IDENTIFYING SUITABLE ADAPTATION OPTIONS FOR DIFFERENT INCOME GROUPS IMPACTED BY HEAT WAVES (CASE STUDY: NEW YORK CITY)

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March, 2017

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ABSTRACT

Climate change is a long-term phenomenon of global scale with a large relevance for cities. impacts of climate change threaten cities, e.g. via the stress on urban areas through increasing the number of extreme events and hazards like heat waves, inland floods, sea level rise and storm surges which are affecting inhabitant's lives and property, essential infrastructure and ecosystems.

This research focuses on heat waves as one of the extreme events caused by climate change. Heat waves and higher temperatures affect urban sectors like water, energy, transportation and telecommunication. These impacts may change the drinking water supply and demand, increase the energy demand and lead to more heat-related mortality (death) and morbidity (illness). There is strong evidence that the duration and frequency of heat waves increase globally.

The City of New York is chosen as the case study of our research because it is a prime example for investigating the potential impacts of heat waves on urban areas and its residents. New York City is a large, dense, highly built up and populated city, which makes it a highly relevant test case. Heat waves are one of the major hazards which threaten the city but, municipal plans and academic research in New York City in regards to climate change adaptation mainly focus on floods and costal storms. The impacts of heat waves are almost ignored, i.e. heat wave risk seems to be underestimated as compared to other hazards caused by climate change.

Citizens experience impacts of heat waves differently due to their various socio-economic characteristics. Considering the huge differences between different income groups in New York City, economic characteristic of citizens like income level seems to play a major role in how people experience heat waves impacts which is almost ignored in researches in this field.

This research will compare different income groups in regards to impact of heat wave to Identify suitable adaptation options based on different income group's cognitive maps in New York City case study.

The main data set which is used in this research is the output of an online interview conducted in July 2013 in New York City sponsored by Centre for Research on Environmental Decisions (CRED), Columbia University under the direction of Dr. Diana Reckien. The interview includes individuals who are 18 years of age or older living in the five different boroughs of New York City, sampled and conducted by using the professional survey provider Qualtrics and their Survey Software. There are 762 valid records (interviews).

The research starts with defining 4 different income groups (In poverty, Low income, Middle Income, High income) in data set based on available official published thresholds in 2013 for New York City. In next step different income groups are compared with each other based on available data in regards to past and future impacts of heat waves and adaptation issues. To have a better understanding of differences between these groups, Non parametric statistical analysis (The Kruskal-Wallis H-Test and The Mann-Whitney U-test) are used due to the structure of data set which included mainly ordinal variables.

The FCM[1] data available in the data set for each income groups sample are used to develop each income groups' cognitive map (aggregated matrix) using FCM methods. The cognitive maps of different income groups are visualized and compered with each other. Finally, Based on out-put of developed cognitive maps (aggregated matrix), different adaptation scenarios are simulated and assessed by using FCM Scenario developer to identify the suitable adaptation options for each income groups.

According to the final results, Investment in transit sector (compare to other simulated adaptation option) shows the strongest positive impacts on all the income groups in New York City.

Keywords: Climate change, Adaptation, Heat wave, New York City, Income groups, Fuzzy Cognitive Mapping (FCM)

[1] Fuzzy Cognitive Mapping

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1. INTRODUCTION

This chapter describes the background of the study followed by research problem, research objectives and questions and structure of thesis report.

1.1. Background and Justification

Climate change is a long-term phenomenon of global scale, with a large impacts on cities. As more than half of the world population live in cities, climate change increases the stress on urban areas through increasing the number of extreme events and hazards like heat waves, inland floods, sea level rise and storm surges which are affecting inhabitant's lives and property, essential infrastructure and ecosystems (Rosenzweig, Solecki, Hammer, & Mehrotra, 2011). In many cases climate change is expected to exacerbate existing challenges in urban areas and worsen existing problems. On the other hand, cities with their share in emissions of Green House Gases (GHG) also play a role in the process of climate change (De Gregorio Hurtado et al., 2014).

This research will focus on heat waves as one of the extreme events caused by climate change.
There is strong evidence that the duration and frequency of heat waves increase globally. For instance, in the IPCC[2] Fifth Assessment Report, it is concluded that "*it is very likely that the length, frequency and/or intensity of warm spells or heat waves will increase over most land areas*"(IPCC, 2012, P. 13).

Heat wave impacts affect human society and natural systems directly and indirectly (Goodess, 2012). Heat waves and higher temperatures affect different sectors in the cities like water, energy, transportation and telecommunication sectors. These impacts threaten the drinking water supply and demand, increasing the energy demand and might lead to more heat-related mortality (death) and morbidity (illness) (Rosenzweig, Solecki, Degaetano et al., 2011). Furthermore, the psychological and physiological health can be affected as one of the indirect health impacts of extreme heat events and cause increasing violence and crime during these events (Wamsler & Brink, 2014).
Among different demographic groups, elderly, disabled and people with health problems are more vulnerable to climate-related hazards like floods and heat waves. Low-income groups are also among the vulnerable group to these hazards due to their limitation to meet energy costs, their dependency on public transport and problems in access to proper health care services during these severe events (Rosenzweig, Solecki, Degaetano et al., 2011).
Heat waves, generally have a disproportionately negative impact on these vulnerable groups, such as elderly and low-income citizens who live in urban areas. The majority of these citizens do not have the ability to handle the cost of air conditioning (Kinney et al., 2015). Energy costs associated with air conditioning use are one of the major concern for low-income families during the heat events. Even during the extreme events, the low-income households which have access to A/C[3], don't use their A/C due to the concerns about energy costs (Tonn & Eisenberg, 2007).

It can be concluded that heat waves as one of the consequences of climate change affect urban areas and urban population in different negative ways. Citizens experience impacts of heat waves differently. Socio-economic characteristics of citizens is an important factor in vulnerability to impacts of heat waves. Due to increasing the number of extreme heat events globally and considering the differences in vulnerability of various socio-economic groups to heat events, more research on this topic seems to be necessary. This research considers economic dimension and will focus on how different income groups experience impacts

[2] Intergovernmental Panel on Climate Change
[3] Air conditioning

of heat waves and tries to identify suitable adaptation options for different income groups based on their cognitive maps with respect to impacts of heat waves in New York City

1.2. Research problem

Among different research in regards to different hazard caused by climate change heat waves are not generally considered as serious hazard compared to other natural hazard caused by climate change such as floods and coastal storms and sea level rise. Unclear public understanding about heat waves could be the main reason for neglecting heat waves compare to other hazards caused by climate change. Public understanding of a problem is directly related to media coverage. " *heat waves does not look like serious natural disaster although it kills far more people than earthquakes or tornadoes*" (Klinenberg, 2002 cited in Healy, 2004, P. 285). Media always cover the story, and because the heat seems to lay over a city equally, it is so difficult to depict a newsworthy image of the disaster. In regards to heat waves, "*the real story, like the victims of the heat wave, was largely invisible, and the story faded along with the heat*" (Klinenberg, 2002 cited in Healy, 2004, P. 287).

The research in regards to heat waves, mainly focus on two major subjects. The first group were focused on projecting the frequency of heat waves in the future and heat related mortality and morbidity rate related to these projections (Habeeb, Vargo, & Stone, 2015; Petkova et al., 2014; Petkova, Horton, Bader, & Kinney, 2013). The second group were mainly focused on socio-demographic characteristics of vulnerable group (like age, ethnicity and etc.) and physical characteristics of vulnerable neighbourhoods (Sampson et al., 2013; Klein Rosenthal, Kinney, & Metzger, 2014; Kinney et al., 2015).
The relation between vulnerability and different socio-demographic factors like age, race, gender, poverty and etc. are examined in existing academic literature in regards to heat waves but economic factors like income level which play an important role in how citizens experience the impacts of heat waves is not considered in the researches in this field.

