Operating Strategy for Semiconductor Industry During COVID 19: Pandemic Working Model

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Executive Summary
The impacts of the COVID-19 pandemic have been felt across various industries around the world, including the semiconductor industry. The semiconductor industry was boosted by pandemic restrictions as changing consumer habits—driven by the rise in remote work, distance learning, gaming, entertainment, and internet shopping—significantly increased demand for consumer electronic devices to the point that demand for semiconductors far outpaced production. Given the globality and complexity of the semiconductor supply chain, many companies are exploring ways to permanently change workplace collaboration for their employees. In this paper, the Hierarchical Decision Modeling (HDM) method is used to evaluate four possible pandemic semiconductor industry working models - Fully Remote, Hybrid, Fully Onsite & Satellite Workspaces. Experts from the industry evaluated the model to determine the most important criteria, sub-criteria and ultimately select the most desirable alternative. The results from the evaluation show that Hybrid option received the highest score. In this paper, we explore the motivation behind this study, the methodology behind the HDM model, the evaluation of the model, analysis and interpretation of the results, limitations of the study, scope for future research, and conclusions.

1. Introduction
The COVID-19 pandemic has turned into a global crisis, evolving at unprecedented speed and scale. It is creating a universal imperative for governments and organizations to take immediate action to protect their people. Its disruptive impacts are being felt in the near term and the full long-term impacts are still unknown. Companies are quickly needing to evaluate impacts on three fronts: supply chain, market demand and workforce:
   i) Global supply chains have disrupted as the virus spreads across the globe bringing uncertainty over quarantine durations.
   ii) Product demand is shifting across Application Specific Integrated Circuits (ASICs), memory, sensors, etc. while consumer behavior changes rapidly and with future volatility.
   iii) Workforce is affected by stay-at-home orders and the uncertainty of how long business as usual will be suspended for.

No industry is immune to the impacts of COVID-19, including the semiconductor industry. The semiconductor market became highly volatile during unprecedented demand and supply. While the semiconductor industry has achieved great successes in 2021, it also faces significant challenges. Chief among them is a widespread global semiconductor shortage. Unanticipated rising demand for semiconductors needed during the pandemic response, coupled with significant fluctuations in chip demand for other products such as cars, triggered a rippling supply-demand imbalance felt across the world. The semiconductor industry has worked diligently to increase production to address high demand, shipping more semiconductors on a monthly basis than ever before by the middle of 2021, but most industry analysts expect the shortage to linger into 2022. To achieve current goals, semiconductor companies are implementing novel strategies in manufacturing, supply chain and employee working culture.
2. Problem Statement

There is a clear need for alternative working arrangements to sustain manufacturing output during COVID-19 restrictions. Since essential employees are required to be onsite to sustain manufacturing demand, companies are exploring novel working models for employees in the non-manufacturing side. In this study, the HDM model will be applied to support the decision-making process in selecting the optimal working model.

3. Alternatives

The COVID-19 pandemic disrupted labor markets globally during 2020. The short-term consequences were sudden and often severe. Millions of people were furloughed or lost jobs, and others rapidly adjusted to working from home as offices closed.

There is no doubt that global working environments have been affected by the Pandemic. This has generated many new challenges that were met with creative working formats. We examined the myriad innovations in the work-format field, consulted a group of professional experts, and through their feedback shortened our list down to these final four alternatives for analysis:

i) Fully Remote: Employees work from home or anywhere else they like.
ii) Hybrid: Employees visit the office when they need to collaborate and work remotely rest of the time.
iii) Fully Onsite: Employees return to the office, i.e. as it was before the pandemic.
iv) Satellite Workspaces: Flexible workspaces within commuting distance for small groups of employees, like a “hub” system of offices.

Most will be familiar with the Fully Remote and Fully Onsite options. The Hybrid model is some mix of those two, usually with a few days in the office and a few days at home.

The Satellite Workspaces option is fairly new and was popularized with businesses such as WeWork and Spaces. A Satellite office is a branch of a company that is physically separate from the organization’s main office. This type of workspace can be located in a different country, thousands of miles away from the primary office, or on the other side of town. A satellite office can range in size from a single desk for an individual employee to a workspace housing hundreds of workers.

Satellite offices exist to solve a number of problems, and lately their usefulness has grown to accommodate trends around flexible working. They can create convenience for a company’s remote employees, help cut down on busy commutes, and reduce the number of workers in the main office at any one time. This type of office can also act as a base camp for expanding into and testing new markets, to provide improved customer services at a local level, or to strategically position a company to recruit the best talent from an industry hub.

