry Condelli, Harriet Ganson, et al., The Impact of Head Start on Children, Families and Communities, Final Report of the Head Start Evaluation, Synthesis and Utilization Project, Washington, D.C.: U.S. Department of Health and Human Services, 85-31193, 1985.
		1987	Copple et al. (1987)	Copple, Carol E., Marvin G. Cline, and Allen N. Smith, Path to the Future: Long-Term Effects of Head Start in the Philadelphia School District, Washington, D.C.: U.S. Department of Health and Human Services, PS 017031, 1987.
		1988	Lally et al. (1988)	Lally, J. Ronald, Peter L. Mangione, and Alice S. Honig, "The Syracuse University Family Development Research Program: Long-Range Impact of an Early Intervention with Low-Income Children and Their Families," Parent Education as Early Childhood Intervention: Emerging Directions in Theory, Research and Practice, D. R. Powell and I. E. Sigel, eds., Norwood, N.J.: Ablex Publishing Corporation, 1988.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
	Reports	1990	U.S. General Accounting Office (1990)	U.S. General Accounting Office, Report to the Chairman, Subcommittee on Labor, health and Human Services, Education, and Related Agencies, Committee on Appropriations, U.S. Senate. Home visiting: A promising early intervention strategy for at-risk families. GAO/HRD-90-83. Washington, DC: U.S. Government Printing Office, July 1990. Available from the U.S. General Accounting Office, P.O. Box 6015, Gaithersburg, MD 20877.
		1993	Gomby et al. (1993)	Gomby, D.S., & Larson, C.S. (eds.) (1993). Home Visiting. The Future of Children, 3(3), 1-216.
		1997	Reynolds (1997)	Reynolds, Arthur J., The Chicago Child-Parent Centers: A Longitudinal Study of Extended Early Childhood Intervention, Discussion Paper No. 1126-97, Madison, Wisc.: Institute for Research on Poverty, 1997 (also available on the Web: http://www.ssc.wisc.edu/irp/).
		1999	Association of Maternal and Child Health Programs. (1999)	Association of Maternal and Child Health Programs. Fact Sheet Home Visiting: An effective strategy for improving the health of mothers and children. March 1999.
		2000	Wagner et al. (2000)	Wagner, M., Spiker, D., Gerlach-Downie, S., & Hernandez, F. (February 2000) Parental engagement in home visiting programs—findings from the Parents as Teachers multisite evaluation. Menlo Park, CA: SRI International.
		2000	Paulsell et al. (2000).	Paulsell, D., Kisker, E.E., Love, J.M., Raikes, H., et al. (December 2000). Leading the way: characteristics and early experiences of selected Early Head Start programs. Vol. III: Program implementation. Report prepared for The Commissioner's Office of Research and Evaluation and the Head Start Bureau, Administration on Children, Youth and Families, Department of Health and Human Services.
		2001	Layzer et al. (2001)	Layzer, J.I. Goodson, B.D., Bernstein, L., & Price, C. (April 2001) National evaluation of family support programs. Final Report Volume A: The meta-analysis. Cambridge, MA: Abt Associates, Inc p. A5-8
		2001	Johnson (2001)	Johnson, K.A. (May 2001). No place like home: State home visiting policies and programs. Johnson Group Consulting, Inc. Report commissioned by The Commonwealth Fund. Available at www.cmwf.org.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
	Reports	2001	Love et al. (2001)	Love, J.M., Kisker, E.E., Ross, C.M., Schochet, P.Z. et al. (June 2001) Building their futures: How Early Head Start programs are enhancing the lives of infants and toddlers in low-income families. Volume II: Technical Report, Appendixes. Prepared for Commissioner's Office of Research and Evaluation; Administration on Children, Youth and Families; U.S. Department of Health and Human Services, Washington, D.C. Available at http://www.acf.dhhs.gov/programs/core/ongoing_research/ehs/ehs_intro.html
		2001	Kay A. Johnson Johnson Group Consulting, Inc. (2001)	Johnson, K.A. (May 2001). No place like home: State home visiting policies and programs. Johnson Group Consulting, Inc. Report commissioned by The Commonwealth Fund. Available at www.cmwf.org.
		2002	Love et al. (2002)	Love, J.M., Kisker, E.E., Ross, C.M., Schochet, P.Z., et al. (June 2002). Making a difference in the lives of infants and toddlers and their families: The impacts of Early Head Start. Volume I: Final Technical Report. Department of Health and Human Services, Washington, DC. Available at http://www.acf.dhhs.gov/programs/core/ongoing_research/ehs/ehs_intro.html
		2002	Cornell (2002)	Cornell, Emily. The Benefits and Financing of Home Visiting Programs. Issue Brief, Washington, DC: NGA Center for Best Practices, 2002.
		2003	LeCroy & Milligan Associates, Inc. (2003).	LeCroy & Milligan Associates, Inc. (November 2003). Healthy Families Arizona Evaluation Report 2003. Prepared for the Arizona Department of Economic Security. Tucson, AZ: LeCroy & Milligan Associates, Inc.
		2004	Green et al. (2004)	Green, B.L., Mackin, J.R., Tarte, J.M., et al. (June 2004). Healthy Start: 2002-2003 Status Report. Prepared for Oregon Commission on Children and Families. Portland, OR: NPC Research. http://www.npcresearch.com/Files/Healthy%20Start%20Status%20Report%202002-2003%20FINAL.PDF
		2005	Coulton (2005).	Coulton, D. (May 2005). Cuyahoga County Early Childhood Initiative Evaluation: Phase II Final Report. Center on Urban Poverty and Social Change. http://povertycenter.cwru.edu/urban_poverty/dev/pdf/ECIExecsum_Final_Rev_0505.PDF
		2005	Williams, Stern & Associates (February 2005).	Williams, Stern & Associates (February 2005). Healthy Families Florida Evaluation Report. January 1, 1999-December 31, 2003. Miami, FL www.wsahealth.com.

Table A.4 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
		2006	Daro (2006)	Daro, D. (2006). Home visitation: Assessing progress, managing expectations. Ounce of Prevention Fund and Chapin Hall Center for Children. Retrieved April 2012 from http://www.buildinitiative.org/pdf/HomeVisitingFinalPDF.pdf
		2010	Child Trends (2010)	Child Trends. "Early Head Start: Research Findings." Washington, 2010.
		2010	Nurse-Family Partnership (2010)	Nurse-Family Partnership. Research Trials and Outcomes. Denver, October 2010, "What We Do." Nurse-Family Partnership. 2010. http://www.nursefamilypartnership.org/about/what-we-do (accessed March 7, 2011).
		2011	US Department of Health and Human Services (2011)	US Department of Health and Human Services "Healthy Families America: In Brief." Home Visiting Evidence of Effectiveness. 2011. http://homvee.acf.hhs.gov/document.aspx?sid=10&rid=1&mid=1 (accessed March 7, 2011).
		2011	Paulsell et al (2011)	Paulsell, D., Avellar, S., Sama Miller, E., & Del Grosso, P. (2011). Home Visiting Evidence of Effectiveness: Executive summary. Princeton, NJ: Mathematica Policy Research. http://homvee.acf.hhs.gov/HomVEE_ExecutiveSummary_Rev10-15-2011.pdf
		2011	Del Grosso et al. (2011)	Del Grosso, P., Kleinman, R., Esposito, A.M., Sama Martin, E., & Paulsell, D. (2011). Assessing the evidence of effectiveness of home visiting program models implemented in tribal communities. Office of Planning, Research and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services. Washington, DC.
	Dissertation /Thesis	1983	Pressman (1983)	Pressman, S. (1983). The effects of a home-based early intervention program on parents' self-confidence and children's development. Dissertation Abstracts International, 44, 07A. (University Microfilms No. AA 18325904).
		1983	Dennis (1983)	Dennis, B.P. (1983). Acceptance of preventive care regimens among sub-groups of low income mothers of infants: The effects of indigenous home visitors on immunization. Dissertation Abstracts International, 44, 04B. (University Microfilms No. AA18316682)
	Books	1982	Scarr (1982)	Scarr, S. On quantifying the intended effects of interventions: A proposed theory of the environment. In Facilitating infant and early childhood development. L. Bond and J. Joffe, eds. Hanover, NH: University Press of New England, 1982, pp. 466-84.
		1997	Wheeden et al. (1997)	Wheeden, C. A., Mahoney, G., Fewell, R., & Spiker, D. (1997, April). The effects of a comprehensive early intervention program on mother-child interaction with low-birth- weight, premature infants. Paper presented at the biennial meeting of the Society for Research on Child Development, Washington, DC.

Table A. 5 Taxonomy of Evaluation and Comparison Studies

Type of Study	Publication Type	year	Researcher(s)	Reference
Evaluation/ Comparison Studies	**Journals**	1966	Wolff (1966)	Wolff, Max, and Annie Stein, Study I: Six Months Later, A Comparison of Children Who Had Head Start, Summer 1965, with Their Classmates in Kindergarten, Washington, D.C.: Research and Evaluation Office, Project Head Start, Office of Economic Opportunity, 1966.
		1969	Cicirelli (1969)	Cicirelli, Victor G., The Impact of Head Start: An Evaluation of the Effects of Head Start on Children's Cognitive and Affective Development, Athens, Ohio, and New York: Ohio University, and Westinghouse Learning Corporation, 1969.
		1978	Bentler and Woodward (1978)	Bentler, P. M., and J. A. Woodward, "Head-Start Re-Evaluation—Positive Effects Are Not Yet Demonstrable," Evaluation Quarterly, Vol. 2(3), 1978, pp. 493–510.
		1980	Gray and Ruttle (1980).	Gray, S. W., & Ruttle, K. (1980). The family-oriented home visiting program: A longitudinal study. Genetic Psychology Monographs, 102, 299-316.
		1982	Stanwick et al. (1982)	Stanwick RS, Moffat ME, Robitaille Y, Edmond A, Dok C. An evaluation of the routine public health nurse home visit. Can J Public Health 1982; 73:200-5.
		1985	Craig et al. (1985)	Ramey, Craig T., Donna M. Bryant, Joseph J. Sparling, et al., "Project CARE: A Comparison of Two Early Intervention Strategies to Prevent Retarded Development," Topics in Early Childhood Special Education, Vol. 5(2), 1985, pp. 12–25.
		1987	Shonkoff and Hauser-Cram (1987)	Shonkoff, J.P., & Hauser-Cram, P. (1987). Early intervention for disabled infants and their families. A quantitative analysis. Pediatrics, 80, 650-658.
		1988	Rauh et al. (1988)	Rauh, V.A., Achenbach, T.M., Nurcombe, B., et al. (1988). Minimizing adverse effects of low birthweight: Four-year results of an early intervention program. Child Development, 59(3), 544-553.
		1988	Scarr and McCartney (1988)	Scarr, S., & McCartney, K. (1988). Far from home: An experimental evaluation of the Mother-Child Home Program in Bermuda. Child Development, 59, 531-543.
		1990	Olds and Kitzman (1990)	David L. Olds and Harriet Kitzman, Can Home Visitation Improve the Health of Women and Children at Environmental Risk? Pediatrics, 1990;86;108, http://pediatrics.aappublications.org/content/86/1/108

Table A.5 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Evaluation /Comparison Studies	**Journals**	1990	Lee et al. (1990)	Lee, V., J. Brooks-Gunn, E. Schnur, and F-R. Liaw (1990). 'Are Head Start Effects Sustained? A Longitudinal Follow-Up comparison of Disadvantaged Children Attending Head Start, No Preschool, and Other Preschool Programs'. Child Development, 61: 495-507.
		1990	Seitz (1990)	Seitz, Victoria, "Intervention Programs for Impoverished Children: A Comparison of Educational and Family Support Models," Annals of Child Development, Vol. 7, 1990, pp. 73–103.
		1993	Achenbach et al. (1993)	Achenbach, T. M., Howell, C. T., Aoki, M. F. and Rauh, V. A. 1993: Nine-year outcome of the Vermont Intervention Program for Low Birth Weight Infants. Pediatrics 91, 45–55.
		1994	Olds et al. (1994)	David L. Olds, PhD*; Charles R. Henderson, Jr4; and Harriet Kitzman, RN, PhDı, Does Prenatal and Infancy Nurse Home Visitation Have Enduring Effects on Qualities of Parental Caregiving and Child Health at 25 to 50 Months of Life?Pediatrics 1994; 93;89 No. 1 http://pediatrics.aappublications.org/content/93/1/89
		1994	Brooks-Gunn et al. (1994)	Brooks-Gunn, Jeanne, Cecelia M. McCarton, Patrick H. Casey, et al., "Early Intervention in Low-Birth-Weight Premature Infants, Results Through Age 5 Years from the Infant Health and Development Program," Journal of the American Medical Association, Vol. 272(16), 1994a, pp. 1257–1262.
		1994	Greenberg et al. (1994)	Greenberg RA, Strecher VJ, Bauman KE, Boat BW, Fowler MG, Keyes I1, et al. Evaluation of a home-based intervention program to reduce infant passive smoking and lower respiratory illness. J Behav Med 1994; 17: 273-90.
		1994	Ramey and Ramey (1994)	Ramey, Craig T., and S. L. Ramey, "Which Children Benefit the Most from Early Intervention?" Pediatrics, Vol. 6(2), Dec. 1994, pp. 1064–1066.
		1995	Currie and Thomas (1995)	Currie, Janet M., and Duncan Thomas, "Does Head Start Make a Difference?" The American Economic Review, Vol. 85(3), 1995, pp. 341–364.
		1996	Gelfand et al. (1996)	Gelfand, D. M., Teti, D. M., Seiner, S. A., & Jameson, P. B. (1996). Helping mothers fight depression: Evaluation of a home-based intervention program for depressed mothers and their infants. Journal of Clinical Child Psychology, 25, 406-422.
		1996	Seeley et al. (1996)	Seeley S, Murray L, Cooper PJ. The outcome for mothers and babies of health visitor intervention. Health Visit 1996; 69:135–8.

