A Group Model Building Process to Address the Rise in Cardiovascular Severe Maternal Morbidity in Black Women in North Texas

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ABSTRACT
The aim of this paper is to share the lessons learned from an ongoing System Dynamics Group Model Building (SD GMB) process, serving as the initial phase of a multi-year project focused on addressing cardiovascular severe maternal morbidity (CSMM) among non-Hispanic Black women (NHBW) in North Texas. CSMM is rising in high-income countries and has become the leading cause of maternal mortality, with NHBW bearing a disproportionate burden of CSMM impact. In this study we used System Dynamics Group Model Building (SD GMB) to identify and map key mechanisms underlying disproportionally high and increasing rates in CSMM prevalence among NHBW. SD GMB activities took place during an in-person workshop across one and a half days with thirteen community experts attending day one and eleven participants attending day two. The SD GMB workshop applied multiple systems thinking exercises to elicit hopes and concerns, key variables (5 R's), behavior-over-time graphs (BOTGs), and causal loop diagrams. Two causal loop diagrams were developed by two different groups to explain CSMM rates among NHBW in North Texas: One mainly focused on the mechanisms underlying healthcare availability, accessibility, quality, and affordability, while the other focused on neighborhood wealth and built environment factors relevant to CSMM.

INTRODUCTION
Non-Hispanic Black Women (NHBW) are three times more prone to die from a pregnancy-related cause than White counterparts, a disparity that has remained nearly unchanged for over a decade [1]. Furthermore, for every maternal death, there are 100 women who experience severe morbidity which means they receive a life-threatening diagnosis or undergo a lifesaving procedure during their delivery [2]. Severe maternal morbidity (SMM) imposes an enormous risk to well-being of women and their health during their lifetime. Similar to pregnancy-related mortality, women from racial and ethnic minority groups also experience elevated rates of severe maternal morbidity events [3, 4]. In fact, NHBW have the highest rates for 22 of 25 SMM utilized by the Center for Disease Control (CDC) in monitoring population estimates for severe maternal morbidity [3]. A subset of SMM, cardiovascular severe maternal morbidity (CSMM) stands as the primary contributor to maternal mortality in the U.S. and other high-income nations [5-7]. Due to the significant correlation between CSMM and

maternal mortality outcomes, as well as existing disparities, CSMM emerges as a crucial focal point for preventive endeavors aimed at reducing severe maternal morbidity and maternal mortality rates overall [7]. This is particularly critical for NHBW, who bear a disproportionate burden of CSMM.

As discussed in the literature, the racial disparities in CSMM are most effectively understood as dynamically complex systems, involving biologic, social, psychologic, historical, economic, political, and other forces that are interacting at multiple levels and may be nonlinear, adaptive, and changing over time [8, 9]. This complexity should be considered when formulating and executing policies aimed at addressing reproductive health outcomes. However, the majority of studies on the reproductive health system tend to concentrate on the linear cause-and-effect relationships of one or two risk factors of interest (variable isolation) and the health outcome at a time using analytical statistical techniques [8, 9]. As a result, despite established preventive measures to address CSMM, ongoing inequalities persist implying that current initiatives are inadequate in addressing health equity at the population-level [10]. Thus, alternative methods are required to reshape the pertinent knowledge base and foster advancements in prevention.

In particular, such alternative approaches to maternal health should be rooted in systems thinking and embrace a comprehensive understanding of the multilevel, interconnected, and dynamic nature of the systems responsible for generating maternal health outcomes and disparities [10]. Systems thinking, in essence, emphasizes viewing issues from a broader perspective, considering the interconnectedness of different factors, feedback loops, and dynamic behavior over time. It helps in identifying underlying patterns, structures, and dynamics within systems, which can lead to more effective interventions and solutions to complex problems. One such technique for analysis of complex systems is system dynamics modeling (SDM), a method used to study and understand complex systems by analyzing their causal structure, feedback mechanisms, and interconnections. SDM helps analyze how changes in one part of the system affect others over time, aiding in understanding and predicting system behavior.