Our consequent discussion and analysis will dissect these alternatives, outline their advantages and disadvantages, and offer our insights as to which format may be the best option for the present and in the future for the semiconductor industry. While each alternative has its own advantages and disadvantages, the HDM model has been employed to provide a holistic evaluation.
The summary of the advantages and disadvantages of each alternative is summarized in Table 1 below. Each alternative is contrasted against the others on the basis of Collaboration, Commute, Talent Recruitment, Employee Location and Virus Infection Risk.

<table>
<thead>
<tr>
<th>Fully Remote</th>
<th>Hybrid</th>
<th>Fully Onsite</th>
<th>Satellite Workspaces</th>
</tr>
</thead>
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<tr>
<td>Collaboration is big challenge, need additional infrastructure for communication</td>
<td>Collaboration is a challenge, better than Fully remote.</td>
<td>Better collaboration with team</td>
<td>Collaboration is challenge, better than Fully remote</td>
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<tr>
<td>Reduces time and cost related to commute. Added convenience.</td>
<td>Better than Fully onsite, only spend when going to office, Added convenience.</td>
<td>Routinely spending time and money on traveling</td>
<td>Only required to spend on need basis, Added convenience.</td>
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<tr>
<td>Recruiting talent is easier, as no location constraint and cheaper</td>
<td>Recruiting talent is little better, location is not much of constraint.</td>
<td>Recruiting talent is challenging, employee need to commute</td>
<td>Recruiting talent is easier, location is not much of a constraint.</td>
</tr>
<tr>
<td>Employees can stay at cheaper places and work for any employer.</td>
<td>Employees spend more on housing to commute to the office. But better than Fully Onsite.</td>
<td>Employees spend more on housing to commute to the office.</td>
<td>Employees can stay in a little cheaper area and save on housing, as no daily commute.</td>
</tr>
<tr>
<td>No threat of virus due to work.</td>
<td>Less threat of virus due to work.</td>
<td>High risk of contracting virus.</td>
<td>Less threat of virus due to work.</td>
</tr>
</tbody>
</table>

Table 1

4. Criteria & Sub-Criteria

Based on our research and from experts interviewing we derived four criteria: Safety, Political, Economic, Organizational Culture.

i) Safety

Safety is the set of shared attitudes, beliefs, and practices demonstrated by workers at all levels of the company. Due to the rise of COVID-19, all the companies had imposed strict safety regulations at the workplace for employee’s safety and health. For instance, Intel Corporation publishes daily safety notes in regular operation meetings/websites to remind all the employees that safety is a high priority. After interviewing the experts, we found that companies are conducting onsite drills on social distancing, sign
boards, mask mandates to have safe workplace choices. Furthermore, we decided on four sub criteria considering the personal experience of the team members and the experts: **Personal protective equipment (PPE), Vaccination, Onsite regulations, Regular testing.**

Some of the details describing why we considered these sub criteria are highlighted below:

**a) Personal Protective equipment (PPE):**
Experts from Hybrid/Onsite options who are in manufacturing pointed out that PPE kits would be mainly used. These kits should be maintained in clean spaces and disposed regularly with maintenance tasks (only 2 people for task) and mask mandates to avoid possible transmission of COVID-19 spread in a cleanroom environment.

**b) Vaccination/Onsite Regulations/Regular Testing:**
All the experts in the panel irrespective of their work culture mode (hybrid/remote/onsite) strongly aligned with the fact that all the employees should be vaccinated, and the company should educate them on COVID-19 health practices. In addition, employees (especially essential workers) should be tested regularly as they are high risk candidates, perform routine cleaning and disinfection to maintain the health of the employees.

**ii) Political**
During the COVID-19 outbreak, the main bodies **CDC (Center for Disease Control and Prevention), Federal/State Agencies and OSHA (Occupational Safety Health Administration)** directed companies to develop new safety standards and regulations. These main bodies have released safety guidelines for preventing and mitigating COVID-19 at the workplace. Experts’ personal experience pointed out the following factors:

a) Facilitate employees to get vaccination
b) Avoid the spread of COVID-19 if workers are infected/exposed to COVID-19 symptoms through stay-at-home guidance.
c) Provide workers with face coverings or surgical masks
d) Emphasize on COVID-19 policies and procedures using accessible formats and different languages
e) Maintain proper ventilation systems at the workplace and perform routine cleaning at the busy places of work.
f) Employ internal company working groups and audits regularly to monitor employee safety and standards.