This research focuses on New York City as case study, because According to the model adopted by different research (Horton et al, 2011; Kinney et al, 2015) for New York City, heat events are projected to increase approximately triple in frequency. Furthermore New York City is one of the socially most unequal cities in the world and the third most unequal city in the U.S. regarding economic issues (Long, 2014). Almost 4 million citizens live below poverty line based on census bureau data. On the other hand, New York is the home to most richest people in the world (Long, 2014). There is a huge difference between different income groups in New York City and economic characteristics of citizens seem to play an important role in how New York citizens experience impacts of heat waves by changing the way they access to adaptation options (like access to air conditioning). Economic characteristics like income level can change the way heat waves impacts are experienced by citizens and how different income groups experience heat wave impacts seems to be important for developing adaptation options.

It should be consider that, in New York City, the municipal plans in regards to climate change adaptation mainly focus on floods and costal storms and impacts of heat waves are almost ignored. For instance, The PlaNYC[4] report which is developed by New York City mayor office is one of the important documents on climate change mitigation and adaptation. This comprehensive and important plan developed in 2007 had been updated regularly until 2014 so far. The adaptation section in the plan mainly focus on NYC[5] 100 year

[4] PlaNYC is a plan released first by New York City Mayor Michael Bloomberg in 2007 to prepare the city for one million more residents, strengthen the economy, combat climate change, and enhance the quality of life for all New Yorkers. The Plan brought together over 25 City agencies to work toward the vision of a greener, greater New York. Since then, significant progress has been made towards the long-term goals set by the Plan.
[5] New York City

flood plain maps and developing flood evacuation zones and convening NYC climate change Task Force to develop coordinated strategy to maintain the critical infrastructure of the city in regards to impacts of climate change. In 2012 improving community resilience was added to the plans goals and emphasised more in 2014 plan (The city of New York Mayor Office, 2014; The City of New York Mayor Office, 2012; The City of New York Mayor Office, 2007). However increasing heat waves frequency have been considered in all PlaNYC reports, but not its impacts on different social and vulnerable groups in the city. The plan mainly focuses on impacts of floods and coastal storms as main hazards threaten New York City and heat waves impacts are neglected.

To conclude, between different extreme events caused by climate change in New York City, the majority of the municipal plans and researches focus on storms and sea level rise and heat wave is on the second priority due to its invisible impacts. Citizens experience impacts of heat waves differently due to their various socio-economic characteristics. Considering the huge differences between different income groups in NYC, economic characteristic of citizens like income level seems to play a major role in how people experience heat waves impacts which is almost ignored in researches in this field. For these reasons, this research will compare different income groups in regards to impact of heat wave and will identify suitable adaptation options for different income groups with respect to their cognitive maps in New York City case study.

1.3. Research objectives and Questions

The research objectives and research questions are presented in Table 1.

Main Objective
"To identify the suitable adaptation options for different income groups impacted by Heat waves in New York City."
Sub-Objective 1
To Identify main differences across different income groups in NYC in regards to the past and future impacts of heat waves
- What are the main differences across different income groups in regards to their experience about past impacts of HW[6]? - What are the main differences across different income groups in regards to their concerns about future impacts of HW?
Sub-Objective 2
To Identify the main differences across different income groups in NYC in regards to orientation of future HW adaptation practices
- What are the main differences, across different income groups in regards to their opinion about citizens' responsibility in HW adaptation practices in NYC? - What are the main differences, across different income groups in regards to their opinion about the important urban sector(s) in the future HW adaptation practices in NYC?
Sub-Objective 3
To capture the citizens' Cognitive Maps in regards to impacts of HW across different income groups in NYC
- What are the main elements (concepts and relation between them) in each income groups' cognitive maps in regards to impacts of heat waves in NYC? - What are the main differences between different income groups' cognitive maps structure in regards to impacts of heat waves in NYC?
Sub-Objective 4
To Identify the suitable HW adaptation options for each income groups with respect to their cognitive maps in NYC
- How Different adaptation options affects different income groups in NYC, with respects to their cognitive maps about Heat wave impacts? - What are the suitable HW adaptation options for each income groups with respect to citizens' cognitive maps in NYC?

Table 1: Research Objectives and Questions
Source: Own draft

[6] Heat Waves

1.4. Structure of thesis report

This report is divided to seven chapter which are described below:

Chapter 1: Introduction
In this chapter the research background, research problem and research objectives and questions are presented.
Chapter 2: Literature review
In this chapter the research in regards to vulnerability and adaptation concepts, heat wave impact and heat wave adaptation measures and cognitive maps are reviewed.
Chapter 3: Research Methodology
In this chapter the research case study introduced briefly and the analysis methods are explained in detail with respect to related literature.
Chapter 4: Results and Discussion
In this chapter the results of analysis and the discussion with respect to research objectives are presented.
Chapter 5: Conclusion
In this chapter the research results with respects to research objective and questions are concluded and research limitations are discussed. C

Chapter 6: List of References

Chapter 7: Appendix

2. LITERATURE REVIEW

In this chapter, literature related to research topic are reviewed. In first section, vulnerability and adaptation concepts are introduced. In next section, Impact of heat wave and suggested heat wave adaptation measures with respect to New York City are reviewed. In the last section literature in regards to cognitive maps and application of Fuzzy Cognitive Mapping (FCM) analysis in the field of climate change are reviewed.

2.1. Vulnerability concept

The vulnerability concept is useful to understand and evaluate impacts and adaptation of climate change on human and environment system because both human and natural system are considered in the concept (Rosenzweig, Solecki, Degaetano et al., 2011). According to IPCC (2012) definition, vulnerability is "*The propensity for the health of individuals or groups to be adversely affected as a result of exposure to a climate hazard. The vulnerability is an internal characteristic of the affected system and includes the characteristics of persons or groups and their situation that influence their capacity to anticipate, cope with, resist, and recover from an adverse climate event*"(IPCC, 2012, P. 5).

Connected to vulnerability concept is the capability of the targeted society to adjust itself to respond better to climate change impacts which defined as climate change adaptation. Adaptation in the context of climate change defined as "*Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects*"(Kinney et al., 2015, P. 69). Adaptation practices can be seen as adaptive capacity which citizens use. Adaptive capacity can be defined as "*the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences*"(Wamsler & Brink, 2014, P. 69). Adaptation practices can take place in a different level from individual and house hold level to the community and institutional level. In community and institutional level, it includes planning policies and strategies that can help natural and human systems to withstand negative impacts of climate change and also use the opportunities caused by climate change.

Therefore the vulnerability concept is a useful concept to evaluate the impact and potential adaptation options of heat waves which is the main aim of the study.

2.2. Heat wave impacts and adaptation

Heat waves can be generally defined as periods of unusually hot weather over an extended period of time, relative to local conditions. According to Rosenzweig, Solecki, Degaetano, et al. (2011) and Kinney et al. (2015), In New York City, a heat wave is defined as :

- Individual days with maximum temperatures at or above 95ºF (35 °C)
- Period of three consecutive days with maximum temperatures above 90ºF (32 .2 °C)

There is strong evidence that the duration and frequency of heat waves increase globally. For instance, in the IPCC[7] Fifth Assessment Report, it concluded that "*it is very likely that the length, frequency and/or intensity of warm spells or heat waves will increase over most land areas*" (IPCC, 2012, P. 13).