Table A.5 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Evaluation /Comparison Studies	**Journals**	1996	Marcenko et al. (1996)	Marcenko, M. O., Spence, M., & Samost, L. (1996). Out- comes of a home visitation trial for pregnant and post- partum women at-risk for child placement. Children and Youth Services Review, 18, 243-259.
		1996	Barnes-Boyd et al. (1996)	Barnes-Boyd, C.; Nacion, K. W.; Norr, K. F. 1996. Evaluation of an Interagency Home Visiting Program to Reduce Postneonatal Mortality in Disadvantaged Communities. Public Health Nursing 13(3): 201-208.
		1999	Gomby et al (1999)	Deanna S. Gomby Patti L. Culross Richard E. Behrman"Home Visiting: Recent Program Evaluations," The Future of Children, Vol. 9, No. 1, 1999.
		1999	Duggan et al. (1999)	Duggan, A.K., McFarlane, E.C., Windham, A.M., Rohde, C.A., et al. (1999), Evaluation of Hawaii's Healthy Start program. The Future of Children, 9(1), 66-90.
		2000	Duggan et al. (2000)	Duggan, A., Windham, A., McFarlane, E., Fuddy, L, et al. (2000) Hawaii's Healthy Start program of home visiting for at-risk families: Evaluation of family identification, family engagement, and service delivery. Pediatrics, 105(1), 250-259.
		2003	Galbraith et al. (2003)	Galbraith AA, Egerter SA, Marchi KS, Chavez G, Braveman PA. Newborn early discharge revisited: are California newborns receiving recommended postnatal services? Pediatrics. 2003;111:364–371
		2003	Norr et al. (2003)	Maternal and infant outcomes at one year for a nurse-health advocate home visiting program serving African Americans and Mexican Americans. Norr KF, Crittenden KS, Lehrer EL, Reyes O, Boyd CB, Nacion KW, Watanabe K. Public Health Nurs. 2003 May-Jun;20(3):190-203.
		2003	Nguyen et al. (2003)	Nguyen JD, Carson ML, Parris KM, Place P., A comparison pilot study of public health field nursing home visitation program interventions for pregnant Hispanic adolescents. Public Health Nurs. 2003 Sep-Oct; 20(5):412-8.
		2007	Krysik and Lecroy 2007	Krysik, J.; Lecroy C. W. 2007. The Evaluation of Healthy Families Arizona: A Multisite Home Visitation Program. Journal of Prevention and Intervention in the Community 34(1-2): 109-127.
		2009	Drotar et al. (2009)	Drotar, D., Robinson, J., Jeavons, L., & Lester Kirchner, H. (2009). A randomized, controlled evaluation of early intervention: The Born to Learn curriculum. Child: Care, Health & Development, 35(5), 643-649

Table A.5 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
Evaluation /Comparison Studies	**Journals**	2010	Whipple and Whyte (2010)	Ellen Elizabeth Whipple and John Douglass Whyte, Evaluation of a Healthy Families America (HFA) Programme: A Deeper Understanding, British Journal of Social Work (2010) 40, 407–425 doi:10.1093/bjsw/bcn177
	Reports	1974	Fellenz et al. (1974)	Fellenz, P., Cerva, T., Ernst, R., Ferraro, I., Haflinger, C., Nauta, M., Ruopp, R., et al. (1974, February). The National Home Start Evaluation. Interim Report IV: Program analysis. Cambridge, MA: Abt Associates.
		1974	Deloria et al. (1974)	Deloria, D., Love, J. M., Goedinghaus, L., Gordon, S., Hanvey, R., Hockman, E., et al. (1974, September). The National Home Start Evaluation. Interim Report IV: Summative evaluation results. Ypsilanti, MI: High/Scope Educational Research Foundation.
		1981	Craig and Campbell (1981)	Ramey, Craig T., and Frances A. Campbell, "Educational Intervention for Children at Risk for Mild Mental Retardation: A Longitudinal Analysis," Frontiers of Knowledge in Mental Retardation (Vol. I), P. Miller, ed., Baltimore, Md.: Baltimore University Park Press, 1981.
		1996	Max and Stein (1996)	Wolff, Max, and Annie Stein, Study I: Six Months Later, A Comparison of Children Who Had Head Start, Summer 1965, with Their Classmates in Kindergarten, Washington, D.C.: Research and Evaluation Office, Project Head Start, Office of Economic Opportunity, 1966.
		1999	Galano and Huntington (1999).	Galano, J., & Huntington, L. (1999). Year VI evaluation of the Hampton Virginia Healthy Families Partnership 1992-1998. Williamsburg, VA: The College of William & Mary. Unpublished manuscript.
		2000	Loman & Sherburne (2000)	Loman, L. A., & Sherburne, D. (2000). Intensive home visitation for mothers of drug-exposed infants: An evaluation of the St. Louis linkages program. St. Louis, MO: Institute of Applied Research.
		2001	Carnahan (2001)	Carnahan, S. (2001). Home visiting to prevent child maltreatment and support families: An evaluation of the Healthy Families Orange Program 1995-2000. Winter Park, FL: Rollins College Child Development Center. Unpublished manuscript.
		2005	Jacobs and Esterbrooks (2005)	Jacobs, S., & Easterbrooks, M. A. (2005). Healthy Familes Massachusetts final evaluation report. 2005; Retrieved from http://www.healthyfamiliesamerica.org/downloads/eval_hfm_tufts_2005.pdf.
		2005	Mitchell-Herzfeld et al. (2005)	Mitchell-Herzfeld, S., Izzo, C., Greene, R., Lee, E., & Lowenfels, A. (2005). Evaluation of Healthy Families New York (HFNY): First year program impacts. Albany, NY: Healthy Families New York.

Table A.5 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
	Dissertation /Thesis	1990	Graham (1990)	Graham, A.V. (1990). An evaluation of an intervention to reduce the incidence of low birthweight in an inner-city black population. Dissertation Abstracts International, 51, 03A. (University Microfilms No. AA19021369).
		1991	Murdock (1991)	Murdock, S.A. (1991). A program evaluation of the Welcome Baby Project: A primary prevention program for teenage mothers and their infants. Dissertation Abstracts International, 52, 101B.(University Microfilms No. AA19208328).
	Books	1988	Mitchell et al. (1988)	Mitchell, S. K., Magyary, D. L., Barnard, K. E., Sumner, G. A., & Booth, C. L. (1988). A comparison of home-based prevention programs for families of newborns. In L. A. Bond & B. M. Wagner (Eds.), Families in transition: Primary prevention programs that work. Primary prevention of psychopathology (Vol. 11, pp. 73-98). Beverly Hills, CA: Sage.
	Conference proceedings	2000	Windham et al. (2000)	Windham, A., Duggan, A.K., Rohde, C., Young, E., et al. 2000? Comprehensive evaluation of the Hawaii Healthy Start program: Effects on maternal mental health, substance use and social support at one year. 11th Annual Research Conference Proceedings.

Table A.6 Taxonomy of General Studies on Home Visitation

Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1970	Kames et al. (1970)	Kames, M.B., Teska, J.A., Hodgins, A.S., & Badger, I.D. (1970). Educational intervention at home by mothers of disadvantaged infants. Child Development, 41, 925 935.
		1975	Grantham-McGregor and Desai (1975)	Grantham-McGregor SM, Desai P. A home visiting intervention programme with Jamaican mothers and children. Devel Med Child Neurol 1975; 17:605–13.
		1976	Yanover et al. (1976)	Yanover MJ, Jones D, Miller MD. Perinatal care of low-risk mothers and infants. Early discharge with home care. N Engl J Med. 1976;294:702–705
		1980	Field et al. (1980)	Field, T.M., Widmayer, S.M., Stringer, S., and Ignatoff, E. Teenage, lower-class, black mothers and their preterm infants: An intervention and developmental follow-up. Child Development (1980) 51:426-36.
		1983	Currie et al. (1983)	Currie AL, Gehibach SH, Massion C, Thompson S. Newborn home visits. JFam PFact 1983; 17:635-8.
		1984	Halpern (1984)	Halpern R. Lack of effects for home-based intervention? Some possible explanations. Am J Orthopsychiatry. 1984;54:33-42
		1984	Haynes (1984)	Haynes, C.F., Cutler, C., Gray, J., & Kempe, R.S. (1984). Hospitalized cases of nonorganic failure to thrive: The scope of the problem and short-term lay health visitor intervention. Child Abuse & Neglect, 8(2), 229-242.
		1985	Coyner (1985)	Coyner A. Home visiting by public health nurses: a vanishing resource for families and children. Zero to Three. 1985;6:1-7
		1986	Rosen et al. (1986)	Rosen CL, Glaze DG, Frost JD Jr. Home monitor follow-up of persistent apnea and bradycardia in preterm infants. Am J Dis Child. 1986; 140:547–550
		1986	Barrera et al (1986)	Barrera, M.E., Rosenbaum, P.L., and Cunningham, C.E. Early home intervention with lowbirth-weight infants and their parents. Child Development (1986) 57:20-23.
		1987	Lamer and Halpern (1987)	Lamer M, Halpern R. Lay home visiting programs: strengths, tensions and challenges. Zero to Three. 1987;8:1-7
		1987	Resnick et al. (1987)	Resnick, M.B., Eyler, F.D., Nelson, R.M., et al. Developmental intervention for low weight infants: Improved early developmental outcome. Pediatrics (1987) 80:68-74.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1987	Hardy-Brown et al. (1987)	Hardy-Brown, K., Miller, B., Dean, J., et al. Home based intervention: Catalyst and challenge to the therapeutic relationship. Zero to Three (1987) 8, 1:8-12.
		1988	Beckwith (1988)	Beckwith L. Intervention with disadvantaged parents of sick pre-term infants. Psychiatry 1988; 51:242-7.
		1988	Osofsky et al. (1988)	Osofsky, J.D., Culp, A.M., and Ware, L.M. Intervention challenges with adolescent mothers and their infants. Psychiatry (1988) 51:236-41.
		1989	Chamberlin (1989)	Robert Chamberlin (1989), Home Visiting: A Necessary but not in Itself Sufficient Program Component for Promoting the Health and Development of Families and Children
		1989	Infante-Rivard et al. (1989)	Infante-Rivard C, Filion G, Baumgarten M, Bourassa M, Labelle J, Messier M. A public health home intervention among families of low socio-economic status. Child Health Care 1989;18:102–7
		1989	Powell and Grantham-McGregor (1989)	Powell, C., and Grantham-McGregor, S. Home visiting of varying frequency and child development. Pediatrics (1989) 84:157-64.
		1989	Holden et al. (1989)	Holden JM, Sagovsky R, Cox JL. Counselling in a general practice setting: Controlled study of health visitor intervention in treatment of postnatal depression. BMJ 1989; 298:223–226.
		1989	Kowal et al.(1989)	Kowal, L., Kottmeier, C. P., Ayoub, C. C., Komives, J. A., Robinson, D. S., & Allen, J. P. (1989). Characteristics of families at risk of problems in parenting: Findings from a home-based secondary prevention program. Child Welfare, 58, 529-538
		1990	Roberts and Wasik (1990)	Roberts RN, Wasik BH. Home visiting programs for families with children birth to three: Results of a national survey. Journal of Early Intervention 1990;14(3):274-284.
		1990	Barrera et al. (1990)	Barrera, M. E., Doucet, D. A., & Kitching, K. J. (1990). Early home intervention and socioemotional development of preterm infants. Infant Mental Health Journal, 1, 142-157.
		1992	Fetus and Newborn Committee,(1992)	Fetus and Newborn Committee, Canadian Paediatric Society. The infant home monitoring dilemma. Can Med Assoc J. 1992;147:1661–1669