Based on these considerations, CDC/Federal/State mandates, OSHA, Public perception were finalized as the key items for the various workplace criteria.

**iii) Economic**
The economic response to the pandemic by all countries worldwide has been accelerated to great levels compared to past outbreaks. In this phase, chip making companies gained high importance due to consumer high demands as people across the globe started remote/hybrid work culture practices. When we compare stock value from 2019 to 2022, the year-on-year return of the major semiconductor companies (Intel, Taiwan Semiconductors (TSMC), AMD, Samsung, Global Foundries, Qualcomm) are
between 10-15% and the growth revenue has been rapid compared to other sectors. Furthermore, the companies have increased employee benefits and pay levels at most levels of management and practiced aggressive hiring to sustain this demand for the future. The interview of experts yielded the following insights:

a) Revenue:
Due to high demand for chips, company revenue and earnings are very important to employees. Experts outlined that companies are releasing new novel products to attract market buyers especially due to the 5G market, rise in Cryptocurrency, and the huge demand of the automobile industry.

b) Employee Benefits/Pay levels:
Experts mentioned that benefits such as paid time off limits have been extended due to COVID-19. In addition to reimbursement programs for office setups and monthly Wi-Fi, employers are awarding stock grants for employees and increasing pay levels and frequency of promotions to sustain employee performance during the inflation period. Virtual team building events and remote happy hours have been added to the benefits package by companies such as Intel.

c) Investments:
The major semiconductor companies are moving aggressively on investments to meet customers/consumers goals. World’s largest manufacturing semiconductors TSMC, Intel, Samsung have led by building huge 40-80 billion USD investments across the globe (United States & Europe) to sustain company goals. Experts regard these investments as the key to future growth while increasing their scope of work and future goals. Apart from the investment in manufacturing, Intel, AMD, Qualcomm & IBM etc. are making huge investments in software and hardware architecture to innovate new chips (Moore's law). Furthermore, companies like Tokyo Electron Limited, ASML, Hitachi, Lam Research, the sector that manufactures tools to produce these chips play a vital role. In a nutshell, based on the personal experience and judgements of the experts, Revenue is an important factor, but it does not hugely impact the work format choice.

iv) Organization Culture
COVID-19 has diversified organizational culture for all the companies considering new workplace choices. The proposed alternatives: fully remote, hybrid, fully onsite and, satellite workspaces have different perspectives/impacts on employee morale and mental health compared to pre-pandemic culture. For instance, few experts raised concerns that working from home is comparatively tough due to childcare, lack of abilities to produce the same results at the workplace, resource constraint and limited team socializing activities. These factors directly impact employee health. One of the experts brought up that working remotely could feel like 24/7 shifts for those who opt for remote and hybrid options. Considering these opinions, companies are coming up with new innovative ideas such as virtual team buildings every month to improve mental health, imposing no work after 5pm rules, new metrics to analyze employee performance, flexible work culture (based on employee priorities), increased critical talent grants program for employee retention, and mid-year promotions to support employee growth.
Few companies are running “four days’ work week” pilots to promote better organization culture through work-life balance.

In consideration of the above discussion, we selected Employee Turnover, Hiring Model, Employee Growth, Morale and Mental Health as the key sub-criteria under Organization Culture.

5. HDM Model

5.1 Methodology & HDM Overview

The applied methodology to evaluate the best option for the “Operating strategy for semiconductor industry during COVID-19” is the hierarchical decision modeling (HDM). HDM is widely used to support industry decision making processes. The model helps stakeholders to evaluate not only quantitative but qualitative variables for decision making. See Fig 2.

The methodology implementation plan consisted of 3 main steps:

i) First Step:
The initial HDM model was designed based on literature review and team brainstorming.
Details:
Five original main criteria were identified
 a) Twenty sub-criteria were proposed
 b) Six strategies to choose from were proposed
The initial HDM was designed based on this analysis. See Fig 1.

ii) Second Step:
This phase consisted of early validation of the initial HDM by a group of semiconductor experts. Based on the focus group observations a second HDM was designed.

The general observations made by the experts were as follows:
 a) The definitions and differences between certain sub-criteria was unclear, for example:
   a.1) Federal/State Policies vs Mandates vs Executive Orders under Political

 b) Some of the sub-criteria would make more sense to be combined, for example:
   b.1) Social Distancing & Cleaning under Safety can be grouped as Onsite Regulations and
   b.2) Employee Growth Potential & Novel Performance Assessment Tools under Organization Culture can be combined into a single categorization

 c) Certain alternatives could be omitted at this time:
   c.1) Alternatives in the original AR Workspace criteria would not be feasible during the ongoing pandemic and could be considered as a future option
   c.2) The staggered approach was considered redundant.