According to Rosenzweig, Solecki, Degaetano, et al. (2011), higher frequency of heat waves, will increase fatigue of materials in the energy, water, telecommunications and transportation sectors; put stress on drinking water supply and distribution system; have negative impacts on plants and animals; and declines the air quality.

According to Kinney et al. (2015) the main weather-related causes of death in the United States in 2012 was heat. They argue that heat-related mortality (deaths) and morbidity (Illness and disease) are the most

[7] Intergovernmental Panel on Climate Change

measurable, and yet preventable impacts of climate change on human health. "*Morbidity and mortality effects of heat may be especially severe if a blackout occurs during an extreme heat event. Blackouts are more likely during heat waves due to the increased demand for electricity for air conditioning, an effect that places stress on the systems that supply and deliver electricity*" (Kinney et al., 2015, P. 76).

According to Bouchama et al. (2007), home air conditioning is a critical factor for prevention of heat-related illness and death. "*Air conditioning is especially important for elderly, very young, and health-compromised individuals, all of whom have a lower internal capacity to regulate body temperature*"(Rosenzweig, Solecki, Degaetano, et al., 2011, P. 410).

According to Rosenzweig, Solecki, Degaetano, et al. (2011), more frequent heat waves increase energy demand for air conditioning. For lower-income residents, increased energy costs may be difficult to afford. Vulnerable group especially low-income elderly residents, may be reluctant to use their air conditioners due to concerns about energy costs.

Lemmen & Warren (2004) argue that to improve the effectiveness of air conditioning as an adaptive measure, it is important to develop strategies to ensure energy access for vulnerable group, as well as ensure that functional air conditioners are available and in use by them. They suggest monetary support of low-income populations to ensure the use of air-conditioning and programs for peak load and or voltage reduction as possible adaptation measures. "*Adaptation strategies, such as provision of subsidization of air conditioning for low-income urban residents will entail new financial outlays. Such outlays may be offset by health-related cost savings due to the reductions in heat-related morbidity and mortality*" (Rosenzweig, Solecki, Degaetano, et al., 2011, P. 62).

In addition to these measures, infrastructure investments, particularly in vulnerable urban areas, Urban greening programs such as green roofs, and building codes requiring reflective exterior surfaces are among the options that should be considered (Rosenzweig, Solecki, Hammer, et al., 2011).

Bolitho & Miller (2016), focus on differences between addressing heat as an emergency and heat as a source of chronic stress based on desktop research and interviews in Melbourne, Australia. According to research results, "*the responses of government and non-government community sector organizations to extreme heat reflect a tension between a risk management paradigm (heat as an emergency) and a social vulnerability perspective (heat as chronic stress)*" (Bolitho & Miller, 2016, P.13). This research classification of heat wave adaptation measures with respects to risk management approaches (which focus especially on the emergency dimensions of heat) and vulnerability perspective (which focus especially on the chronic dimensions of heat) is presented in table 2. it is concluded in this research that, "*policy and institutional responses that better appreciate the interconnections between the emergency and chronic aspects of heat would likely reduce vulnerability and contribute to more urban sustainability*" (Bolitho & Miller, 2016, P. 1).

Approaches	Heat wave Adaptation Measures
Risk management approaches	▪ Identification and mapping of at-risk groups ▪ Communication strategy involving heat alerts ▪ Promotion of behavioural modification ▪ Education and awareness programmes on minimising harm from heat ▪ Coordinated responses within and between agencies for preparedness planning and emergency response
Vulnerability approaches	▪ Direct engagement with vulnerable people through support of social networks and partnerships ▪ Improve housing quality, for example, retrofitting ▪ Improve access to healthcare and social services ▪ Improve access to cool public and private spaces, for example, air-conditioning concessions ▪ Integrate thermal considerations, shading, and vegetation into urban design and planning ▪ Address access and mobility considerations, for example, shade at bus stops ▪ Coordinated responses within and between agencies in planning and emergency and long-term responses

Table 2: Heat wave adaptation measures with respect to Risk management and Vulnerability Approaches. Source: (Bolitho & Miller, 2016, P.13)

The Academic research in regards to heat wave related to New York City can be classified to two main groups.

One group of the researcher mainly focuses on the projection of future heat waves and heat-related mortality rate. Habeeb et al. (2015) in their research examine changes in timing, duration, intensity and frequency of heat waves between 1961 and 2010 in 50 U.S. cities. They conclude that all these four characteristics of heat waves will increase significantly in five decade period. Some research estimates the future mortality caused by heat waves. Heat-related premature mortality in the 1990s and 2050s in New York City were estimated by Knowlton et al. (2007) by using different climatic approaches and scenarios. The acclimatisation issues such as physiological adaptation and use of air conditioning is considered in their model. Based on their research results, the heat-related premature mortality in 2050 would increase in average 70% compared with the 1990s and acclimatisation impacts reduce the mortality rate by nearly 25%. They conclude that current acclimatisation may not mitigate the impacts of climate change in New York City. In another study, Petkova et al. (2013) considered United States northeast region as their case study. They present the projection of heat-related mortality in New York, Philadelphia and Boston by using models developed with the support of IPCC's Fifth Assessment Reports (AR5). According to results of this study, projected heat-related mortality is the highest in New York City in the period between the 2020s and 2080s.

The other group of researches, mainly focus on characteristics of vulnerable citizens to negative impacts of heat waves. Madrigano, Ito, Johnson, Kinney, & Matte (2015) examine the heat-related mortality records in New York City between 2000 and 2011 to identify the characteristics of at-risk citizens and neighbourhoods. According to this research results, death caused by heat waves is more likely to happen at home compared to other institutional setting and more likely to happened in the neighbourhoods that receive higher public assistance. Between different race/ethnicities, black (non-Hispanic) citizens are more likely to be at risk of

death during the heat waves. Klein Rosenthal et al. (2014) evaluated the socio-economic and build environment characteristics of the place with the high heat-related mortality rate in New York City. The results show there is a significant positive association between heat-related mortality rate and neighbourhood characteristics like the lower rate of access to A/C, poor housing conditions and poverty. According to Rosenthal et al. (2014) who show a relation between build environment characteristics of the place and consequences of heat waves and some of these characteristics such as availability and access of air conditioning, as well as solid housing can be proxy indicator for income.

However, as we can observe from reviewed literature, there are very limited studies on the direct relation between income levels and heat wave risks.

2.3. Fuzzy Cognitive Mapping (FCM)

The importance of mental models and cognitive maps in identifying and evaluating the key elements of climate change impacts has been highlighted in adaptation research (Moser & Ekstrom, 2010; Reckien, Wildenberg, & Bachhofer, 2013; Marta Olazabal & Pascual 2013; Gray et al., 2014; Reckien (2014); Olazabal & Reckien, 2015).Cognitive maps are a representation of external reality by using individual's perceptions, experiences and knowledge which structure their reasoning in regards to decision making. Capturing groups or individual's cognitive maps clearly illustrates how individuals understand climate problems in regards to decision making in adaptive responses (Gray et al., 2014) which can be used to develop robust adaptation strategy.

FCM is a semi-quantitative analysis method which is based on casual reasoning. FCM method translate Stakeholder's knowledge or experience to network consisting of nodes which represent the main concept and weighted interconnections which represent relations (cause and effect) between main concepts of the system. By using this method, the cause-effect relationship between the main concept of the system will be quantified which can be used in the process of decision making (Olazabal & Reckien, 2015).

FCM method is generally used for four purposes:

- Explanation (to understand how different actors see the system)
- Prediction (to predict the consequences of decisions in the future)
- Reflection (to observe different representation of the system)
- Strategic evaluation (to understand a complex system by gaining detailed knowledge about it) (Papageorgiou & Salmeron, 2013; Olazabal & Reckien, 2015).