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1992	Olds (1992)	Olds DL. Home visitation for pregnant women and parents of young children. Am J Dis Child. 1992;146:704–708
		1992	Ramey and Ramey (1992)	Ramey, C.T., and Ramey, S.L. Effective early intervention. Mental Retardation (1992) 30,5:1-9.
		1993	Wasik (1993)	Wasik, B.H. (1993) Staffing issues for home visiting programs. The Future of Children, 3(3), 140-157.
		1993	Kamerman and Kahn	Kamerman SB, Kahn AJ. Home health visiting in Europe. The Future of Children. 1993;33:39-52
		1993	Weiss (1993)	Weiss HB. Home visits: necessary but not sufficient. Future Child. 1993; 3:113–128
		1993	Feldman et al. (1993)	Effectiveness of home-based early intervention on the language development of children of mothers with mental retardation. Feldman MA, Sparks B, Case L. Res Dev Disabil. 1993 Sep-Oct;14(5):387-408.
		1993	McCormick et al. (1993)	McCormick, Marie C., Cecelia M. McCarton, C. Tonascia, and Jeanne Brooks-Gunn, "Early Educational Intervention for Very Low Birth Weight Infants: Results from the Infant Health and Development Program, Journal of Pediatrics, Vol. 123, 1993, pp. 527–533.
		1993	Powell (1993)	Douglas R. Powell, Inside Home Visiting Programs, The Future of Children Home Visiting Vol. 3, No. 3 – Winter 1993
		1993	Ramey and Ramey (1993)	Craig T. Ramey Sharon Landesman Ramey,Home Visiting Programs and the Health and Development of Young Children, The Future of Children HOME VISITING Vol. 3 • No. 3 – Winter 1993
		1995	Blair et al. (1995)	Blair, C., Craig T. Ramey, and J. Michael Hardin, "Early Intervention for Low Birthweight, Premature Infants: Participation and Intellectual Development," American Journal on Mental Retardation, Vol. 99(5), 1995, pp. 542–554.
		1995	Kang et al. (1995)	Preterm infant follow-up project: a multi-site field experiment of hospital and home intervention programs for mothers and preterm infants. Kang R, Barnard K, Hammond M, Oshio S, Spencer C, Thibodeaux B, Williams J. Public Health Nurs. 1995 Jun; 12(3):171-80.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1995	Frede (1995)	Frede, E.C. The role of program quality in producing early childhood program benefits. The Future of Children (Winter 1995) 5, 3:115–32.
		1996	Cooper et al. (1996)	William 0. Cooper, Uma R. Kotagal, Harry D. Atherton, Carrie A. Lippert, Elizabeth Bragg, RNı; Edward F. Donovan, and Paul H. Perlstein, Mdı, Use of Health Care Services by Inner-city Infants in an Early Discharge program, 1996
		1997	Olds et al (1997)	Olds, David, Harriet Kitzman, Robert Cole, and JoAnn Robinson, "Theoretical Foundations of a Program of Home Visitation for Pregnant Women and Parents of Young Children," Journal of Community Psychology, Vol. 25, No. 1, 1997, pp. 9–25.
		1997	Olds and Korfmacher (1997)	Olds, D., & Korfmacher, J. (1997). The evolution of a program of research on prenatal and early childhood home visitation: Special issue introduction. Journal of Community Psychology, 25, 1-7.
		1997	Burchinal et al. (1997)	Burchinal, M. R., Campbell, F. A., Bryant, D. M., Wasik, B. H., Ramey, C. T. (1997). Early intervention and mediating processes in cognitive performance of children of low-income African American families. Child Development, 68, 935-954.
		1997	Hutcheson et al. (1997)	Hutcheson, J.J., Black, M.M., Talley, M., Dubowitz, H., Howard, J.B., Starr, R.H.J., & Thompson, B.S. (1997). Risk status and home intervention among children with failure-to-thrive: Follow-up at age 4. Journal of Pediatric Psychology, 22(5), 651-668.
		1997	Logan (1997)	Logan, S. 1997. Home Visiting Reduces the Rates of Childhood Injuries. Child: Care, Health & Development 23(1): 101-102.
		1997	Olds and Korfmacher (1997)	Olds, D.L., and Korfmacher, J. Maternal psychological characteristics as influences on home visitation contact. Journal of Community Psychology (1997) 26:23–36.
		1998	Olds et al. (1998)	Olds, D.L., Pettitt, L.M., Robinson, J., Henderson, C. Jr., Eckenrode, J., Kitzman, H., et al. (1998b). Reducing risks for antisocial behavior with a program of prenatal and early childhood home visitation. Journal of Community Psychology, 26, 65-83.
		1998	Egerter et al. (1998)	Egerter SA, Braveman PA, Marchi KS. Follow-up of newborns and their mothers after early hospital discharge. Clin Perinatol. 1998;25:471–481

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1998	Korfmacher et al. (1998)	Korfmacher J, Kitzman H, Olds DL. Intervention processes as predictors of outcomes in a preventative home visitation program. Journal of Clinical Child & Adolescent Psychology 1998;26(1):49-64.
		1998	Cole et al. (1998)	Cole, R., Kitzman, H., Olds, D., & Sidora, K. (1998). Family context as a moderator of program effects in prenatal and early childhood home visitation. Journal of Community Psychology, 26, 37-48.
		1999	Shultz et al. (1999)	Shultz, B., Pawel, D., & Murphy, A. (1999) A retrospective examination of inhome educational visits to reduce childhood lead levels. Environmental Research, 80(4), 364-368.
		1999	Olds et al. (1999)	Olds, D.L., Henderson, C.R., Kitzman, H.J., Eckenrode, J.J, et al. (1999) Prenatal and infancy home visitation by nurses: Recent findings. The Future of Children, 9(1), 44-65.
		1999	Baker et al. (1999)	Baker, J.L., Piotrkowski, C.S., & Brooks-Gunn, J. (1999) The Home Instruction Program for Preschool Youngsters (HIPPY). The Future of Children, 9(1), 116-133.
		1999	Wagner and Clayton (1999)	Wagner, M.M., & Clayton, S.L. (1999) The Parents as Teachers program: results from two demonstrations. The Future of Children, 9(1), 91-115.
		1999	Early Head Start National Resource Center @ ZERO TO THREE (1999)	Early Head Start Home-Based Program Option Recruiting, Training, and Retaining Qualified Staff, Early Head Start National Resource Center @ ZERO TO THREE (1999)
		1999	Behrman (1999)	Behrman RE, ed. The Future of Children: Home visiting: Recent program evaluations 1999;9(1):4-223.
		1999	Ernst et al. (1999)	Ernst, C. C., Grant, T. M., Streissguth, A. P., & Sampson, P. D. (1999). Intervention with high-risk alcohol and drug-abusing mothers: II. Three-year findings from the Seattle model of paraprofessional advocacy. Journal of Community Psychology, 27(1), 19-38.
		1999	Gomby (1999)	Deanna S. Gomby,Understanding Evaluations of Home Visitation Programs, The Future of Children Home Visiting: Recent Program Evaluations Vol. 9 • No. 1 – Spring/Summer 1999

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	1999	Heinicke et al. (1999)	Heinicke, C. M., Fineman, N. R., Ruth, G., Recchia, S. L., Guthrie, D., & Rodning, C. (1999). Relationship-based intervention with at-risk mothers: Outcome in the first year of life. Infant Mental Health Journal, 20, 349-374
		1999	Packard Foundation (1999)	Packard Foundation. (1999). Home visiting: Recent program evaluations. Future of Children, 9, 4-223.
		1999	World Health Organization Technical Working Group. (1999)	World Health Organization Technical Working Group. Post-partum care of the mother and newborn: A practical guide. Birth 1999; 26:255–258.
		2000	MacMillan (2000)	MacMillan, H.L. with the Canadian Task Force on Preventive Health Care. (2000). Preventive health care, 2000 update: prevention of child maltreatment. CMAJ, 163(11); 1451-1458.
		2000	Olds et al. (2000)	Olds, D., et al. (2000). Update on home-visiting for pregnant women and parents of young children. Current Problems in Pediatrics. 30: 109-41.
		2000	Eckenrode et al. (2000)	Eckenrode, J., Ganzel, B., Henderson, C.R., Smith, E., et al. (2000). Preventing child abuse and neglect with a program of nurse home visitation: The limiting effects of domestic violence. Journal of the Medical Association, 284(11), 1385-1391.
		2000	Gomby (2000)	Gomby, D. S. (2000). Promise and limitations of home visitation. Journal of the American Medical Association, 284(11), 1430-1431.
		2000	Goodson et al. (2000)	Goodson, B.; Layzer, J.; St. Pierre, R.; Bernstein, L.; Lopez, M. 2000. Effectiveness of a Comprehensive, Five-year Family Support Program for Low-income Children and Their Families: Findings from the Comprehensive Child Development Program. Early Childhood Research Quarterly 15(1): 5-39.
		2001	King et al. (2001)	King, W.J., Klassen, T.P., LeBlanc, J., Bernard-Bonnin, A-C, et al. (2001). The effectiveness of a home visit to prevent childhood injury. Pediatrics, 108(2), 382-388.
		2001	Black et al. (2001)	Black, M.M., Siegel, E. H., Abel, Y.A., & Bentley, M.E. (2001) Home and videotape intervention delays complementary feeding among adolescent mothers. Pediatrics, 107(5). Available at http://www.pediatrics.org/cgi/content/full/107/5/e67