Based on the previous focus group observations, a second HDM was designed. The model was updated from six to four alternatives as Fully Remote, Fully Onsite, Hybrid and Satellite Workspaces. Also, the original twenty-four sub-criteria were reduced to sixteen. These changes made it easier to do the pairwise comparisons in the HDM tool as the previous model was very heavy with six alternatives.
iii) Third step:
The final evaluation consisted of semiconductor experts pairwise comparison of the four main criteria. The previous applied changes made it a more efficient HDM and even easier to do the pairwise comparisons in the HDM tool by evaluators compared to the previous model.

The evaluation results were normalized and supported the decision process to choose one of the possible outcomes to operate during the pandemic times described as Fully Remote, Hybrid, Fully Onsite and Satellite Workspaces.

5.2 Final HDM Model:
The HDM model consists of four levels:

i) First Level: Depicts the goal to identify the best “Semiconductor industry operating strategy during COVID19”.

ii) Second Level: Describes the second level of nodes with four main criteria of evaluation starting with Safety, Political, Economy and Organization Culture.

iii) Third Level: Describes the sixteen different sub-criteria to perform a pairwise evaluation related to the second level criteria.

iv) Fourth Level: The fourth level shows the four strategy options being evaluated as Fully Remote, Hybrid, Fully Onsite and Satellite Workspaces.

v) Results: The final results are normalized to show the relative contribution of each action to achieve the project goal.
The final HDM model is shown below in Fig 2 with the four levels described in the previous section.

![HDM Diagram]

**5.3 Initial and Final HDM Diagram**
The view of the Initial and Final HDM models changed as the team applied the methodology described in the previous section as shown in the appendix Fig 3 and Fig 4.

**6. Expert Selection**
The HDM model was sent to experts for evaluation by pairwise comparison. A total of 8 experts completed the evaluation. Out of the 8 experts, 4 experts were team members who are currently working in the semiconductor industry. The rest of the experts are colleagues and personal contacts of the team members.

The experts provided early feedback to help improve the initial HDM model. Several sub-criteria under Safety, Political and Organizational Culture criteria were combined to get a more compact and balanced HDM model. Two of the proposed alternatives were dropped: Augmented Reality Workspaces due to concerns around technological readiness and the Staggered Approach of alternating between the first three alternatives to reduce redundancy.

**7. Results & Analysis**
The experts evaluate each level of the HDM model through pairwise comparisons. Each node is compared against the other nodes to award weights between 1-99. HDM software was used to gather and analyze the results of expert evaluation. We analyze the results at three levels - alternatives, criteria and sub-criteria.

At the alternatives level, Hybrid Work option received the highest score (0.29) closely followed by Fully Onsite (0.27) and Fully Remote (0.26) as shown in the appendix Table 1. We observed that two of the
experts are more inclined towards the Fully Remote option whereas three experts favor the Fully Onsite option. It is imperative that Hybrid is the second-best option of most of the experts who evaluated the HDM model, thereby bridging the divide between the Fully Remote and the Fully Onsite options. In addition, the HDM software showed that the inconsistency levels for each expert and the overall disagreement were within 0.1.

At the criteria level, Safety was the highest rated (0.42) followed by Economic (0.26) as shown in the appendix Table 2. Political perspective received the lowest score (0.15). At the sub-criteria level, Vaccination under the Safety perspective received the highest score (0.36) closely followed by State/Federal Mandates under the Political perspective (0.35). Under Organizational Culture, Morale & Mental Health received the third highest score (0.34) followed by Revenue under Economic perspective (0.30) as shown in the appendix Table 3.

8. Interpretation of Results
The expert evaluations were grouped by their current working environments. A summary of these grouped evaluations can be seen in the appendix Fig 5. The fully onsite alternative received the highest preference score among experts who belonged to the onsite and hybrid groups. However, experts belonging to the fully remote group (62.5% of the experts in the study) favored the hybrid alternative instead. Satellite working environments were the least preferred alternative among all of the experts, receiving a preference score of only 0.18.

Among the selected criteria, Safety was ranked by the experts as most important by far with a mean weight of 0.42. One of the experts even ranked safety with a score of 0.96 as shown in the appendix Fig 6, which signifies that they believe that safety is so important that it completely overshadows the other criteria. The second most important criterion was economic, with a mean score of 0.26. Comparatively, political and organizational culture perspectives were ranked by the experts as being relatively unimportant with mean weights of 0.18 and 0.15 respectively.