System dynamics modeling (SDM) can exhibit significant effectiveness when coupled with participatory approaches, especially through the use of system dynamics group model building (SD GMB). SD GMB facilitates creation of a shared mental model and a shared understanding of the problem, in collaboration with community stakeholders. This can constitute a first step in developing policies that can curb CSMM [8]. Within the area of reproductive health, SD GMB has been effectively used in several studies [8, 9, 11]. However, a limited number of studies have described their implementation process and the insights obtained from such processes.

In this article, we share the lessons learned from the first workshop of an ongoing SD GMB approach that aims to identify and map key mechanisms underlying the disproportional increase in CSMM, as well as the relevant policy leverage points, among NHBW in North Texas. The workshop we describe here is ongoing, representing the first phase of a 5-year project grounded in SDM. Although outside the scope of this paper, we plan on describing the scientific outcomes of the SD GMB activities at a later date. However, by focusing on implementation, this study adds to the limited but expanding literature by investigating the potential of SD GMB in enhancing comprehension and tackling maternal health disparities.

METHODS

We implemented the first in-person workshop of an ongoing SD GMB activity in North Texas (the Dallas/Fort Worth metroplex [DFW]) in response to the significant and persistent racial disparities evident in various reproductive health outcomes within the state. It is also noteworthy that Texas holds the highest rate of uninsured reproductive-age women; furthermore, the state ranks last in the U.S. in terms of access to maternal and reproductive care services, as well as preventive healthcare access and affordability [12]. Additionally, part of the core team of investigators is situated in Texas and has access to an extensive existing network of community partners, facilitating the successful application of SD GMB in the realm of reproductive health. The initial workshop spanned one and a half days, during which participants were involved in a variety of individual and group activities. Their input was collected and documented throughout the sessions. The first day took place from 8:00 a.m.–4:00 p.m., and the second day took place from 8:00 a.m.–12:00 p.m., with several breaks across both days.

Participants

Building on the strong partnerships between project investigators and community partners, a group of stakeholders with complementary expertise were recruited from the DFW region for the group model-building workshops. The group included a mixture of Black women with lived experience in life-threatening pregnancy complications, Black healthcare providers and birth workers, leaders of Black-led organizations addressing cardiovascular health, faith leaders, researchers, and other subject-matter experts with knowledge of CSMM. We initially invited 30 people to participate in the first group model-building workshop, of which 16 people accepted the invitation: 13 people attended day one, and 11 people attended day two. Two participants represented the same organization. Of the people who attended the second day, two of them could not attend the first day of the workshop. One of the two participants on Day 2 had an organizational representative present on Day 1. The second individual was not able to

attend due to scheduling conflicts. To ensure fair access and participation, we offered to cover travel expenses, parking, meals, and childcare for participants attending the workshop. Additionally, a per diem stipend was offered to all participants attending the workshop. Some participants were familiar with one another before the workshop began. However, due to the diversity in organizations and community members, noted that some new connections formed after participants attended the workshop, as their roles and organizational objectives aligned. Before attending the workshop, participants were requested to complete a survey that collected demographic information, inquired whether they required any accommodations to attend the workshop, and included a validated measure to evaluate their understanding of systems thinking.

Orientation Session
A 30-minute orientation session was held virtually one week before the SD GMB workshop commenced. During the orientation session, participants were briefed on the project objectives and phases, the purpose and structure of the upcoming workshop, what they needed to anticipate, as well as logistical details including registration, parking arrangements, meals, compensation, and other relevant information, ensuring smooth coordination and minimizing potential disruptions. The overall goal of the orientation session was to set the stage for a successful SD GMB workshop by ensuring that participants are informed, prepared, and motivated to actively contribute to the process, as well as to alleviate any anxiety or uncertainty participants may have about the workshop by addressing their questions and concerns up-front.