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	2001	Barnes-Boyd et al. (2001)	Barnes-Boyd, C., Norr, K., F., Nacion, K. W. (2001). Promoting infant health through home visiting by a nurse-managed community worker team. Public Health Nursing, 18, 225-235.
		2001	Roggman et al. (2001)	Roggman, L., Boyce, L., Cook, G., & Jump, V. (2001). Inside home visits: a collaborative look at process and quality. Early Childhood Research Quarterly, 16, 53-71.
		2001	Cowen(2001)	Cowen, P. S. (2001). Effectiveness of a parent education intervention for at-risk families. Journal of the Society of Pediatric Nursing, 6(2), 73-82.
		2001	Hammond-Ratzlaff and Fulton (2001)	Hammond-Ratzlaff, A., & Fulton, A. (2001). Knowledge gained by mothers enrolled in a home visitation program. Adolescence, 36(143), 435-442.
		2001	Spurway et al. (2001)	Gray, J., Spurway, P. and McClatchey, M. (2001) 'Lay therapy intervention with families at risk for parenting difficulties: The Kempe Community Caring Program', Child Abuse & Neglect, 25, pp. 641–55.
		2002	Brown et al. (2002).	Brown, J.V., Bakeman, R., Celano, M.P., et al. (2002). Home-based asthma education of young low-income children and their families. Journal of Pediatric Psychology, 27(8), 677-688.
		2002	Levenstein et al. (2002)	Levenstein, P., Levenstein, S., & Oliver, D. (2002). First grade school readiness of former child participants in a South Carolina replication of the Parent-Child Home Program. Applied Developmental Psychology, 23, 331-353.
		2003	Minkovitz et al. (2003)	Minkovitz, C.S., Hughart, N., Strobino, D., Scharfstein, D., et al. (2003). A practice based intervention to enhance quality of care in the first 3 years of life: The Healthy Steps for Young Children Program. JAMA, 290(23), 3081-3091.
		2003	McCurdy et al. (2003)	McCurdy, K., Gannon, R. A., & Daro, D. (2003). Participation patterns in home-based family support programs: Ethnic variations. Family Relations, 52, 3-11.
		2004	El-Kamary et al. (2004)	El-Kamary, S.S., Higman, S.M., Fuddy, L., McFarlane, E. et al. (2004). Hawaii's Healthy Start home visiting program: Determinants and impact of rapid repeat birth. Pediatrics, 114, 317-326.
		2004	Kitzman (2004)	Kitzman, H. "Effective Early Childhood Development Programs for Low-Income Families: Home Visitation Interventions During Pregnancy and Early Childhood." In Encyclopedia on Early Childhoon Development. 2004.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	2004	Culp et al. (2004)	Culp, A. M., Culp, R. E., Hechtner-Galvin, T., Howell, C. S., Saathoff-Wells, T., & Marr, P. (2004). First-time mothers in home visitation services utilizing child development specialists. Infant Mental Health Journal, 25, 1-15.
		2005	Moore et al. (2005)	Use of home visit and developmental clinic services by high risk Mexican-American and white non-Hispanic infants. Moore PD, Bay RC, Balcazar H, Coonrod DV, Brady J, Russ R., Matern Child Health J. 2005 Mar;9(1):35-47.
		2005	Lecroy and Whitetaker (2005)	Lecroy, C. W., & Whitaker, K. (2005). Improving the quality of home visitation: An exploratory study of difficult situations. Child Abuse & Neglect, 29, 1003-1013.
		2005	Tandon et al. (2005)	Tandon, S. D., Parillo, K. M, Jenkins, C. J., & Duggan, A. K. (2005). Home visitors' recognition of and response to malleable risk factors among low-income pregnant and parenting women. Maternal Child Health Journal, 9, 273-283.
		2005	De la Rosa, et al. (2005)	Iván A. de la Rosa, Joanne Perry, Lisa E. Dalton, Victoria Johnson, Strengthening Families With First-Born Children: Exploratory Story of the Outcomes of a Home Visiting Intervention, Research on Social Work Practice 2005 15: 323, DOI: 10.1177/1049731505277004
		2005	Tandon et al. (2005)	Tandon, S., D., Parillo, K., M., Jenkins, C. & Duggan, A. K. (2005). Formative evaluation of home visitors' role in addressing poor mental health, domestic violence, and substance abuse among low-income pregnant and parenting women. Maternal and Child Health Journal, 9(3), 273-283.
		2006	Ammerman et al. (2006)	Ammerman, R. T., Stevens, J., Putnam, F. W., Altaye, M., Hulsmann, J. E., & Lehmkuhl, H. D., et al. (2006). Predictors of early engagement in home visitation. Journal of Family Violence, 21(2), 105-115.
		2006	McCormick et al. (2006)	McCormick MC, Brooks-Gunn J, Buka SL, Goldman J, Yu J, Salganik M, Scott DT, Bennett FC, Kay LL, Bernbaum JC, Bauer CR, Martin C, Woods ER, Martin A, Casey PH., Early intervention in low birth weight premature infants: results at 18 years of age for the Infant Health and Development Program. Pediatrics. 2006 Mar;117 (3):771-80.
		2006	Raikes et al. (2006)	Raikes, H., Green, B. L., Atwater, J., Kisker, E., Constantine, J., & Chazan-Cohen, R. (2006). Involvement in Early Head Start home visiting services: Demographic predictors and relations to child and parent outcomes. Early Childhood Research Quarterly, 21, 2-24.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	2007	Donovan (2007)	Donovan, E. "Intensive Home Visiting Is Associated with Decreased Risk of Infant Death." Pediatrics, 2007: 1145-1151.
		2007	Black et al (2007)	Early intervention and recovery among children with failure to thrive: follow-up at age 8. Black MM, Dubowitz H, Krishnakumar A, Starr RH Jr. Pediatrics. 2007 Jul;120(1):59-69.
		2007	Korfmacher et al. (2007)	Korfmacher, J., Green, B., Spellmann, M., & Thornburg, K. R. (2007). The helping relationship and program participation in early childhood home visiting. Infant Mental Health Journal, 28, 459-480.
		2007	Ammerman et al. (2007)	Ammerman, R. T.; Putnam, F. W.; Kopke, J. E.; Gannon, T. A.; Short, J. A.; Van Ginkel, J. B.; Clark, M. J.; Carrozza, M. A.; Spector, A. R. 2007. Development and Implementation of a Quality Assurance Infrastructure in a Multisite Home Visitation Program in Ohio and Kentucky. Journal of Prevention & Intervention in the Community 34(1-2): 89-107.
		2007	Heaman (2007)	Heaman, M.; Chalmers, K.; Woodgate, R.; Brown, J. 2007. Relationship Work in an Early Childhood Home Visiting Program. Journal of Pediatric Nursing 22(4): 319-30.
		2007	Stevens et al. (2002)	Stevens, J., Ammerman, R. T., Putnam, F. G., & Van Ginkel, J. B. (2002). Depression and trauma history in first-time mothers receiving home visitation. Journal of Community Psychology, 30(5), 551-564.
		2008	Korfmacher et al. (2008)	Korfmacher, J., Green, B., Staerkel, F, Peterson, C., Cook, G., Roggman, L, Faldowski, R.A., & Schiffman, R. (2008). Parent involvement in early childhood home visiting. Child and Youth Care Forum, 37, 171-196.
		2009	Zielinski et al. (2009)	Zielinski DS, Eckenrode J, Olds DL., Nurse home visitation and the prevention of child maltreatment: impact on the timing of official reports. Dev Psychopathol. 2009 Spring;21(2):441-53.
		2009	Mills et al. (2009)	Mills RM, Siever JE, Hicks M, Badry D, Tough SC, Benzies K., Child guardianship in a Canadian home visitation program for women who use substances in the perinatal period. Can J Clin Pharmacol. 2009 Winter; 16(1):e126-39. Epub 2009 Jan 30.
		2009	Ammerman et al. (2009)	Ammerman, R. T., Putnam, F. W. , Altaye, M., Chen, L., Holleb, L., Stevens, J., Short, J., & Van Ginkel, J. B. (2009). Changes in depressive symptoms in first time mothers in home visitation. Child Abuse & Neglect, 33, 127-138.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV general information	**Journals**	2009	Howard and Brooks-Gunn (2009)	Howard, K.S. & Brooks-Gunn, J. (2009). The role of home-visiting programs in preventing child abuse and neglect. The Future of Children, 19, 119-146.
		2010	McFarlane et al. (2010)	McFarlane, E. C., Burrell, L., Fuddy, L., Tandon, D., Derauf, D. C., Leaf, P. and Duggan, A. (2010), Association of home visitors' and mothers' attachment style with family engagement. Journal of Community Psychology, 38: 541–556.
		2011	Lowell et al. (2011)	Lowell, D.I., Carter, A.S., Godoy, L., Paulicin, B., &Briggs-Gowan, M.J. (2011). Child FIRST: A comprehensive home-based intervention translating research into early childhood practice. Child Development, 82 (1), 193-208.
		2011	Ammerman et al. (2011)	Ammerman, R. T., Putnam, F. W., Stevens, J., Bosse, N. R., Short, J. A., Bodley, A. L., & Van Ginkel, J. B. (2011). An open trial of in-home CBT for depressed mothers in home visitation. Maternal and Child Health Journal, 15, 1333-1341.
		2012	Ammerman and Tandon (2012)	Robert T. Ammerman & S. Darius Tandon, Maternal mental health outcomes and children's mental health and home visiting, September 2012, In Encyclopedia on Early Childhood Development
		2012	Boller (2012)	Evidence for the role of home visiting in child maltreatment prevention Kimberly Boller September 2012, In Encyclopedia on Early Childhood Development
HV Investigative Studies		1972	McNeil and Holland (1972)	McNeil HJ, Holland S. A comparative study of public health nurse teaching in groups and in home visits. Am J Public Health 1972; 62:1629–36.
		1987	Waldenstrom (1987)	Waldenstrom U. Early discharge with domiciliary visits and hospital care: parents' experiences of two modes of post-partum care. Scand J Caring Sci. 1987;1:51–58
		1991	Jessop and Stein (1991)	Jessop, D.J., and Stein, R.E.K. Who benefits from a pediatric home care program? Pediatrics (1991) 88:497-505.
		1991	Serwint et al. (1991)	Serwint JR, Wilson MH, Duggan AK, et al. Do postpartum nursery visits by the primary care provider make a difference? Pediatrics 1991; 88:444–449.
		1992	Benasich et al (1992)	Benasich, April A., Jeanne Brooks-Gunn, and Beatriz Chu Clewell, "How Do Mothers Benefit from Early Intervention Programs?" Journal of Applied Developmental Psychology, Vol. 13, 1992, pp. 311–362.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV investigative studies	**Journals**	1995	Byrd (1995)	Byrd, M. E. 1995. The Home Visiting Process in the Contexts of the Voluntary vs. Required Visit: Examples from Fieldwork. Public Health Nursing 12(3): 196-202.
		1996	Braveman et al. (1996)	Braveman P, Miller C, Egerter S, et al. Health service use among low-risk newborns after early discharge with and without nurse home visiting. J Am Board Fam Pract. 1996;9:254–260
		1997	Baker and Roth	Baker, A.J.L., and Roth, J. Predictors of parent involvement in an early intervention program: Comparing sites, cohorts, and types of involvement. Applied Behavioral Science Review (1997) 5:199–217.
		1997	Institute for Research on Poverty (IRP)(1997)	Institute for Research on Poverty (IRP), "Do Intervention Programs for Young Children Reduce Delinquency and Crime?" Focus, Vol. 19(1), Summer/Fall 1997a.
		2001	Stevens-Simon et al. (2001)	Stevens-Simon, C., Nelligan, D., & Kelly, L. (2001). Adolescents at risk for mistreating their children Part II: A home- and clinic-based prevention program. Child Abuse & Neglect, 25(6), 753-769.
		2001	Aughinbaugh (2001)	Aughinbaugh, Alison, "Does Head Start Yield Long-Term Benefits?" Journal of Human Resources, Vol. 36, No. 4, Autumn 2001, pp. 641–665.
		2001	McCurdy (2001)	McCurdy, K. (2001). Can home visitation enhance maternal social support? American Journal of Community Psychology,29, 97-112.
		2002	Hebbeler and Gerlach-Downie (2002)	Hebbeler, K. M., & Gerlach-Downie, S. G. (2002). Inside the black box of home visiting: A qualitative analysis of why intended outcomes were not achieved. Early Childhood Research Quarterly, 17, 28-51.
		2002	Vogler et al. (2002)	Vogler, S. D., Davidson, A. J., Crane, L. A., Steiner, J. F., & Brown, J. M. (2002). Can paraprofessional home visitation enhance early intervention service delivery? Journal of Developmental and Behavioral Pediatrics, 23(4), 208-216.
		2003	McGuigan et al. (2003)	McGuigan, W. M., Katzev, A. R., & Pratt, C. C. (2003). Multi-level determinants of retention in a home-visiting child abuse prevention program. Child Abuse & Neglect, 27(4), 363–380.
		2004	Chaffin (2004)	Chaffin, M. (2004). Is it time to rethink Healthy Start/Healthy Families? Child Abuse & Neglect, 28, 589-595.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV investigative studies	**Journals**	2005	Carabin et al. (2005)	Hélène Carabin, Linda D. Cowan, Laura A. Beebe, Valerie J. Skaggs, David Thompson and Christophe Agbangla, Does participation in a nurse visitation programme reduce the frequency of adverse perinatal outcomes in first-time mothers? Paediatric and Perinatal EpidemiologyVolume 19, Issue 3, 27 APR 2005
		2008	Roggman et al. (2008)	Roggman, L. A., Cook, G. A., Peterson, C. A., & Raikes, H. H. (2008). Who drops out of Early Head Start home visiting programs? Early Education & Development, 19(4), 574-599.
HV best practices and strategies		1976	Kempe (1976)	Kempe CH. Approaches to preventing child abuse: the health visitors' concept. Am J Dis Child. 1976;130:130-141
		1976	Ryan (1976)	Ryan, T.J. (1976). Promoting child development through a program of home visiting. Canadian Journal of Behavioral Science, 8(1), 102-105
		1980	Chamberlin (1980)	Chamberlin (1980) American Academy of Pediatrics. Proceedings- of Conference Exploring the Use of Home Visitors to Improve the Delivery of Preventive Services to Mothers with Young Children. Washington, DC, 1980: Elk Grove Village. IL: American Academy of Pediatrics; 1980:272-274
		1980	Gray and Wandersman(1 980)	Gray, S.W., & Wandersman, L.P. (1980). The methodology of home-based intervention studies: Problems and promising strategies. Child Development, 51, 993 1009.
		1982	Thompson et al. (1982).	Thompson, R. J., Cappleman, M. W., Conrad, H. H., & Jordan, W. B. (1982). Early intervention program for adolescent mothers and their infants. Developmental and Behavioral Pediatrics, 3, 18-21.
		1984	Ross (1984)	Ross, G. S. (1984). Home intervention for premature infants of low-income families. Journal of Orthopsychiatry, 51, 236-241.
		1985	Barnett and Parker (1985)	Barnett, B., & Parker, G. (1985). Professional and non-professional intervention for highly anxious primiparous mothers. British Journal of Psychiatry, 146, 287-293.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV best practices and strategies	**Journals**	1986	Barrera and Rosenbaum (1986)	Barrera, M. E., & Rosenbaum, P. L. (1986). The transactional model of early home intervention. Infant Mental Health Journal, 7, 112-131.
		1986	Halpern (1986)	Halpern R. Home-based early intervention: dimensions of current practice. Child Welfare. 1986;65:387-398
		1986	Barrera et al. (1986)	Barrera, M. E., Cunningham, C. C., & Rosenbaum, P. L. (1986). Low birth weight and home intervention strategies: Preterm infants. Journal of Developmental and Behavioral Pediatrics, 7, 361 -366.
		1989	Hardy and Streett. (1989)	Hardy JB, Streett R. Family support and parenting education in the home: an effective extension of clinic-based preventive health care services for poor children. I Pediatr. 1989;1 15:927-931
		1989	Howing et al. (1989)	Howing, P., Wodarski, J., Gaudin, J., and Kurtz, P. Effective interventions to ameliorate the incidence of child maltreatment: Empirical base. Social Work (1989) 34,4:330–38.
		1992	Ramey et al. (1992)	Infant Health and Development Program for low birth weight, premature infants: program elements, family participation, and child intelligence. Ramey CT, Bryant DM, Wasik BH, Sparling JJ, Fendt KH, LaVange LM. Pediatrics. 1992 Mar;89(3):454-65
		1993	Gomby et al. (1993)	Gomby, D. S., Larson, C. S., Lewit, M. E., Behrman, R. E. (1993). Home visiting: analysis and recommendations. The Future of Children 3: 6-22.
		1993	Halpern (1993)	Robert Halpern,The Societal Context of Home Visiting and Related Services for Families in Poverty ,The Future of Children HOME VISITING Vol. 3 • No. 3 - Winter 1993
		1993	Slaughter-Defoe (1993)	Diana T. Slaughter-Defoe, Home Visiting with Families in Poverty: Introducing the Concept of Culture, The Future of Children HOME VISITING Vol. 3 ž No. 3 – Winter 1993
		1994	Casey et al. (1994)	Casey PH, Kelleher KJ, Bradley RH, Kellogg UTW, Kirby RS, Whiteside L. A multifaceted intervention for infants with failure to thrive. Arch Pediatr AdokscMed 1994;148:1071-7.
		1995	Shapiro (1995)	Shapiro C. Shortened hospital stays for low birth weight infants: nuts and bolts of a nursing intervention project. Journal of Obstetric, Gynaecologic and Neonatal Nursing 1995;24:56–63.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV best practices and strategies	**Journals**	1997	Hiatt et al. (1997)	Hiatt, S. W., Sampson, D. and Baird, D. (1997) 'Paraprofessional home visitation: Conceptual and pragmatic considerations', Journal of Community Psychology, 25(1), pp. 77–93.
		1998	Pratt et al. (1998)	Pratt L. K.; Margolis P. A.; Cohen L. R.; Runyan C. W. 1998. Home Visitors' Beliefs and Practices Regarding Childhood Injury Prevention. Public Health Nursing 15(1): 44-49.
		1998	Scott (1998)	Scott S. Intensive interventions to improve parenting. Arch Dis Child 1998;79:90–3.
		1998	Barnard (1998)	Barnard, K.E. Developing, implementing, and documenting interventions with parents and young children. Zero to Three (Feb/Mar 1998) 18(4):23-29.
		1998	AAP Council on Child and Adolescent Health –The American Academy of Pediatrics (1998)	AAP Council on Child and Adolescent Health –The American Academy of Pediatrics. The role of home visitation programs in improving health outcomes for children and families. Pediatrics, 1998; 101:486-489.
		1999	Guterman, N.B. (1999)	Guterman, N.B. (1999) Enrollment strategies in early home visitation to prevent physical child abuse and neglect and the "universal versus targeted" debate: A metaanalysis of population-based and screening-based programs. Child Abuse & Neglect, 23(9), 863-890.
		1999	Daro and Harding(1999)	Daro, D.A. & Harding, K.A. (1999) Healthy Families America: Using research to enhance practice. The Future of Children, 9(1), 152-176.
		1999	Johnson et al. (1999)	Johnson TS, Brennan RA, Flynn-Tymkow CD. A home visit program for breastfeeding education and support. J Obstet Gynecol Neonatal Nurs. 1999;28:480–485.
		1999	St.Pierre and Layzer (1999)	Robert G. St.Pierre, Jean I. Layzer, Using Home Visits for Multiple Purposes: The Comprehensive Child Development Program, The Future of Children, Home Visiting: Recent Program Evaluations, Vol.9 • No. 1 – Spring/Summer 1999