FCM has been increasingly applied in different environmental studies. In regards to climate change, for instance, Singh & Nair (2014) deployed a semi-quantitative fuzzy cognitive mapping (FCM) approach for Livelihood vulnerability assessment to climate variability and change. They quantify stake- holders' perspectives in order to estimate livelihood vulnerability to climate change of poor agro-pastoralists in the Bhilwara in Western India. According to this research findings, natural and financial assets are most susceptible to harm while financial and organisational assets provide resilience against climate variability and change.

Reckien et al. (2013) focus on the perceived impacts of weather-related extreme events (heavy rain events and heat waves) on different social groups in New Delhi, India. They use scenario analysis and network statistics with the Fuzzy Cognitive Mapping which provide qualitative and quantitative measures to compare impacts and effect of adaptation strategies on different social groups. According to this research results, "*Rain events affect the lower income classes more, while heat waves are the bigger burden for higher income classes. Overall, the strength of perceived impacts is larger for lower income classes, directly threatening their daily incomes*"(Reckien et al., 2013, P. 159). The results of FCM scenario analysis in this research shows that during rain events, investments in schemes to ease traffic such as improving the sewage and drainage infrastructure which enable transport of goods for lower income classes, has the strongest positive effect on low income group. During heat events,

improving the water supply system would reduce burden across all socio-economic groups, while improving electricity supply system is an effective adaptation option for high income classes in particular.

Reckien (2014) use Fuzzy Cognitive Mapping method to evaluate differences in sensitivities to rainstorms and heat waves across socio-economic groups and for ranking the useful adaptation options in Hyderabad, India. According to research results, "*rainstorms affect low-income residents more than heat waves, while the opposite is true for medium-income respondents*"(Reckien, 2014, P. 1). According to results of this research FCM scenario simulation, Investment in the health infrastructure is the most effective adaptation option in reducing the negative impacts of heat waves while investment in traffic infrastructure is the most effective adaptation option for rain storms.

3. RESEARCH METHODOLOGY

This chapter of the report includes introducing the case study, structure of available data set for the research and the research methodology.

3.1. Research case study

New York City is chosen as a case study of this research. The city is founded as Dutch colonial in the 1600s and had become the largest city of United States, and it remains up to now. New York City is one of the most populated cities in the world. Based on 2010 census data, the official population of the city was 8,175,133 and approximately there are another 14,000,000 residents living in the metropolitan region out of city borders. The city is located in the eastern coastal zone of United States and has a temperate continental

Figure 1: New York City boroughs Map
Source: NYCmap360, 2016

climate (Solecki, 2012). The official city region includes five boroughs: Manhattan, Bronx, Queens, Brooklyn, and Staten Island which are shown in figure 1.

New York City experiences different challenges in its history, and the latest challenge is climate change. According to the latest projections, the climate change will affect New York City's major infrastructure and population through sea-level rise, more intense floods and more extreme heat events (Solecki, 2012). According to the projection model adopted for New York City, "*the current 1-in-10-year coastal flood is projected to occur more than once every three years by the end of the century and heat events are projected to triple approximately in frequency*" (Horton et al., 2011, P. 2247).

Kinney et al. (2015) in their report argue that New York City's public health will be threatened by two major climate hazards:

1. Floods and Coastal storms

2. Heat waves and increasing temperatures

In the case study of this research frequency of heat wave follows the global pattern and increasing gradually. Table 3 shows that the total number of hot days in New York State is expected to increase as this century progresses.

New York City: Full range of changes in extreme events: minimum, (central range), and maximum					
	Extreme event	Baseline	2020s	2050s	2080s
	Number of days per year with maximum temperature exceeding				
Heat Waves & Cold Events	90°F	19	20 (23 to 31) 42	24 (31 to 47) 58	31 (38 to 66) 80
	95°F	4	4 (6 to 9) 15	6 (9 to 18) 28	9 (12 to 32) 47
	Number of heat waves per year	2	3 (3 to 4) 6	3 (4 to 6) 7	4 (5 to 8) 9
	Average duration	4	4 (5 to 5) 5	5 (5 to 5) 6	5 (5 to 7) 8
	Number of days per year with min. temp. at or below 32°F	72	48 (53 to 62) 66	31 (45 to 54) 56	22 (36 to 49) 56

Table 3: Projection of future heat waves in New York State until 2080
Source: (Rosenzweig, Solecki, Degaetano et al., 2011, P. 34)

Table 4, shows a general overview of socio-economic characteristics of each borough citizens in New York City according to latest projection of American Community Survey (ACS) for 2015.

Boroughs	Bronx	Brooklyn	Manhattan	Queens	Staten Island	Total (in NYC)
Population	1,455,444	2,636,735	1,644,518	2,339,150	474,558	8,550,405
Male	687,295	1,250,574	778,476	1,135,453	229,900	4,081,698
Female	768,149	1,386,161	866,042	1,203,697	244,658	4,468,707
Total Number of Households	495,513	940,176	751,244	774,752	167,462	3,129,147
Average household size	2.85	2.76	2.11	2.98	2.79	2.68
Unemployed Citizens	71,971	101,496	59,144	83,638	11,826	328,075
% of Unemployed in Borough	4.94%	3.85%	3.60%	3.57%	2.49%	3.84%
Population below poverty level	432,177	582,808	280,406	318,154	67,312	1,680,857
% of Population below poverty level in Borough	29.69%	22.10%	17.05%	13.60%	14.18%	19.66%

Table 4: New York City citizens' socio-economic characteristic overview according to different boroughs data
Source: (American Community Survey (ACS), 2015)

According to table 4, Brooklyn and Queens have the highest population while Staten Island has the lowest population. Bronx has the highest share of unemployed citizens and in poverty groups with respect to its population while Staten Island has the lowest share of unemployed and Queens has the lowest share of in poverty groups with respect to its total population.

3.2. Structure of research dataset

The main data set which is used in this research is the output of an online interview conducted in July 2013 in New York City sponsored by Center for Research on Environmental Decisions (CRED), Columbia University under the direction of Dr Diana Reckien. The interview includes individuals who are 18 years of age or older and living in five different boroughs of New York City. The Interview conducted by using the professional survey provider Qualtrics and their survey software. There are 762 valid records (interviews) in the data set. Table 5, shows different boroughs projected population for 2013 and distribution of data set records in different boroughs.

Boroughs	Bronx	Brooklyn	Manhattan	Queens	Staten Island	Total
Population (based on 2010 Census data)	1,385,000	2,505,000	1,586,000	2,231,000	469,000	8,176,000
Projected Population for 2013 (ACS[8])	1,418,733	2,592,149	1,626,159	2,296,175	472,621	8,405,837
Projected number of household for 2013 (ACS)	481,143	925,489	726,357	784,243	167,629	3,084,861
Number of records in each borough	111	194	200	177	80	762
% of each borough across dataset records	14.6 %	25.5 %	26.2 %	23.2 %	10.5 %	100 %

Table 5: New York City Boroughs' population and distribution of research data set across different boroughs of New York City.
Source: (Census Data, 2010; American Community Survey, 2013)

As it shown in the table 5, the population in all boroughs are projected to increase in 2013 compare to 2010. Manhattan and Brooklyn which have the highest population, have the highest share in data set records while Staten Island with lowest population, has the lowest share in dataset records.

Figure 2 shows the distribution of records at zip code level across New York City. As it is shown in figure 2, there are just some limited area that doesn't have any share in data set records.