Workshop Structure
The activities performed on day one of the SD GMB workshop are as below:
1. Participant Introductions: The first day of the SD GMB workshop started with participants introducing themselves, talking about their stake in the issue, why they chose to be present in the workshop, as well as mentioning the name of anyone they know that they liked to honor that day. This activity helped the participants and the core modeling team to get to know each other.
2. Sharing objectives of the project and the SD GMB workshop: The overarching objectives of the project, the key questions we aim to collaboratively address during the workshop (centered on CSMM among NHBW in North Texas), the various phases of the project, the expected outcomes, and the necessity for adopting a systems thinking approach to tackle the problem at hand were discussed.
3. Hopes and concerns: The participants were asked to share what they "hope" to emerge from the SD GMB workshop or from the project as a whole, as well as a "concern" they may have about the SD GMB or even about the project as a whole. Hopes and concerns provide valuable insights into stakeholders' aspirations and apprehensions, guiding the development of strategies and interventions.

4. Variable elicitation: The "5 R's" approach (United States Agency International Development, 2016) was then used to identify as many of the factors/forces that shape CSMM among Black Women in North Texas as possible. This approach was used as a lens to view maternal health disparities among NHBW across five key dimensions. More specifically, inputs were gathered concerning what defines success in terms of outcomes ("Results"); who influences, or is impacted by, changes in maternal health outcomes among NHBW ("Roles"); the significant relationships between these roles affecting or being affected by the outcomes ("Relationships"); the formal and informal regulations impacting the outcomes ("Rules"); and the resources available to enhance the outcomes ("Resources"). Additionally, for the Roles category, participants were asked to identify the power and interest of each item on a scale of 1 to 10. For each of these R's, the process began with a divergent activity, where participants individually listed and sorted the items they could identify. Subsequently, in a convergent activity, participants shared the items they identified with the group, which were then documented and grouped into thematic clusters.

5. Behavior-over-time graphs: Following the development of the "Results" category during the 5 R's activity, participants proceeded to select the Result they felt was most important to understanding the problem and created an illustration for each. These illustrations, known as "behavior-over-time graphs" (BOTG), depicted the historical changes in the selected outcomes over time, along with the causes underlying these changes. Additionally, participants identified the time horizon for the Result that they chose to graph and outlined the anticipated, expected, and concerning trends for that Result. These BOTGs will serve as reference modes during future development of the SD simulation model.

6. Developing the model boundary chart: In this step, the participants were asked to Identify the BOTG that they believed best represents the dynamic characterization of CSMM among Black women in North Texas. Moreover, they were asked to identify the two most important, as well as the least important, variables for each R in the 5 R's. Overall, development of model boundary chart helped define the scope of the model, focus attention on relevant aspects of the system, and align stakeholders about what to include in the model during subsequent workshop activities.

7. Developing the casual loop diagram (CLD):
To develop the Causal Loop Diagram (CLD), we followed three steps. Initially, we utilized a simple System Dynamics (SD) model that focused on population dynamics to illustrate key elements of CLDs, including variables, links, link polarities (positive or negative), delays, as well as reinforcing and balancing loops. In the second step, two simple loops pertinent to CSMM among NHBW in North Texas were collaboratively developed with all participants. This resulted in the creation of what we termed the "seed model." This step was instrumental in helping participants grasp the concept of CLDs and understand their applicability to the causes and consequences of CSMM.

Lastly, participants were divided into two groups, with each group tasked with expanding upon the seed model to develop their own ("small group") CLD. Information gathered from the 5 R's and BOTGs was utilized in this process to inform the development of the CLDs.

Day 2 of the workshop began with a review of the outcomes from the previous day. Participants were then divided into two groups, similar to the arrangement on the preceding day, and they continued developing their small group CLD from the previous day. At the end of day 2 of the workshop, each group shared their CLD with the other group. The workshop concluded with an evaluation survey to gather participants' feedback.

RESULTS:
A brief overview of key results obtained during the one and a half days workshop is provided below.

Hopes and Concerns: The participants articulated 14 Hopes during the discussion. Several clusters emerged from these expressed Hopes, including the aspiration to derive tangible benefits for the community through collaborative efforts, ensuring true change in impacted communities, advocating for an increase in preconception care and education, and fostering the learning and growth of participants. This growth was seen as instrumental in enabling participants to better serve their communities.

Moreover, the participants identified 15 Concerns. Among these concerns, clusters emerged regarding the potential complexity and impracticality of policy recommendations resulting from the collaborative efforts, which could lead to their dismissal by policymakers. There was also apprehension about the potential cessation of project funding, which could divert attention away from the project's objectives. Additionally, there was a concern that the project might exceed the anticipated timeframe, potentially delaying its intended impact.