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV best practices and strategies	**Journals**	2001	Chalmers et al. (2001)	Chalmers B, Mangiaterra V, Porter R. WHO principles of perinatal care: The essential antenatal, perinatal, and postpartum care course. Birth 2001;28:202–207.
		2001	Klebanov et al. (2001)	Pamela Kato Klebanov, Jeanne Brooks-Gunn, and Marie C. McCormick, "Maternal Coping Strategies and Emotional Distress: Results of an Early Intervention Program for Low Birth Weight Young Children," Developmental Psychology 37 (2001): 654–67
		2002	Drummond et al. (2002)	Drummond, J. E., Weir, A. E., Kysela, G. M. (2002). Home visitation practice: Models, documentation, and evaluation. Public Health Nursing, 19(1), 21-29.
		2003	Wagner et al. (2003)	Wagner M, Spiker D, Linn M, Gerlach-Downie S, Hernandez F. Dimensions of parental engagement in home visiting programs: Exploratory study. Topics in Early Childhood Special Education 2003;23(4):171-183.
		2003	Daro et al. (2003)	Daro, D. A., McCurdy, K., Falconnier, L., & Stojanovic, D. (2003). Sustaining new parents in home visitation services: Key participant and program factors. Child Abuse & Neglect, 27, 1101–1125.
		2004	Galano et al. (2004)	Galano, J., Credle, W., Perry, D., Berg, S. W., Huntington, L., & Stief, E. (2004). Report from the Field: Developing and Sustaining a Successful Community Prevention Initiative: The Hampton Healthy Families Partnership. The Journal of Primary Prevention, 21(4), 495-509.
		2004	Grietens et al. (2004)	Grietens, H., Gerard, L. and Hellinckx, W. (2004) 'A scale for home visiting nurses to identify risks of physical abuse and neglect among mothers with newborn infants', Child Abuse & Neglect, 28, pp. 321–37.
		2006	Boris et al. (2006)	Boris, N. W.; Larrieu, J. A.; Zeanah, P. D.; Nagle, G. A.; Steier, A.; McNeill, A. The Process and Promise of Mental Health Augmentation of Nurse Home-visiting Programs: Data from the Louisiana Nurse-Family Partnership. Infant Mental Health Journal, 2006, 27(1): 26-40.
		2006	Olds (2006)	Olds, David L. 2006. "The Nurse-Family Partnership: An Evidence-Based Preventive Intervention." Infant Mental Health Journal 27, no. 1: 5–25.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV best practices and Strategies	**Journals**	2006	Brookes et al. (2006)	Brookes, S. J., Summers, J. A., Thornburg, K. R., Ispa, J. M., & Lane, V. J. (2006). Building successful home visitor-mother relationships and reaching program goals in two Early Head Start programs: A qualitative look at contributing factors. Early Childhood Research Quarterly, 21, 25-45.
		2007	Peterson et al. (2007)	Peterson, C. A., Luze, G. J., Eshbaugh, E. M., Jeon, H. J., & Kantz, K. R. (2007). Enhancing parent-child interactions through home visiting: Promising practice or unfulfilled promise? Journal of Early Intervention, 29, 199-140.
		2008	Kemp et al. (2008)	Kemp L, Harris E, McMahon C, Matthey S, Vimpani G, Anderson T, Schmied V, Miller Early Childhood Sustained Home-visiting (MECSH) trial: design, method and sample description. BMC Public Health. 2008 Dec 29;8:424.
		2008	Tandon et al. (2008)	Tandon, S. D., Mercer, C., Saylor, E., & Duggan, A. K. (2008). Paraprofessional home visitors' perceptions of addressing poor mental health, substance abuse, and domestic violence: A qualitative study. Early Childhood Research Quarterly, 23, 419-428.
		2009	de la Rosa et al. (2009)	de la Rosa, I. A., Perry, J., Johnson, V., & Rao, S. P. (2009). Benefits of Increased Home-Visitation Services: Exploring a Case Management Model. Family & Community Health, 32(1), 58-75.
		2010	Paulsell et al. (2010)	Paulsell, D., Boller, K, Hallgren, K., & Esposito, A. M. (2010). Assessing home visit quality: Dosage, content, and relationships. Zero To Three, 30, 16-21.
HV reports for policy makers		1982	Magidson and Soerbom (1982)	Magidson, Jay, and Dag Soerbom, "Adjusting for the Confounding Factors in Quasi-Experiments: Another Reanalysis of the Westinghouse Head Start Evaluation," Educational Evaluation and Policy Analysis, Vol. 4(3), 1982, pp. 321–329.
		1988	Wolfe and Edwards (1988)	Wolfe, D. A., & Edwards, B. (1988). Early intervention for parents at risk of child abuse and neglect: A preliminary investigation. Journal of Consulting and Clinical Psychology, 56, 40-47.
		1990	Powell (1990)	Powell, D.R. Home visiting in the early years: Policy and program design decisions.Young Children (1990)46:65-73.
		1993	Krugman (1993)	Richard D. Krugman, Universal Home Visiting: A Recommendation from the U.S. Advisory Board on Child Abuse and Neglect, The Future of Children HOME VISITING Vol. 3 No. 3 - Winter 1993

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV reports for policy makers	**Journals**	2005	Santos (2005)	Santos, R. "Voices from the Field-Research on Home Visiting: Implications for Early Childhood Development Policy and Practice across Canada." In Encyclopedia on Early Childhood Development. 2005.
		2012	Paulsell (2012)	Replicating and scaling up evidence-based home visiting programs: the role of implementation research, Diane Paulsell, September 2012, In Encyclopedia on Early Childhood Development,
HV future prospects		1983	Zigler and Berman (1983)	Zigler, E., and Berman, W. Discerning the future of early childhood intervention. American Psychologist (1983) 38,8:894-906.
		1984	Halpern(1984)	Halpern, R. (1984). Home-based early intervention: emerging purposes, intervention approaches and evaluation strategies. Infant Mental Health Journal 6:379.
		1997	Gutterman (1997)	Gutterman, N. B. (1997) 'Early prevention of physical child abuse and neglect: Existing evidence and future directions', Child Maltreatment, 2(1), pp. 12–34.
		2001	Guterman (2001)	Guterman, N.B. (2001) Stopping child maltreatment before it starts: Emerging horizons in early home visitation services. Thousand Oaks, CA: Sage Publications
		2001	Butz et al. (2001)	Butz, A.M., Pulsifer, M., Marano, N., et al. (2001). Effectiveness of a home intervention for perceived child behavioral problems and parenting stress in children with in utero drug exposure. Arch Pediatr Adolesc Med, 155, 1029- 1037.
		2002	Olds et al. (2002)	Olds, D.L., Hill, P.L., O'Brien, R., Racine, D. & Moritz, P. (2002). Taking preventive intervention to scale: The Nurse-Family Partnership. Cognitive and Behavioral Practice Special Issue (in press).
	Reports	1971	Forrester et al. (1971)	Forrester, B., Hardge, B., Brooks, G., Outlaw, D., & Boismier, J. (1971). Home visiting with mothers and infants. Nashville, TN: Peabody College, Demonstration and Research Center for Early Education.
		1983	Olds et al. (1983)	Olds, D.L., Henderson, C., Birmingham, M., & Chamberlin, R. (1983). Final report: Pre-natal~early infancy project. Prepared for the Maternal and Child Health and Crippled Children's Services Research Grants Program, Elmira, New York.
		1988	Olds and Kitzman (1988)	Olds, D.L., and Kitzman, H. Study of nurse home visiting for mothers and children. NIH No. R0lNR0l-69101Al. Bethesda, MD: National Center for Nursing Research, 1988