[8]American Community Survey (ACS)

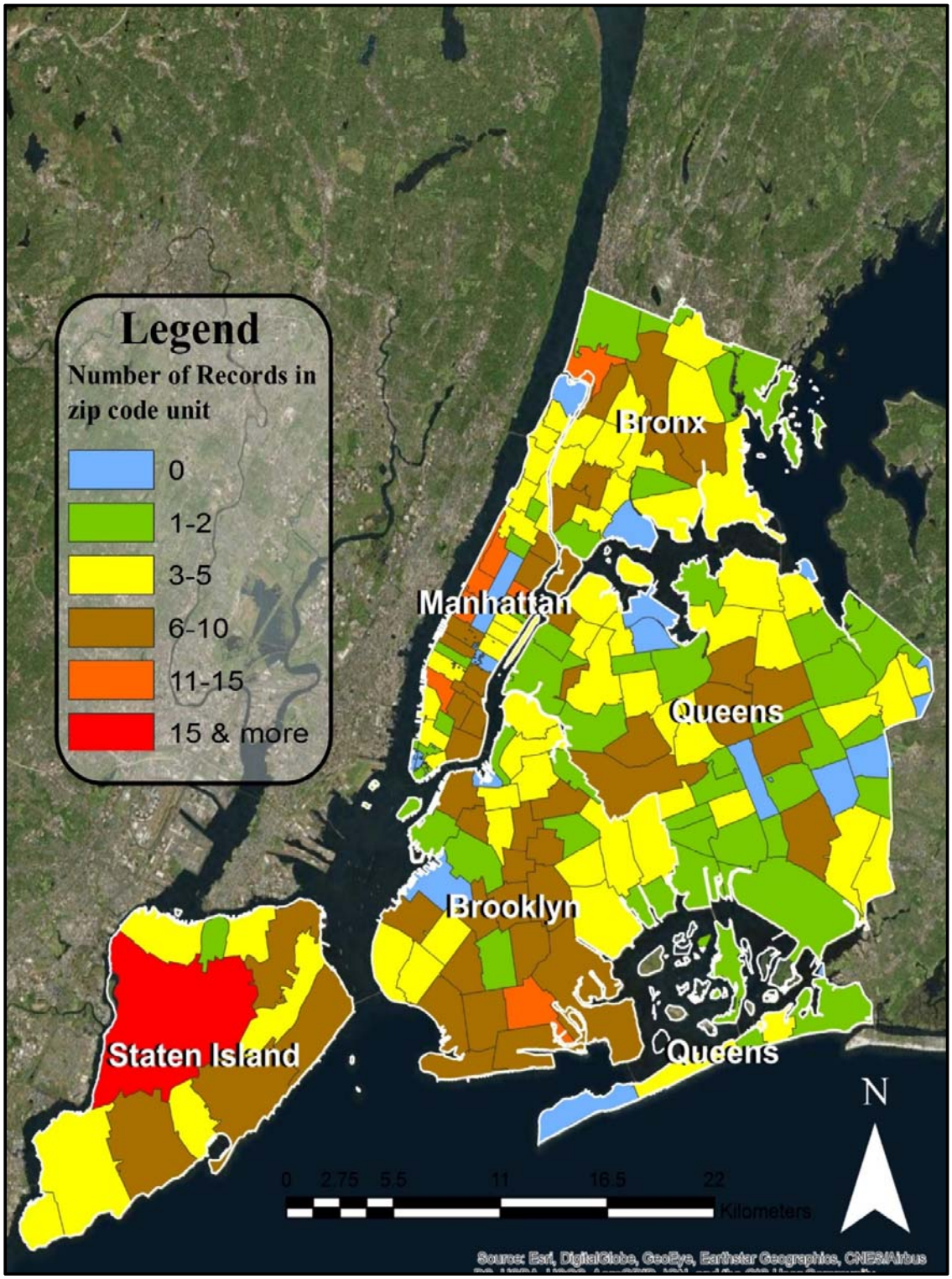


Figure 2: The distribution of dataset records across New York City (zip code level)
Source: Own draft

The structure of this data set is presented in figure 3.

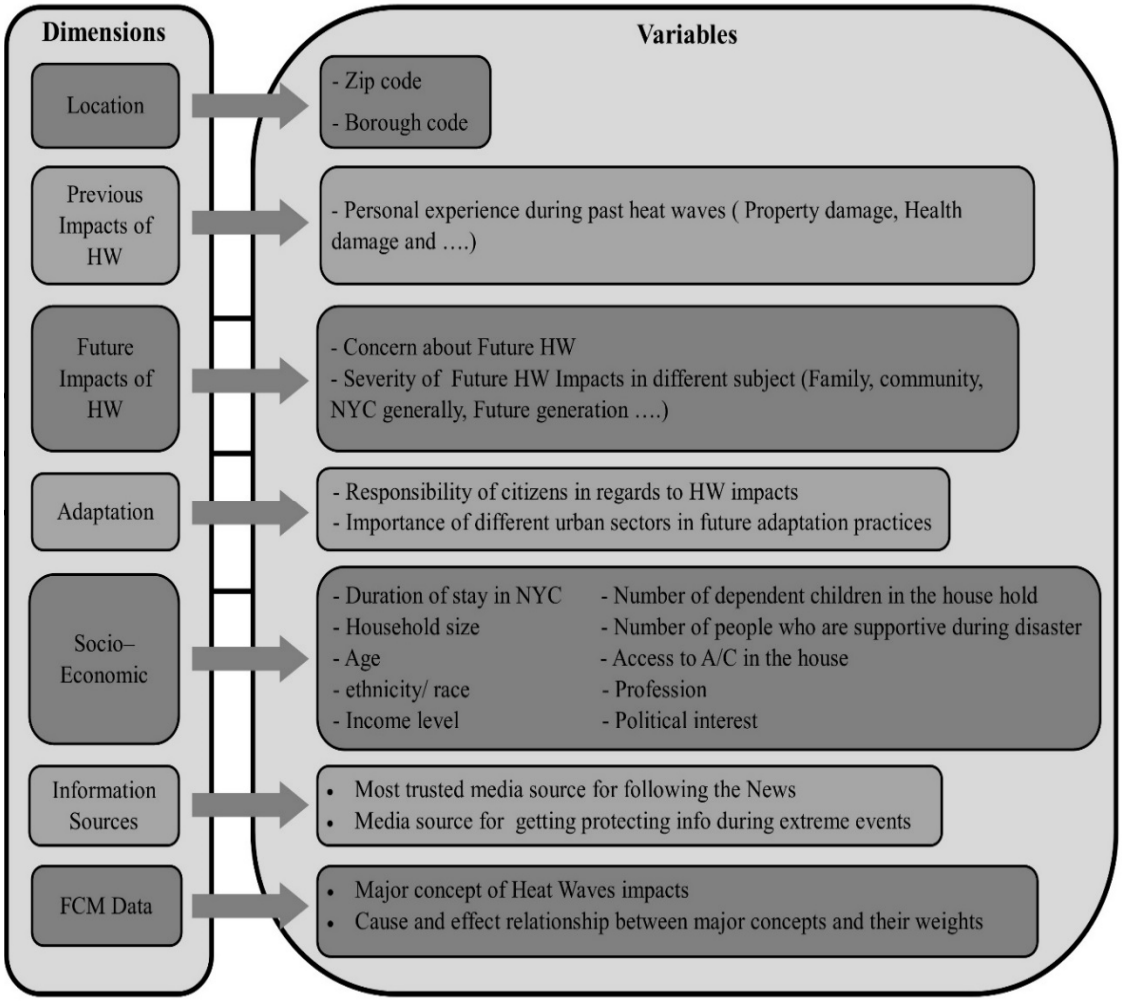


Figure 3: Structure of the research data set.
Source: Own draft

As is shown Figure 3, the data set includes seven main dimensions, and each dimension includes different variables. The "*location*" dimension includes variable about the location of interviewees on the scale of zip code level in New York City. The dimensions in regards to "*pervious and future impacts of heat waves*" and "*adaptation*" focus on citizens' perceptions and "*socio-economic*" and "*information source*" dimensions include information about household's characteristics. The "*FCM data*" dimension focus on basic information in regards to formulating FCM method and develop social cognitive maps related to impacts of heat waves in New York City.