As mentioned in the previous section, we conducted analysis of the sub-criteria level results based on expert evaluations. Justifications for these sub criteria and factors we considered are discussed in detail in the criteria/sub-criteria section.

i) Under the Safety sub-criterion, experts pointed out that Vaccination/Onsite regulations/PPE are key elements to be taken into account. Especially Onsite/Hybrid experts highly weighted Vaccination/PPE here. See the appendix Fig 7.

ii) Under the Political sub-criterion, experts weighed State/Federal mandates as highest priority, whereas CDC and OSHA are given equal importance here. See the appendix Fig 8.

iii) Under the Economic sub-criterion, all the experts leaned towards Revenue and company growth as the highest priority considering future semiconductor demand/supply across all sectors. See the appendix Fig 9.

iv) Under the Organizational Culture sub-criterion, experts ranked Morale and Mental Health as the first priority (especially experts related to Remote/Hybrid culture), Employee Benefits as the second priority (all experts weighed high considering COVID-19 risks and factors) and followed by other factors such as Hiring & Employee Turnover. See the appendix Fig 10.
9. Limitations & Future Research

Some limitations to the specific implementation of the HDM model in this report were identified. It was determined that many experts brought their personal experiences and biases towards how they answered the survey. Thus, experts with more experience with on-site working environments tended to favor this alternative and experts with more experience working remotely tended to favor that one. Additionally, the sets of alternatives, criteria and sub-criteria were by no means exhaustive, and additional considerations could provide different results. Further work can be made to refine the existing HDM model and address some of these concerns. Some possibilities include an expansion of the pool of experts used to evaluate the model, an implementation of preliminary priority weighting and an expansion of the sets of alternatives, criteria and/or sub-criteria evaluated.

One possibility considered is to expand upon the pool of experts used to evaluate the model. Expanding the pool of experts could reduce any unintended skew of results caused by bias introduced by the experts’ differing personal experiences. This would also reduce the effect of outliers.

Another possibility is towards implementing preliminary priority weighting. This would involve an initial poll of experts to determine which sets of criteria and sub-criteria were deemed more important than others and thus give an initial weighting reflecting these results. This would potentially result in a selection of alternatives that consider such criteria to a greater degree. For example, if safety was pre-weighted to a greater degree, alternatives which more greatly consider safety (like the fully remote option) could see even higher results.

One more possibility proposed is the inclusion of additional alternatives and/or the set of criteria and sub-criteria evaluated by the pool of experts. During the initial stages of the development of the model employed herein, several additional alternatives were considered. This included a staggered approach alternative, whereby a business would begin fully- or partially- remote and slowly transition toward on-site operations. Another alternative that was considered was the “metaverse approach.” This approach simulates an on-site working environment remotely through the implementation of virtual and augmented reality technologies and has in fact been considered as a viable possibility by several companies [12]. Additional criteria could include the corporate strategy section outlined in the earlier stages of this report, as well as others not considered by this team. The refinement of the model in this way comes at the cost of increased complexity, and thus the relative gain to this approach must be considered.

Lastly, some additional future work could involve refining and optimizing other parameters of the HDM model. A sensitivity analysis could provide insights into criteria with a higher impact on the decision making process and further inform preliminary criteria weighting. Boundary analysis could also be performed to identify and establish limits on valid decision quantifiers. Finally, benchmarking throughout other sectors of the semiconductor industry could pinpoint how the decision making changes by the local perception associated with the region or customer profile where the analysis has been conducted, which could in turn reduce the effects of bias in the expert panel.
10. Conclusion
The ongoing effects of the COVID-19 pandemic has changed the landscape of how businesses in the semiconductor industry must operate. Given the challenges presented by this current climate, the HDM model provided an effective means of deciding between a set of alternatives pursuant to this objective. When considering a set of alternatives including fully remote, hybrid, fully onsite and satellite workspaces, the results of the HDM model evaluated by a poll of experts within the industry determined that the hybrid approach was the best alternative, with safety the most heavily weighted criterion. However, the results of the fully remote and fully onsite alternatives were not far behind the hybrid approach. Additional refinement of the HDM model could potentially improve upon these findings.
References


### Table 2

<table>
<thead>
<tr>
<th>Experts</th>
<th>Fully Remote</th>
<th>Hybrid</th>
<th>Fully Onsite</th>
<th>Satellite Workspaces</th>
<th>Inconsistency</th>
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### Table 3

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Political Sub Criteria Results

Safety Sub Criteria Results

Fig 7

Fig 8