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Reports**	1988	Powell (1988)	Powell DR. A proposed typology for home visitor programs. Presented at the Family Resource Coalition National Conference, 1988; Chicago, IL
		1988	Alexander et al. (1988)	Alexander, N., Buckley, J., Dorris, D., et al. Study of the home-based option in Head Start. Final Report Vol. II. Report to Administration for Children, Youth and Families, U.S. Department of Health and Human Services. Hampton, NH: RMC Research Corporation, 1988.
		1989	National Commission to Prevent Infant Mortality, (1989)	National Commission to Prevent Infant Mortality. Home Visiting: Opening Doors for America's Pregnant Women and Children. Washington, DC: National Commission to Prevent Infant Mortality; 1989
		1990	van Doominck et al. (1990)	Van Doominck, W. J., Dawson, P., Butterfield, P. M., & Al- exander, H. L. (1990, March). Parent - infant support through lay health visitors. (Final report to Maternal and Child Health Service, Bureau of Community Health Services, U.S. Public Health Service, National Institutes of Health, Department of HEW. Grant MC-R-080398-03-0) Washington, DC: Department of Health and Human Services.
		1990	Houlares and Oden (1990)	Houlares, J., & Oden, S. 1990. A follow-up study of Head Start's role in the lives of children and families. Interim Report. (Ypsilanti, MI: High/Scope Educational Research Foundation, High/Scope Press, 600 N. River Street, Ypsilanti, MI 48197).
		1991	Klerman (1991)	Klerman, Lorraine V., Alive and Well? A Research and Policy Review of Health Programs for Poor Young Children, New York: National Center for Children in Poverty, Columbia University School of Public Health, 1991.
		1995	American Nurses Association.(1995)	American Nurses Association. Home care for mother, infant and family following birth; 1995. Available at: http://nursingworld.org/readroom/position/social/scnnat.htm
		1995	Olds (1995)	Olds, D. L. (1995a). Five-year follow-up of women and children enrolled in trial of prenatal and infancy nurse home visitation: Focus on maternal life course. Proposal to Smith Richardson Foundation. Denver, CO: University of Colorado Health Sciences Center.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Reports**	1996	Wagner et al. (1996)	Wagner, M., Cameto, R., and Gerlach-Downie, S. Intervention in support of adolescent parents and their children: A final report on the Teen Parents as Teachers Demonstration. Menlo Park, CA: SRI International, 1996.
		1998	Olds et al. (1998)	Olds, D., Hill, P., & Rumsey, E. (Nov 1998) Prenatal early childhood home visitation. OJJDP Office of Juvinile Justice and Deliquency Prevention Bulletin. https://www.ncjrs.gov/html/ojjdp/172875/contents.html
		1998	Carrilio (1998)	Carrilio, T. E. (1998). California Safe and Healthy Families Model Program: A family support home visiting model: Executive summary. San Diego, CA: Policy Institute, School of Social Work. Unpublished manuscript.
		1999	Kisker et al. (1999).	Kisker, E.E., Love, J.M., Raikes, H., Boller, K. et al. (December 1999). Leading the way: Characteristics and early experiences of selected Early Head Start programs. Volume I: Cross-site perspectives. Prepared for Administration on Children, Youth and Families, U.S. Department of Health and Human Services, Washington, D.C.
		2001	Rapoport and O'Brien-Strain (2001)	In-Home Visitation Programs: A Review of the Literature, Dana Rapoport with Margaret O'Brien-Strain, report to Orange County Children and Families Commission and Social Services Agency, April 2001. Available at www.sphereinstitute.org/.
		2002	Landsverk et al. (2002)	Landsverk, J., Carrilio, T., Connelly, C. D., Granger, W. C., Slymen, D. J., & Newton R. R. (2002). Healthy Families San Diego clinical trial: Technical report: San Diego, CA: San Diego Children's Hospital and Health Center.
		2002	Hobbler et al. (2002)	Hobbler, K. M. and Gerlach-Downie, S. (2002) 'Inside the black box of home visiting: A qualitative analysis of why intended outcomes were not achieved', Early Childhood Research Quarterly, 17, pp. 28–51.
		2003	Early Head Start Research and Evaluation Project. (2003)	Early Head Start Research and Evaluation Project. (December 2003) Research to practice: Early Head Start home-based services. Administration for Children and Families, U.S. Department of Health and Human Services. http://www.acf.hhs.gov/programs/opre/ehs/ehs_resrch/reports/homebase_services/homebase_services.pdf (Accessed 7/18/05)
		2003	Gomby (2003).	Gomby, D. (2003). Building school readiness through home visitation. For the First 5 California Children and Families Commission. Available at: http://www.ccfc.ca.gov/SchoolReady.htm.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Reports**	2006	Association of State and Territorial Health Officials (2006)	Association of State and Territorial Health Officials. Issue brief: bringing home better birth outcomes. 2006.www.astho.org/pubs/HomeVisitingBriefFinal.pdf.
		2006	Administration for Children and Families (2006)	Administration for Children and Families. Early Head Start Benefits Children and Families. April 2006.
		2006	ASTHO (2006)	ASTHO. Strides Among States to Improve Birth Outcomes: A Compendium of Program. 2005. Available at http://www.astho.org/pubs/MCH_BirthOutcomesCompendium_FINAL.pdf. Accessed 04/29/2006
		2006	Association of State and Territorial Health Officials, (2006)	2006 Association of State and Territorial Health Officials, Issue Brief: Home Visiting
		2007	Schuyler Center (2007)	Schuyler Center. Universal Prenatal/Postpartum Care and Home Visitation: The Plan for an Ideal System in New York State. Schuyler Center for Analysis and Advocacy (SCAA), 2007.
		2008	Zero to Three Policy Center (2008)	Zero to Three Policy Center. Supporting Parents and Child Development through Home Visiting. Washington, DC: Zero to Three, 2008.
		2009	Stoltzfus and Lynch (2009)	Stoltzfus, E., & Lynch, H. (2009). Home visitation for families with young children. Washington, DC: Congressional Research Service.
		2009	Astuto and Allen, (2009)	Jennifer Astuto and LaRue Allen, Home Visiting and Young Children: An Approach Worth Investing In? (Ann Arbor, MI: Society for Research in Child Development, 2009), http://www.srcd.org/.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Reports**	2010	Conrad N. Hilton Foundation (2010)	Conrad N. Hilton Foundation, Early Childhood Home Visiting Program, In partnership with The National Center on Family Homelessness, National Alliance to End Homelessness, and ZERO TO THREE: National Center for Infants, Toddlers and Families http://www.familyhomelessness.org/media/179.pdf
		2010	Cawthorne and Arons (2010)	Cawthorne, A., and J. Arons. There's no Place like Home: Home Visiting programs can support pregnant women and new parents. Center for American Progress, 2010.
		2010	Every Child Succeeds (2010)	Every Child Succeeds. "Every Child Succeeds 2010 Report Card." Cincinnati, 2010. "Home Visitation Programs." Every Child Succeeds. 2010. http://www.everychildsucceeds.org/Home-Visitation-Programs.aspx (accessed March 5, 2011).
		2010	West Virginia Department of Health and Human Resources (2010).	West Virginia Department of Health and Human Resources. "Right from the Start Program Policy and Procedures Manual." West Virginia Right from the Start. November 10, 2010. http://www.wvdhhr.org/rfts/manual/ (accessed March 29, 2011).
		2010	Coffee-Borden and Paulsell (2010)	Coffee-Borden, B., & Paulsell, D. (2010). Recruiting and training home visitors for evidence based home visiting: Experiences of EBHV grantees. Princeton, NJ: Mathematica Policy Research.
		2010	Paulsell et al. (2010)	Paulsell, D., Porter, T., Kirby, G., Boller, K., Sama Martin, E, Burwick, A., Ross, C., & Begnoche, C. (2010). Supporting quality in home-based child care: Initiative design and evaluation options. Princeton, NJ: Mathematica Policy Research
		2011	Avellar and Paulsell (2011)	Avellar, S. & Paulsell, D. (2011). Lessons learned from the home visiting evidence of effectiveness review. Princeton, NJ: Mathematica Policy Research.
		2011	Kilburn and Cannon (2011)	M. Rebecca Kilburn And Jill S. Cannon, Factors That Influence Successful Start-Up Of Home Visiting Sites: Lessons Learned From Replicating The First Born® Program, Working Paper, Rand Corporation, October 2011.
		2012	Star-Ledger Editorial board,(2012)	Star-Ledger Editorial board, "Home visitation program benefits babies in need of more care" http://blog.nj.com/njv_editorial_page/2012/06/home_visitation_program_benefi.html, tuesday, June 12, 2012, 6:00 AM

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Books**	1983	Clarke-Stewart and Fein (1983)	Clarke-Stewart, K.A., & Fein, G.G. (1983). Early childhood programs. In P.H. Mussen (Ed.), Handbook of child psychology (4th ed., Vol. 4, pp. 918-999). New York: Wiley.
		1983	Levenstein et al. (1983)	Levenstein, P., O'Hara, J., & Madden, J. (1983). The Mother-Child Home Program of the Verbal-Interaction Project. In Consortium of Longitudinal Studies (Ed.), As the twig is bent . . . Lasting effects of preschool programs. Hillsdale, NJ: Erlbaum.
		1985	Field (1985)	Field, T., Widmayer, S., Greenberg, R., & Stoller, S. (1985). Home and center-based intervention for teenage mothers and their offspring. In S. Harel & N. J. Anastasiow (Eds.), The at-risk infant: Psycho/social medical aspects. Baltimore: Brookes.
		1987	Shearer (1987)	Shearer, D.E. The Portage Project: A home approach to early education of young children with special needs. In Approaches to early childhood education. J. Roopnarine and J. Johnson, eds. Columbus, OH: Merrill, 1987, pp. 269-82.
		1988	Olds (1988)	Olds, D.L. Common design and methodological problems encountered in evaluating family support services: Illustrations from the Prenatal/Early Infancy Project. In Evaluating family programs. H.B. Weiss and F.H. Jacobs, eds. New York: Aldine de Gruyter, 1988.
		1988	Unger and Wandersman (1988)	Unger, D.G., and Wandersman, L. P. A support program for adolescent mothers: Predictors of participation. In Parent education as early childhood intervention: Emerging directions in theory, research, and practice. D.R. Powell, ed. Norwood, NJ: Ablex, 1988, pp. 105-30.
		1990	Brooks-Gunn(1990)	Brooks-Gunn, J. (1990b). Promoting healthy development in young children: What educational interventions work? In D.E. Rogers & E. Ginzberg (Eds.), Improving the life chances of children at risk (pp. 125 145). Boulder, CO: Westview Press.
		1990	Meisels and Shonkoff (1990)	Meisels, Samuel J., and Jack P. Shonkoff, eds., Handbook of Early Childhood Intervention, New York: Cambridge University Press, 1990.
		1990	Zigler (1990)	Zigler, Edward F., "Foreword," Handbook of Early Childhood Intervention, Samuel J. Meisels and Jack P. Shonkoff, eds., New York: Cambridge University Press, 1990.
		1990	Olds (1990)	Olds, D. L. (1990). The Prenatal/Early Infancy Project: A strategy for responding to the needs of high-risk moth- ers and their children. In R. P. Lorion (Ed.), Prevention in human services. 7: Protecting the children: Strategies for optimizing emotional and behavioral development (pp. 59-87). New York: Haworth.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Books**	1990	Olds (1990)	Olds, D.L. (1990). Can home visitation improve the health of women and children at risk? In D.L. Rogers & E. Ginsburg (Eds.), Improving the life chances of children at risk (pp. 79-103). Boulder, CO: Westview Press.
		1992	Larner et al. (1992)	Larner, M., Halpern, R., & Harkavy, O. (Eds.) 1992. Fair start for children: Lessons learned from seven demonstration projects. New Haven, CT: Yale University Press.
		1992	Arocena,et al. (1992)	Arocena, M., Adams, E. V., & David, P. F (1992). Ceden's Parent-Child Program: A fair start for Mexican-origin children in Texas. In M. Larner, R. Halpern, & O. Harkavy (Eds.), Fair start for children: Lessons learned from seven demonstration projects (pp. 68-90). New Haven, CT: Yale University Press.
		1993	Zigler and Styfco (1993)	Zigler, Edward F., and Sally J. Styfco, Head Start and Beyond: A National Plan for Extended Childhood Intervention, New Haven, Conn.: Yale University Press, 1993.
		1993	Arthor and Ayoub (1993)	Richmond, Arthur J., and Catherine C. Ayoub, "Evolution of Early Intervention Philosophy," Implementing Early Intervention: From Research to Effective Practice, Donna M. Bryant and Mimi A. Graham, eds., New York: The Guilford Press, 1993.
		1996	Klass and Klass (1996)	Home Visiting: Promoting Healthy Parent and Child Development by Carol Speekman Klass and Carol S. Klass (Sep 1996)
		1997	Guralnick (1997)	Guralnick, Michael J., ed., Effectiveness of Early Intervention, Baltimore, Md.: Paul Brookes Publishing, 1997.
		1997	Bromwich and Parmelee (1979)	Bromwich, R., & Parmelee, A. (1979). An intervention program for pre-term infants. In T. Field, A. Sostek, S. Goldberg, & H. Sherman (Eds.), Infants born at risk: Behavior and development (pp. 389-411). New York: S.P. Medical & Scientific Books.
		1997	Olds (1997)	Olds, D. (1997) The prenatal/early infancy project: Fifteen years later. In G. Albee and T. Gullotta (Eds.), Primary Prevention Works. Issues in Children's and Families' Lives, Volume 6. Thousand Oaks, CA: Sage.
		1997	Gross et al. (1997)	Gross RT, Spiker D, Haynes C. Helping low birth weight, premature babies: The Infant Health and Development Program. Stanford, Calif: Stanford University Press; 1997.
		1998	Cowan et al. (1998)	Cowan, P.A., Powell, D., & Cowan, C.P. (1998). Parenting interventions: A family systems perspective. In Sigel, I.E., & Renninger, K.A., (volume editors), Damon, W. (editor-in-chief), Handbook of child psychology. New York: John Wiley and Sons, p. 3-72.