3.3. Research methodology

The flow chart of research methodology is presented in figure 4. As it is shown in the flow chart, this research starts with literature review which represent in chapter 2.

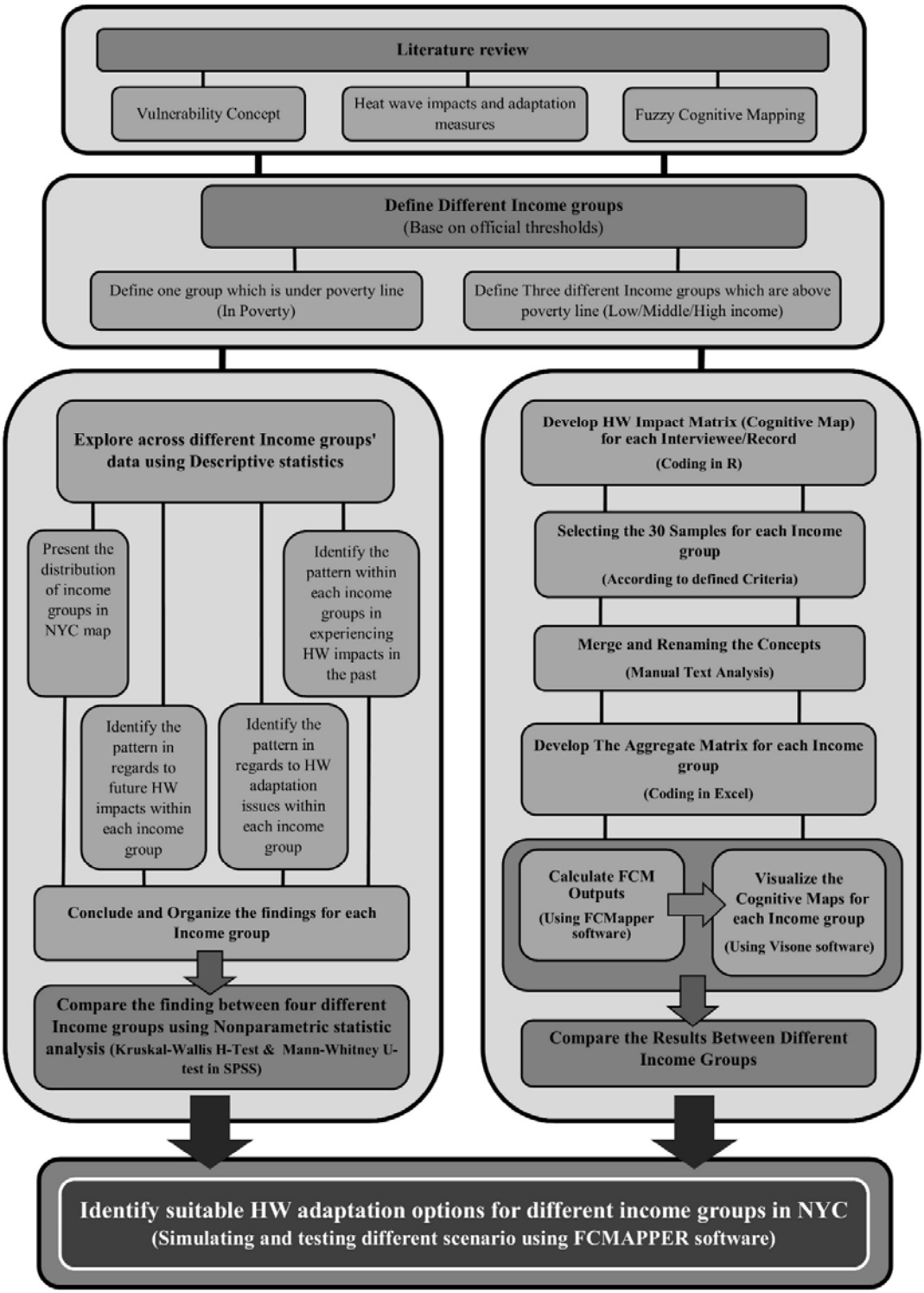


Figure 4: Flowchart of Research Methodology
Source: Own draft

After literature review, in the first step the records in the data set are divided to different income groups by using existing official threshold for 2013 in New York City. In this step, first according to DeNavas-Walt & Proctor (2014), in poverty group is defined based on suggested poverty thresholds by using household income and household size variables available in the dataset. The poverty threshold which is used is presented in appendix (section 7.1).

The rest of the data set records which are not below poverty line are categorized to three different groups:

- Low income group
- Middle income group
- High income group

To define these three groups, at least the household income threshold for middle income group should be defined. It is important to consider that "*there is no official government definition of who belongs to the middle class. The middle class may refer to a group with a common point of view or to those having similar incomes*" (Elkwell, 2014, P. 4). Based on distribution of household income in different income classes, there are different method to define the middle classes. In this research, the method introduced in Congressional Research Service report about middle class in USA (Elkwell, 2014) and formulated by the Pew research center is selected.
The Pew research center defines "*middle-income households as those whose annual household income is two-thirds to double the U.S. median household income after incomes have been adjusted for household size*" (Kochhar & Fry, 2015, P1). Kiersz & Kane (2015) used the Pew research centre method and applied it on median income numbers from the US Census Bureau's 2013 American Community Survey to define the thresholds for middle income group in New York State and New York City. The results are presented in table 6.

Location	Lower Bound	Upper Bound
New York State	38,264 $	114,738 $
New York City	43,875 $	131,572 $

Table 6: Selected Threshold (household income per year) to define Middle Income group
Source: (Kiersz & Kane, 2015)

By considering the threshold for New York City as listed in table 6 and using the household income and personal income field in the data set, three income groups which are not under poverty line are defined in this research.

As is explained, the records in research data set are divided to 4 different income groups. The frequency information and structure of these 4 groups in the research data set are presented in table 7 and table 8.

Groups		Frequency in Dataset	% in Dataset
Valid	**In Poverty**	101	13.3
	Low Income	221	29.0
	Middle Income	365	47.9
	High Income	70	9.2
	Total	757	99.3
Missing		5	.7
Total		762	100.0

Table 7: Frequency Information about the Income groups in research dataset
Source: Own draft

After defining the income groups, the research include three major part which are explained in the next sections.

Table 8: Structure of different income groups in research dataset
Source: Own draft

Income group	Frequency of MEN (% in the group)	Frequency of FEMALE (% in the group)	Mean of Household size	Frequency of Youth[9] (% in Group)	Frequency of Adults[10] (% in Group)	Frequency of Seniors[11] (% in Group)
In-Poverty	37 (36.6%)	64 (63.4%)	3	34 (33.7%)	63 (62.4%)	4 (4.0%)
Low-Income	99 (44.8%)	122 (55.2%)	2	41 (18.6%)	157 (71.0%)	23 (10.4%)
Middle-Income	172 (47.1%)	193 (52.9%)	3	42 (11.5%)	276 (75.6%)	47 (12.9%)
High-Income	53 (75.7%)	17 (24.3%)	3	0 (0.0%)	59 (84.3%)	11 (15.7%)
Total	361 (47.7%)	396 (52.3%)	2.61	117 (15.4%)	555 (73.3%)	85 (11.2)

3.3.1. Statistical analysis

The first part of which is mainly a statistical analysis, starts with exploring different characteristics across four defined income groups by using descriptive statistics. The goal in this step is to find the main patterns in regards to heat wave impacts and adaptation dimensions in each income groups. At the end of this section of research, the main similarity and differences between four income groups are identified. To have a better understanding of differences between these groups non-parametric statistical analysis will be used.