Behavior-Over-Time Graphs: The participants developed eleven BOTGs to illustrate the dynamics of various factors over time. These graphs depicted crucial aspects such as the "number of NHBW maternal morbidity," revealing a concerning upward trend attributed to factors like the closure of maternal health clinics. Additionally, the potential impact of significant policy changes, such as the recent overthrowing of Roe vs. Wade, was highlighted, suggesting a further exacerbation of the issue. Another graph focused on "Access to health insurance," showcasing the positive effect of Medicaid expansion in improving access but also raising concerns about potential setbacks following recent policy changes. Furthermore, the "number of trained doulas" graph indicated a gradual

increase in recent years, reflecting efforts to address maternal health disparities. Similarly, the graph depicting "doulas' payments via insurance" showed a positive trend since the year 2000, although projections suggested a stabilization in the future.

5 R's: The 5 R's were discussed in the following order: Roles, Results, Rules, Relationships, and Resources. Some of the key Roles identified and ranked as particularly significant included "black birthing people" (with medium power and high interest in the problem), "policy makers" (with high power and an interest in the problem ranging from medium to high), "healthcare workers" (with medium power and high interest in the problem), and "hospital administrators" (with relatively high power and relatively high interest in the problem). In terms of Results, priority was given to "decreasing CSMM," "increasing patient satisfaction," and "enhancing awareness d levels regarding CSMM" which were ranked relatively high compared to other results listed. Among the Relationships identified, particular emphasis was placed on the "relationship between pregnant women and their support system" and the "relationship between healthcare providers and doulas," which were ranked higher. In terms of Rules, attention was drawn to the "lack of voice for Black women" and "insurance regulations," which were ranked higher. Lastly, among the Resources identified, "nonprofit organizations" and "family support" were deemed particularly significant and were ranked higher compared to other resources.

Causal Loop Diagrams: The two CLDs developed by the two teams exhibited minor overlap but overall complemented each other. Together, these CLDs offer insights into the complex interplay of factors influencing maternal health outcomes, highlighting the multifaceted nature of the problem and the need for comprehensive solutions addressing various determinants of health.

One small group's CLD primarily depicted feedback mechanisms underlying healthcare availability (the availability of necessary care for pre-, intra-, and post-partum care in the neighborhood), accessibility (transportation options for doctor visits and neighborhood safety), quality (the quality of care received), and affordability (patients' ability to afford care), which collectively influenced the quality and frequency of doctor visits before, during, and after pregnancy, consequently impacting the incidence of CSMM. Conversely, an increase in CSMM triggered the need for actions, potentially resulting in policies such as expanding Medicaid access to 12 months after delivery as well as the advocacy efforts such as raising awareness about CSMM and its consequences which influenced the health behavior.

The other small group's CLD centered around the notion that an increase in CSMM affects family wealth (through medical expenses and inability to work), subsequently

contributing to a reinforcing loop of declining neighborhood wealth, declining housing value, reduced community investment, and increased marginalization of neighborhoods, which in turn further reduced neighborhood wealth. The degree of neighborhood marginalization affects neighborhood characteristics (access to medical services, availability/access to transportation, food/physical activity deserts, and chronic stress) that contribute to the development of CSMM.

DISCUSSION
This section provides several insights that may be relevant to the effective implementation of SD GMB in similar contexts.

- **The introductory part of the workshop**: The orientation that occurred a week before the workshop was successful in preparing participants for what to expect and alleviate uncertainty. The workshop then commenced with participants introducing themselves and mentioning someone they wished to honor that day. Following this, the overall objectives of the project, the corresponding phases, and the expected outcomes were discussed. Next, they shared their hopes and concerns regarding the SD GMB or the project as a whole. These activities, coupled with the stories shared by participants, helped participants getting to know each other and the team of investigators. Moreover, it fostered a sense of comfort among attendees and the team of investigators. This laid a strong foundation for collaboration in subsequent workshop activities.