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Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Books**	1999	Powers and Fenichel (1999)	Home Visiting: Reaching Babies and Families "Where They Live" by Stefanie Powers and Emily Fenichel (Jan 1, 1999)
		1999	Margie and Philips (1999)	Margie, N. G., & Phillips, D. A. (1999). Revisiting home visiting: Summary of a workshop. Washington, DC: National Academy Press.
		2000	National Research Council and Institute of Medicine (2000)	National Research Council and Institute of Medicine (2000) From neurons to neighborhoods: The science of early childhood development. Committee on Integrating the Science of Early Childhood Development. Jack P. Shonkoff and Deborah A. Phillips, eds. Board on Children, Youth, and Families, Commission on Behavioral and Social Sciences and Education. Washington, D.C.: National Academy Press.
		2000	Farran et al. (2000)	Farran, D.C., in J.P. Shonkoff & S.J. Meisels (Eds.) (2000). Another decade of intervention for children who are low income or disabled: What do we know now? Handbook of early childhood intervention. Cambridge, UK: Cambridge University Press, 510-548.
		2000	Wasik and Donna Bryant (2000)	Barbara Hanna Wasik and Donna M. Bryant (2000), Home Visiting: Procedures for Helping Families, SAGE Publications, Inc
		2000	Wasik Bryant (2000)	Wasik BH, Bryant DM. Home visiting: Procedures for helping families. 2nd Edition. Thousand Oaks, Calif: Sage Publications; 2000.
		2000	Halpern (2000)	Halpern R. Early childhood intervention for low-income children and families. In: Shonkoff JP Meisels SJ, eds. Handbook of early childhood intervention. 2nd Edition. New York, NY: Cambridge University Press; 2000:361-386.
		2000	Brooks-Gunn et al (2000)	Jeanne Brooks-Gunn, Lisa J. Berlin, and Allison Sidle Fuligni, “Early Childhood Intervention Programs: What about the Family?” in Handbook on Early Childhood Intervention, 2nd edition, edited by Shonkoff and Meisels (Cambridge University Press, 2000), pp. 549–88.
		2001	Kimura (2001)	Babies Can't Wait: Relationship-based home visiting by Linda Kimura (2001)
		2006	Barlow (2006)	Barlow, J. (2006). Home visiting for parents of pre-school children in the UK. In C. McAuley, P. J. Pecora, & W. Rose, Enhancing the well-being of children and families through effective interventions: International evidence for practice. London: Jessica Kingsley.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Books**	2007	Carrilio (2007)	Home-Visiting Strategies: A Case-Management Guide for Caregivers (Social Problems and Social Issues (Univ of South Carolina)) by Terry Eisenberg Carrilio (Jul 1, 2007)
		2008	Klass (2008)	The Home Visitor's Guidebook: Promoting Optimal Parent & Child Development 3rd Ed by Carol Speekman Klass (Jun 25, 2008)
		2008	Cook and Sparks (2008)	The Art and Practice of Home Visiting: Early Intervention for Children with Special Needs and Their Families by Ruth E. Cook and Shirley N. Sparks (Sep 12, 2008)
		2010	Olds (2010)	Olds, D. L. (2010). The nurse-family partnership: From trials to practice. In A. J. Reynolds, A. J. Rolnick, M. M. Englund, & J. A. Temple (Eds.) (2010). Childhood programs and practices in the first decade of life: human capital integration (pp.40-75). New York, NY: Cambridge University Press.
		2012	Supplee et al (2012)	Supplee, L., Paulsell, D., & Avellar, S. (2012). What works in home visiting programs? In Curtis, P.A., Alexander, G. eds. What Works in Child Welfare. Washington, DC: Child Welfare League of American Press, 39-61.
	Dissertation and Thesis	1998	Chambliss (1998)	Chambliss, J. W. (1998). An experimental trial of a home visiting program to prevent child maltreatment (Doctoral dissertation, Georgia State University, 1998). Dissertation Abstracts International, 61(03B), 152–1628.
		1998	Keim (1998)	Ann L Keim, Living in different worlds : the efficacy of an intensive home visitation program on increasing social support and improving parenting competency of first-time mothers, Thesis (Ph. D.)--University of Wisconsin--Madison, 1998. Dissertation Abstracts International, 60(1), 0388B.
		2000	Waliser (2000)	Navaie Waliser, M. (2000). An evaluation of the participants, impacts, and cost-effectiveness of the North Carolina Baby Love Maternal Outreach Worker Program. Dissertation Abstracts International, 60(7), 3239B.
	Conference proceedings	1996	Drazen and Haust (1996)	Drazen, S.M., & Haust, M. (August 12, 1996). Lasting academic gains from an early home visitation program. Paper presented at annual meeting of the American Psychological Association, Toronto, Ontario.

Table A.6 Continued

Type of Study	Publication Type	year	Researcher(s)	Reference
HV future prospects	**Conference proceedings**	1996	Olds et al. (1996)	Olds, David L., Reducing Risks for Childhood-Onset Conduct Disorder with Prenatal and Early Childhood Home Visitation, American Public Health Association Pre-Conference Workshop, New York, N.Y., 1996.
		1998	Heinecke and Ponce (1998)	Heinecke, C.M. & Ponce, V.A. (1998). Relation-based early family intervention. In Cichetti, D., & Toth, S.L. (Eds.). Rochester Symposium on Developmental Psycholpathology, Volume IX; Developmental Approaches to Prevention and Intervention. Rochester, NY: University of Rochester Press.
		2001	O'Brien et al. (2001)	O'Brien, R., Molritz, P., & McClatchey, M. (4/21/01). Replication of a model program of prenatal and infancy home visiting by nurses outside of research settings. Presentation at Society for Research on Child Development, Minneapolis, Minnesota.
		1984		Schloesser P, Barquest K. The Kansas Healthy Start/Home Visitor Program. Presented at the American Public Health Association meeting; 1984; Anaheim, CA
		1988		Leeper JD, Nagy C, Hullett S. The Rural Alabama Pregnancy and Infant Health (RAPIH) Program. Presented at the American Public Health Association meeting; 1988; Boston, MA
		2006		Roggman, L. A., Christiansen, K., Cook, G. A., Jump, V. K., Boyce, L. K., & Peterson, C. A. (2006) Home visits: Measuring how they work. Logan, UT: Early Intervention Research Institute Mini-Conference.

B. Home Visitation Program Models

Section B of the appendix contains 26 relevant infant HV program models. The tables show a comparison of their characteristics, monetary benefits, duration of the program, target populations, enrollment, graduation rates, eligibility criteria, intensity, aim and scope of the programs. The programs comprise 14 prenatal and postpartum HV programs for which visitations continues until child is 3years old (Table B. 1); and 12 programs for school going infants who are 3years old and up (Table B.2). The cost benefit comparison is based on the data and analysis presented by [206] [16] [61] and [63].

Table B. 1 HV Program from Prenatal and Postpartum to 3 Years

Duration	Infant Home visitation Programs	Benefits	Costs	Benefits Per Dollar of Cost (B/C Ratio)	Benefits Minus Costs	Author	Year Dollars
1	Children At Risk Program		$4,700			Aos et al (2001)	1995
1	Home visiting programs for at-risk mothers and children	$10969	$ 4892	2.24	6077	Aos et al (2004) and Karoly et al (2005)	2003
3	Comprehensive Child Development Program	-$9	$ 37388	0	-37397	Aos et al (2004)	2003
3	Infant Health and Development Program	$0	$ 49,021	0	-49021	Aos et al (2004)	2003
1	Systems of Care/Wraparound Programs*	$0	$ 1914	0	-(1914)	Aos et al (2004)	2003
1	Early Childhood Education for Disadvantaged Youth		$ 8,936		-(4754) - +6972 ‡	Aos et al (2001)	2000
3	Parents as Teachers (20yrs)	$4,992	$4,227	1.1809794	765	Lee et al. (2012)	2011
1.75	Early Head Start	$ 4768	$ 20972	0.23	-(16204)	Aos et al (2004)	2003
2	Early Head Start	$2,264	$10,420	0.2172745	(8,156)	Lee et al. (2012)	2011
1.2	Healthy Families America	$2,589	$4,601	0.5627038	(2,012)	Lee et al. (2012)	2011
1.18	Healthy Families America	$2052	$ 3314	0.62	-1262	Karoly et al (2005)	2003
2.5	NFP –overall sample (for Low Income Women)	$26298	$ 9118	2.88	17180	Aos et al (2004) and Karoly et al (2005)	2003
2	Nurse Family Partnership for Low-Income Families	$22,781	$9,600	2.3730208	13,181	Lee et al. (2012)	2011

(Sources: Aos et al. (2001, 2004), Karoly et al. (2005), Lee et. Al (2012))

Table B.1 Continued

Duration	Infant Home visitation Programs	Benefits	Costs	Benefits Per Dollar of Cost (B/C Ratio)	Benefits Minus Costs	Author	Year Dollars
1	Parent-Child Interaction Therapy	$ 4724	$ 1296	3.64	3428	Aos et al (2004)	2003
1	Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	$7,168	$1,551	4.6215345	5,617	Lee et al. (2012)	2011
2	Nurse Home Visitation (for low income single mothers)		$ 7,733		-(2067) - +15918 ‡	Aos et al (2001)	2000
1	Other home visiting programs for at-risk mothers and children	$5,138	$5,603	0.9170087	($465)	Lee et al. (2012)	2011
2.5	Nurse Home Visitation		$3,000			Aos et al (2001)	1997
1	Even Start	$0	$ 4863	0	-4863	Aos et al (2004)	2003
1	Even Start	($1,257)	$4,126	-0.304653	($5,383)	Lee et al. (2012)	2011
2	Elmira PEIP home-visit program for higher-risk families.		$3,246			Olds et al., 1993, p. 163	1980
2	Elmira Prenatal/Early Infancy Project - High risk group	$49,217	$7,109			Olds et al., 1993, Fine by nine, 2012	2002
2	Elmira Prenatal/Early Infancy Project - Lower risk group	$10,165	$7,109			Olds et al., 1993, Fine by nine, 2012	2002
2	Elmira PEIP home-visit program for lower-risk families.	$3775 β	$ 6083		-2308	Olds et al. (1994, 1997) and Olds (1996).,Karoly et al. (1998),	1996
2	Elmira PEIP home-visit program for higher-risk families.	$24694β	$ 6083		18611	Olds et al. (1994, 1997) and Olds (1996).,Karoly et al. (1998),	1996
2	NFP –Higher risk sample	$41419	$ 7271	5.7	34148	Karoly et al (2005)	2003
2	NFP—Lower risk sample	$9151	$ 7271	1.26	1880	Karoly et al (2005)	2003

(Sources: Aos et al. (2001, 2004), Karoly et al. (2005), Lee et. Al (2012))

Table B.2 HV Program Models for School Going Infants

Duration	Infant Home visitation Programs	Benefits	Costs	Benefits Per Dollar of Cost (B/C Ratio)	Benefits Minus Costs	Author	Year Dollars
	High/Scope Perry Preschool Project	253154	14830	17.07	238324	Karoly et al (2005)	2003
	Perry Preschool Program child age 3 to 4		$12,356			Barnett (1993), p. 504,	1992
1	Perry Preschool Program child age 3 to 4	25437	12148		13289	Olds et al. (1994, 1997) and Olds (1996).,Karoly et al. (1998),	1996
1	Perry Preschool Program child age 3 to 4	$138,486	$15,895			Schweinhart (1993), Fine by nine, 2012	2002
	Perry Preschool (excluding intangible crime costs)	$76,426	$14,830	5.15	$61,596	Karoly et al (2005)	2003
	Perry Preschool (Including intangible crime costs)	$129,622	$14,830	8.74	$114,792	Karoly et al (2005)	2003
1.5	Chicago Child-Parent Centers 3 yr old	$52,711	$7,428			Reynolds et al (2001), Fine by nine, 2012	2002
	Chicago Child-Parent Centers 3 yr old	$49,337	$6,913	7.14	$42,424	Karoly et al (2005)	2003
5	Abecedarian Early Childhood Intervention	$143,674	$35,864			Masse et al. (2002), Fine by nine, 2012	2002
	Abecedarian	$138,635	$42,871	3.23	$95,764	Karoly et al (2005)	2003
2	Parent Child Home Program 2-3yrs old	$3,920	$5,496	0.713246	($1,576)	Lee et al. (2012)	2011
2	Parent Child Home Program	0	3890	0	-3890	Aos et al (2004)	2003
	IHDP Infant Health and Development Program	$0	$49,021		($49,021)	Karoly et al (2005)	2003
	early childhood education ECE for low-income 3- 4 yrs	$15,742	$6,681	2.36	$9,061	Karoly et al (2005)	2003
1	Intensive Family Preservation Services (Homebuilders) 10yrs	$6,942	$3,288	2.1113139	$3,654	Lee et al. (2012)	2011
1	SafeCare (5yrs)	$1,501	$102	14.715686	$1,399	Lee et al. (2012)	2011

(Sources: Aos et al. (2004), Karoly et al. (1998, 2005), Barnett (1993), Olds (1994, 1996, 1997, Lee et al (2012), Schweinhart (1993), Reynolds et al (2001) and Masse et al. (2002))

Table B.2 Continued

Duration	Infant Home visitation Programs	Benefits	Costs	Benefits Per Dollar of Cost (B/C Ratio)	Benefits Minus Costs	Author	Year Dollars
1	Alternative Response (8yrs)	$852	$96	8.875	$756	Lee et al. (2012)	2011
1	Triple P Positive Parenting Program (System) 4yrs old	$865	$143	6.048951	$722	Lee et al. (2012)	2011
1	Other Family Preservation Services (non-Homebuilders)	($902)	$3,046	-0.296126	($3,948)	Lee et al. (2012)	2011
	HIPPY, Home Instruction Program for Preschool Youngsters 3-4yrs	3032	1681	1.8	1351	Karoly et al (2005)	2003
1	Family Preservation Services (excluding Washington)*	0	2531	0	-2531	Aos et al (2004)	2003

(Sources: Aos et al. (2004), Karoly et al. (1998, 2005), Barnett (1993), Olds (1994, 1996, 1997, Lee et al (2012), Schweinhart (1993), Reynolds et al (2001) and Masse et al. (2002))

C. Monetary Benefit Estimates of HV for Primary and Secondary Participant

Section C of the appendix shows a comparison of infant HV program's monetary benefit estimates related to crime (Table C.1), education (Table C.2), healthcare (Table C.3) and public assistance (Table C.4). Table C. 5 is a sum of all the benefits.