According to Corder & Foreman (2009), one of the major parametric analysis assumptions is that the sample must consist of values on an interval or ratio measurement scale. Due to the structure of this research data set which mainly include nominal and ordinal variables, the parametric analysis is not suitable option for this research and non-parametric statistical analysis are chosen.
According to Corder & Foreman (2009) and Carver & Nash (2010), for comparing more than two unrelated samples which is the task in this part of the research, The **Kruskal-Wallis H-Test** should be computed. *"The Kruskal-Wallis H-Test is a nonparametric statistical procedure for comparing more than two samples that are independent, or not related. The parametric equivalent to this test is the one-way analysis of variance (ANOVA). When the results of Kruskal-Wallis H-Test leads to significant results, then at least one of the samples is different from the other samples. However, the test does not identify where the difference(s) occur"* (Corder & Foreman, 2009, P. 100).
To identify the particular differences between sample pairs, a researcher might use sample contrasts, or post hoc tests, to analyze the specific sample pairs for significant difference(s). According to Corder & Foreman (2009) and Carver & Nash (2010), The **Mann-Whitney U-test** is a useful test for performing sample contrasts between individual sample sets. Therefore this test is selected to identify where the differences are located between four different defined income groups in this research.
In all the statistical analysis which are computed in this research, the null hypothesis (H0) is defined that no difference exists between four different groups and alternate hypothesis or research hypothesis (HA), is defined that there is a significant difference between defined income groups. For the level of significance

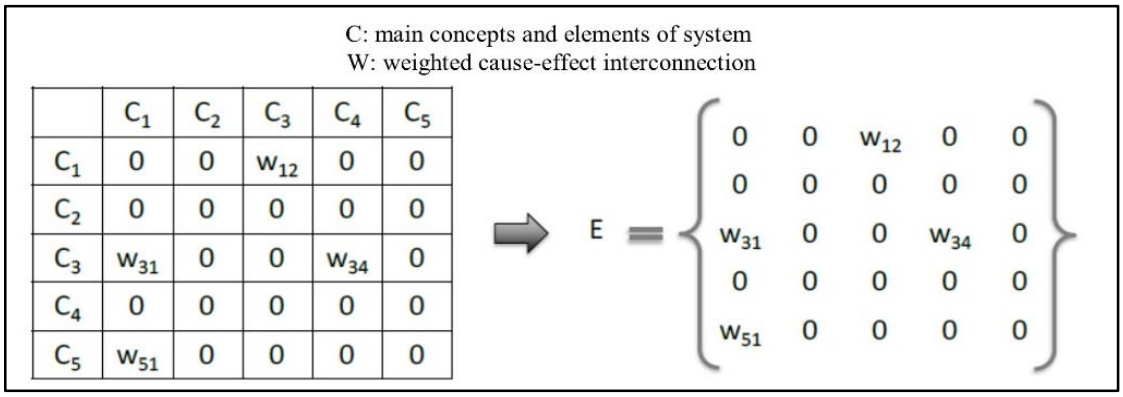
[9] **Youth (18-24 years)**
[10] **Adults (25-64 years)**
[11] **Seniors (65 years and over)**

(or the level of risk) commonly accepted value of $\alpha = 0.05$ is selected. By using this value, "*there is a 95% chance that our statistical findings are real and not due to chance."*(Corder & Foreman, 2009, P. 102) SPSS software is used to compute all the statistical analysis in this research.

3.3.2. FCM analysis

The second part after defining the income groups is about FCM analysis. This part starts with transforming the FCM data in the data set to Heat wave impact matrix (cognitive map) for each interviewee (records). To develop these matrix (which include the concepts that citizens stated and cause and effect relationship between stated concepts), the codding in R package is used. A sample of these matrix is presented in figure 5.

The next step is selecting the sample for FCM analysis based on the socio-demographic characteristics of interviewees (records) in the research dataset. A sample will be selected for each income groups (In Poverty/Low/Middle/High).



	C_1	C_2	C_3	C_4	C_5
C_1	0	0	w_{12}	0	0
C_2	0	0	0	0	0
C_3	w_{31}	0	0	w_{34}	0
C_4	0	0	0	0	0
C_5	w_{51}	0	0	0	0

$$E = \begin{Bmatrix} 0 & 0 & w_{12} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ w_{31} & 0 & 0 & w_{34} & 0 \\ 0 & 0 & 0 & 0 & 0 \\ w_{51} & 0 & 0 & 0 & 0 \end{Bmatrix}$$

Figure 5: A sample of network matrix as a result of FCM method
Source: (Olazabal & Reckien, 2015)

For selecting the sample size, in regards to achieve a sufficient level of validity and reliability in results, this research follows the suggested method by Özesmi & Özesmi (2004). "*FCMs are created with different people until the population to be represented has been sampled sufficiently. To determine this, accumulation curves of the total number of variables versus number of interviews as well as the number of new variables added per interview can be examined"* (Özesmi & Özesmi, 2004, P. 48).

Accumulation curves (average) can be developed by using Monte Carlo techniques. Example of accumulation curves for number of interviews versus total number of variables are presented in Figure 6. Figure 7 shows the accumulation curves for the number of new variables added per interview. As the number of interviews increase the total number of variables and new variables added to maps levels off.

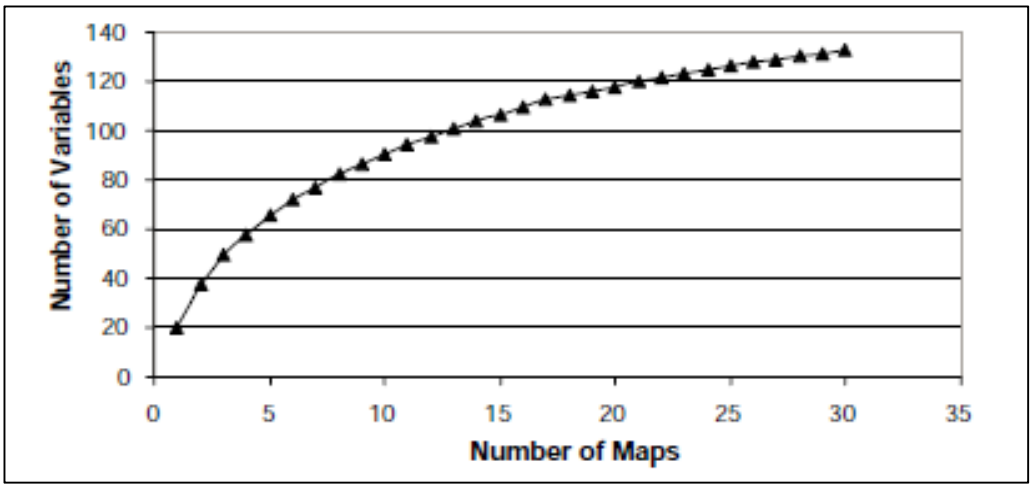


Figure 6: Accumulation curves for number of interviews versus total number of variables (Monte Carlo techniques) Source: (Özesmi & Özesmi, 2004, P. 48)