- **Reading the room and adapting the agenda accordingly:** The workshop started with a detailed agenda for the day and a parallel PowerPoint presentation that included team member responsibilities and time markers in the notes, ensuring thorough planning. Throughout the session, our team was attuned to the room's atmosphere, observing both verbal and non-verbal cues to gauge participants' sentiments accurately. This attentive approach, focusing on indicators like proximity, expressions, posture, and gestures, provided valuable insights into the group dynamics. With this enhanced understanding and our knowledge of stakeholders, we adjusted the timeline and agenda to align with the prevailing emotions and atmosphere effectively.

- **Utilizing a concise introductory SD model unrelated to the subject:** The classic illustration of population dynamics was utilized to impart fundamental principles of CLDs. This example offered the advantage of allowing participants to concentrate on grasping the "language" of CLD, rather than becoming perplexed by the mechanics of how a change in one variable related to CSMM affects another. Once the basics of CLDs were understood, two feedback loops pertinent to the problem context (CSMM) were collaboratively constructed with the entire audience. This approach fostered a learn-by-doing methodology, ensuring participants comprehended the process of

drawing and interpreting a CLD. Moreover, it facilitated the integration of this new language into their problem domain, particularly addressing the increase in CSMM prevalence. This step-by-step and cumulative approach was conducive for subsequent causal loop diagramming among the two small groups, judged by both the insights captured in the CLDs and the depth and quality of conversation that occurred during CLD development.

- **Participants in each group presented their CLD at the end**: Participants in each group were given the opportunity to present their CLD at the conclusion of the session. This presentation format allowed them to showcase and articulate the insights, connections, and dynamics captured within their respective models. By actively sharing their CLDs with the larger group, participants not only demonstrated their understanding and engagement with the material but also fostered a sense of ownership and pride in the collaborative effort of constructing the model within their own group. This presentation aspect served to validate their contributions and provided a platform for discussion and feedback from their peers, further enhancing their investment and commitment to the model-building process.

- **Community Engagement and Partnership:** The groundwork for this project was established three years ago with a one-day pilot project that was implemented in a virtual format. Since then, members of the project team have been able to communicate the nature of this work with community stakeholders. Three of the project team members had close community ties which enabled widespread recruitment of diverse stakeholders. In fact, several stakeholders indicated that their decision to participate hinged, to a great extent, on their personal or professional relationships with the project team members. The project team also includes a community investigator who has contributed to insights and strategies for engaging community stakeholders and also served as a voice for centering the community stakeholders and their needs in this project. The community investigator led both the opening and closing remarks which infused the event with a sense of guidance and moral perspective. This helped set a positive tone for the event, fostering a sense of unity among participants which led to their active engagement and involvement in the proceedings.

- **Student Training:** During the project, undergraduate student research assistants were integrated into the facilitation guide. Each student research assistant was given a role to help ensure the successful implementation of the project. For example, they helped with administrative logistics and paperwork, helped with the implementation of specific scripts, and in several cases co-presented information with the investigators. During team reflections it was revealed that students learned more about the issue of

CSMM and systems thinking and had the opportunity to informally network with the community stakeholders during lunch breaks.

- **Survey results:** A survey conducted at the conclusion of the workshop revealed that the SD GMB was highly successful as a vehicle to foster a high quality of engagement among community experts throughout the workshop, as well as to introduce key concepts in system dynamics modeling methods. All participants rated the overall quality of the GMB session as very good (89%) or good (11%). Additionally, group member participation was evaluated as very good (78%), good (17%), and poor (5%), indicating high levels of engagement. The responsiveness to questions posed by group members was also highly rated, with 89% ranking it as very good and 11% as good.

CONCLUSION

The SD GMB can facilitate the development of a comprehensive understanding of maternal health. Such understanding can lead to transformative changes in prevention strategies. The SD GMB also proved valuable in building community capacity, as demonstrated by the rapid increase in systems thinking mindset among participants. Furthermore, the participatory nature of SD GMB encouraged diverse perspectives and knowledge sharing, facilitating cross-disciplinary collaboration and collective problem-solving. As participants exchanged ideas and co-created models, they developed a shared language and framework for addressing complex issues, fostering a sense of cohesion within the community.

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