Table C.1 HVP's Monetary Benefit Estimates Related to Crime for Both Primary and Secondary Participant

Primary (A)/ Secondary (B) participant	A	A	A	A	B	
Infant Home visitation Programs	Crime	Child abuse and neglect	Property loss from illicit drug disorder	Property loss from alcohol disorder	Crime	Sum of Benefits
Comprehensive Child Development Program						0
Infant Health and Development Program						0
Systems of Care/Wraparound Programs*	0	$ -	$ -	$ -	$ -	0
Parents as Teachers (20yrs)	$ 643	$ 988	$ 1	N/A	N/A	1632
Early Head Start	$ 1	N/A	N/A	N/A	N/A	1
Healthy Families America	N/A	$ 335	$ (4)	$ 6	$ 115	452
Nurse Family Partnership for Low-Income Families	$ 4,049	$ 865	$ 1	N/A	$ 1,773	6688
Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	$ 1,532	$ 4,282	$ 3	N/A	N/A	5817
Other home visiting programs for at-risk mothers and children	N/A	$ 652	$ 1	N/A	$ 369	1022
Even Start						0
Triple P – Positive Parenting Program	171	$ 215				386

Source: Washington State Institute for Public Policy, http://www.wsipp.wa.gov, http://www.wsipp.wa.gov/ReportFile/1102/Wsipp_Return-on-Investment-Evidence-Based-Options-to-Improve-Statewide-Outcomes-April-2012-Update_Full-Report.pdf

Table C.2 HVP's Monetary Benefit Estimates Related to Education for Both Primary and Secondary Participant

Primary (A)/ Secondary (B) participant	A	A	A	A	B	B	
Infant Home visitation Programs	Earnings via high school graduation	Earnings via test scores	K-12 grade repetition	K-12 special education	Earnings via high school graduation	Earnings via extra year of education	Sum of Benefits
Comprehensive Child Development Program							0
Infant Health and Development Program							0
Systems of Care/Wraparound Programs*	0	$ -	0	$ -	$ -	$ -	0
Parents as Teachers (20yrs)	N/A	$ 3,283	N/A	$ 39	N/A	N/A	3322
Early Head Start	N/A	$ 585	$ 33	$ 393	N/A	$ 191	1202
Healthy Families America	N/A	$ 329	$ 3	$ 695	N/A	N/A	1027
Nurse Family Partnership for Low-Income Families	$ 64	$ 4,908	$ (162)	$ (1,573)	$ 11,453	N/A	14690
Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	$ 650	$ 355	N/A	$ 135	N/A	N/A	1140
Other home visiting programs for at-risk mothers and children	N/A	$ 3,651	N/A	$ 36	N/A	N/A	3687
Even Start		-1257					-1257
Triple P – Positive Parenting Program	77	$ 42		$ 14			133

Source: Washington State Institute for Public Policy, http://www.wsipp.wa.gov, http://www.wsipp.wa.gov/ReportFile/1102/Wsipp_Return-on-Investment-Evidence-Based-Options-to-Improve-Statewide-Outcomes-April-2012-Update_Full-Report.pdf

Table C.3 HVP's Monetary Benefit Estimates Related to Healthcare for Both Primary and Secondary Participant

Primary (A)/ Secondary (B) participant	A	A	A	A	A	A	A	A	A	B	
Infant Home visitation Programs	Health care costs for disruptive behavior symptoms	Health care costs via education	Earnings via alcohol disorder	Health care cost for alcohol disorder	Earnings via illicit drug disorder	Earnings via illicit drug disorder	Earnings via depressive disorder	Health care costs via depressive disorder	Health care costs for illicit drug disorder	Health care costs via education	Sum of Benefits
Comprehensive Child Development Program.											0
Infant Health and Development Program.											0
Systems of Care/Wraparound Programs*	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	0
Parents as Teachers (20yrs)	N/A	$ 12	N/A	$ 2	N/A	N/A	N/A	$ 21	$ 4	N/A	39
Early Head Start	$ 55	N/A	N/A	N/A	N/A	N/A	$ 125	$ 371	N/A	N/A	551
Healthy Families America	$ 80	N/A	$ 403	$ 43	$ (6)	N/A	$ 181	$ 251	$ (11)	N/A	941
Nurse Family Partnership for Low-Income Families	$ 166	$ 17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$ 649	832

Source: Washington State Institute for Public Policy, http://www.wsipp.wa.gov, http://www.wsipp.wa.gov/ReportFile/1102/Wsipp_Return-on-Investment-Evidence-Based-Options-to-Improve-Statewide-Outcomes-April-2012-Update_Full-Report.pdf

Table C.3 Continued

Primary (A)/ Secondary (B) participant	A	A	A	A	A	A	A	A	A	B	
Infant Home visitation Programs	Health care costs for disruptive behavior symptoms	Health care costs via education	Earnings via alcohol disorder	Health care cost for alcohol disorder	Earnings via illicit drug disorder	Earnings via illicit drug disorder	Earnings via depressive disorder	Health care costs via depressive disorder	Health care costs for illicit drug disorder	Health care costs via education	Sum of Benefits
Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	N/A	$ 44	$ 37	$ 6	$ 5	$ 12	$ 33	$ 74	N/A	N/A	211
Other home visiting programs for at-risk mothers and children	N/A	N/A	N/A	$ 2	N/A	N/A	$ 124	$ 228	$ 4	$ 13	371
Even Start											0
Triple P – Positive Parenting Program		$5	$4	$1	$1		$4	$9	$1		$25

Source: Washington State Institute for Public Policy, http://www.wsipp.wa.gov, http://www.wsipp.wa.gov/ReportFile/1102/Wsipp_Return-on-Investment-Evidence-Based-Options-to-Improve-Statewide-Outcomes-April-2012-Update_Full-Report.pdf

Table C.4 HVP's Monetary Benefit Estimates Related to Public Assistance for Both Primary and Secondary Participant

Primary (A)/ Secondary (B) participant	A	B	B	
Infant Home visitation Programs	Public Assistance	Public assistance	Out-of-home placement	Sum of Benefits
Comprehensive Child Development Program	-9			-9
Infant Health and Development Program				0
Systems of Care/Wraparound Programs*	$ -	$ -	$ -	0
Parents as Teachers (20yrs)	N/A	N/A	N/A	0
Early Head Start	$ 508	N/A	N/A	508
Healthy Families America	$ 169	N/A	N/A	169
Nurse Family Partnership for Low-Income Families	N/A	$ 572	N/A	572
Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	N/A	N/A	N/A	0
Other home visiting programs for at-risk mothers and children	N/A	N/A	$ 57	57
Even Start				0
Triple P – Positive Parenting Program			321	321

Source: Washington State Institute for Public Policy, http://www.wsipp.wa.gov, http://www.wsipp.wa.gov/ReportFile/1102/Wsipp_Return-on-Investment-Evidence-Based-Options-to-Improve-Statewide-Outcomes-April-2012-Update_Full-Report.pdf

Table C. 5 Total HVP's Monetary Benefit Estimates

Infant Home visitation Programs	Total
Comprehensive Child Development Program	$ (9.00)
Infant Health and Development Program	$ -
Systems of Care/Wraparound Programs*	$ -
Parents as Teachers (20yrs)	$ 4,993.00
Early Head Start	$ 2,262.00
Healthy Families America	$ 2,589.00
Nurse Family Partnership for Low-Income Families	$ 22,782.00
Parent Child Interaction Therapy (PCIT) for Families in the Child Welfare System	$ 7,168.00
Other home visiting programs for at-risk mothers and children	$ 5,137.00
Even Start	$ (1,257.00)
Triple P – Positive Parenting Program	$ 865.00

D. Questionnaire and Interview Questions

Below are the phone interview questions and email communication questions used to collect data and information from the NFP.

Questionnaire and Interview Questions

1. The NFP program is for a period of 2 years; however in the budget provided, the expenses are for a 3 year period. Is there a reason for this or what is the current duration of the program?
2. Are there any metrics or ways of evaluation for measuring the quality of services provided by the visiting nurses? If yes, what are they?
3. What is the maximum number of visits that a nurse can perform in one week averagely?
4. Historically, do you have an idea about the average Maximum visits per week or month that a nurse can perform with the case load of 25?
5. Historically, what is or has been the average maximum and minimum distances a nurse can travel for visits? – Thus, average minimum and maximum distances for nurse transportation are a very important variable in the mathematical formulation in order to set boundaries.
6. What makes up cost in the NFP program are?

Table D. 1 Components of NFP Program's Cost

Item	Nurse Home Visitor	Supervisor
Salaries		
Fringe Benefits		
Administration and Supervision		
Offices		
Supplies/Medical Supplies		
Travel/Transportation/Mileage		
National Service Office (NSO) Fees		
Hiring and Training cost		

   i. How much is allocated averagely to each of these cost items, in dollar amount or percentage? (With the known that NFP cost per family is averagely $8870).

7. Is the salary (grade) for every nurse hired for the NFP the same? For instance, is the salary for a nurse supervisor/registered nurse different from that of the home health nurse/visitor, etc?

8. Are nurses paid hourly or monthly and what is the average salary range for each category of nurse?
9. For the NFP, ideally each nurse is assigned a maximum of 25 families, does this have an impact on their salaries?, say does a nurse who takes on only 17 families instead of 25 gets a lower pay/salary than her colleague who takes on 25?.
10. What is the maximum number of visits that a nurse can perform in one week averagely?
11. What is the minimum number of visits that a nurse can perform in one week averagely?
12. Does the visit for each family cost the same considering the fact that each pregnant mother/mother is at different stages in her pregnancy in the NFP 2year horizon? Some may need more attention, time, supplies, etc. would this affect the cost to each family differently? (With the known that NFP cost per family is averagely $8870).
13. Do nurses receive compensation for travel mileage/transportation to visit families or this is part of their salaries?
14. What is the average cost of training nurses (Education)?
15. What constitute the NFP NSO Fees (service fees)? And how much is the cost averagely?

E. Sample Data Computation

Section E of the appendix shows sample data that was computed based on historical and survey data collected and used for the model's computation. Table E.1 shows a sample input data for 10 patients, Table E.2 shows a sample input data for 8 nurses, and Table E.3 shows a sample computed distance compatibility matrix.

Table E.1 Sample Patient Data

ID	Preg_WeekAtEnrollment	Enroll_Week_WallCalendar	Patient Zone	Patient Need
1	15	21	1	C
2	19	21	3	HD
3	13	17	2	ME
4	13	18	1	PA
5	14	15	3	C
6	23	30	3	HD
7	18	19	3	ME
8	18	29	1	PA
9	16	33	2	C
10	14	21	2	HD

Table E.2 Sample Nurse Data

ID	Hiring_Cost	Salary	Max_Visit	Nurse Skill	Nurse Type	Years (K) Of Nurse's Experience	Nurse Zone
1	8298	74791	12	C	CNA	4	2
2	8298	74791	12	HD	LPN	2	3
3	8298	74791	12	ME	NP	1	2
4	8298	74791	12	PA	RN	1	3
5	8298	74791	12	C	CNA	4	2
6	8298	74791	12	HD	LPN	1	3
7	8298	74791	12	ME	NP	4	1
8	8298	74791	12	PA	RN	4	2

Table E.3 Sample Computed Distance Compatibility Matrix

Travel distance compatibility matrix		Nurse							
		1	2	3	4	5	6	7	8
Patient ID	1	30	22	76	24	60	8	42	6
	2	68	46	68	54	28	30	20	36
	3	40	78	4	56	70	52	38	50
	4	52	6	52	80	80	68	26	24
	5	78	22	14	44	30	48	30	32
	6	16	50	64	14	64	42	52	18
	7	38	48	4	14	70	70	38	46
	8	74	24	30	36	58	50	76	18
	9	52	32	56	42	40	8	46	14
	10	4	16	24	54	76	38	62	54

VITA

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