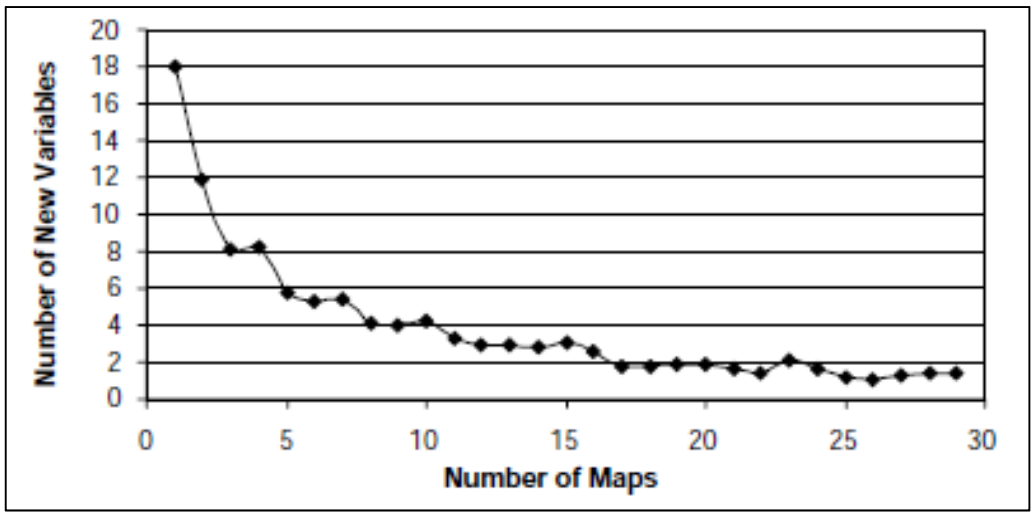


Figure 7: Accumulation curves for the number of new variables added per interview (Monte Carlo techniques) Source: (Özesmi & Özesmi, 2004, P. 48)

Following the suggested method, the sample with 30 records is selected for each income groups (120 in total for all income groups). The main criteria for selecting these samples according to priority are presented below:

1. Highest number of stated concepts (minimum 4 concepts must be stated)
2. Equal distribution in different boroughs (According to database availability)
3. Equal composition in age groups (According to database availability)
4. Equal composition for each Gender (According to database availability)

The detailed spatial and socio-demographic information for records with minimum 4 stated impacts about each income group's sample and availability of data in the research dataset is presented in table 9 to table 12.

In Poverty Group sample Details				Dataset availability for In Poverty group	
Borough (Total number of record in sample)	**Age Group**	**Male**	**Female**	**Male**	**Female**
Staten Islands (4)	**Youth**[12]	-	-	0	0
	Adults[13]	1	2	1	2
	Seniors[14]	-	1	0	1
Queens (7)	**Youth**	1	1	1	1
	Adults	2	3	3	4
	Seniors	-	-	0	0
Manhattan (6)	**Youth**	1	1	1	3
	Adults	1	2	2	5
	Seniors	1	-	1	0
Brooklyn (7)	**Youth**	2	2	2	3
	Adults	2	1	3	3
	Seniors	-	-	0	0
Bronx (6)	**Youth**	2	1	2	1
	Adults	1	2	1	4
	Seniors	-	-	0	0
Total		14	16	17	27

Table 9: Detailed spatial and socio-demographic information about In Poverty Group's sample
Source: Own draft

Low Income Group Sample Details				Dataset availability for Low Income group	
Borough (Total number of record in sample)	**Age Group**	**Male**	**Female**	**Male**	**Female**
Staten Islands (6)	**Youth**	-	-	0	0
	Adults	2	2	6	4
	Seniors	-	2	0	5
Queens (6)	**Youth**	-	2	0	5
	Adults	1	1	11	10
	Seniors	1	1	1	2
Manhattan (6)	**Youth**	-	1	0	1
	Adults	2	1	10	6
	Seniors	-	2	0	3
Brooklyn (6)	**Youth**	-	2	0	7
	Adults	2	1	10	8
	Seniors	-	1	0	1

[12] **Youth (18-24 years)**
[13] **Adults (25-64 years)**
[14] **Seniors (65 years and over)**

Bronx (6)	**Youth**	1	1	1	2
	Adults	1	1	3	6
	Seniors	1	1	1	1
Total		11	19	43	61

Table 10: Detailed spatial and socio-demographic information about Low Income Group's sample
Source: Own draft

Middle Income Group sample Details				**Dataset availability for Middle Income group**	
Borough	**Age Group**	**Male**	**Female**	**Male**	**Female**
Staten Islands (6)	**Youth**	1	1	1	3
	Adults	1	1	4	6
	Seniors	1	1	1	2
Queens (6)	**Youth**	1	1	1	4
	Adults	1	1	13	17
	Seniors	1	1	1	5
Manhattan (6)	**Youth**	-	2	0	5
	Adults	1	1	17	18
	Seniors	1	1	1	5
Brooklyn (6)	**Youth**	1	1	2	3
	Adults	2	1	19	11
	Seniors	-	1	0	1
Bronx (6)	**Youth**	1	1	1	2
	Adults	1	1	4	8
	Seniors	2	-	2	0
Total		15	15	67	90

Table 11: Detailed spatial and socio-demographic information about Middle Income Group's sample
Source: Own draft

High Income Groups sample Details				**Dataset availability for High Income group**	
Borough	**Age Group**	**Male**	**Female**	**Male**	**Female**
Staten Islands (4)	**Youth**	-	-	0	0
	Adults	1	3	1	3
	Seniors	-	-	0	0
Queens (6)	**Youth**	-	-	0	0
	Adults	5	-	5	0
	Seniors	1	-	1	0
Manhattan (14)	**Youth**	-	-	0	0
	Adults	5	4	9	4
	Seniors	5	-	5	0
Brooklyn (6)	**Youth**	-	-	0	0

	Adults	5	1	5	1
	Seniors	-	-	0	0
Bronx (0)	**Youth**	-	-	0	0
	Adults	-	-	0	0
	Seniors	-	-	0	0
Total		22	8	26	8

Table 12: Detailed spatial and socio-demographic information about High Income Group's sample
Source: Own draft

In next step, the first developed individual matrix for each interview analysed (manual text analysis) and the stated concepts are coded in one united format.
After transforming all the individual cognitive maps (matrix) in the same format, the 30 individual cognitive maps will be aggregated to develop the social cognitive maps for each income groups. "*In the process of aggregation, the first task is to identify similar concepts across individual maps through which maps and matrices can be connected. The second task is to average the multiple weights between similar concepts that result from different stakeholders. This means that individual adjacency matrices are aggregated by combining the weights of connections between the same concepts given by the different stakeholders (to end up with just one number in each cell of the matrix) and by adding a new row and column for each new concept given by the stakeholder added*"(Olazabal & Reckien, 2015, P. 154).
According to Olazabal & Reckien (2015), the most common way to merge multiple weight between the same concepts is simple averaging which is accepted and used in this research.
The whole process of aggregation and developing the social cognitive maps (aggregated matrix) for each income groups after uniting them in the same format is done by coding in Excel in VBE[15].

After aggregation process is completed, statistical analyses can be performed on the social map(s). The last version of FCMAPPER software (open access software downloaded from www.FCMAPPER.net) is used in this research to perform FCM analysis. According to the results of FCM analysis, assessing the structure of income group's cognitive maps in regards to impacts of heat waves would be possible. Furthermore, different scenarios could be simulated and the effect of each scenario on the network can be assessed.

The equations used in FCM analysis are shown in Table 8 (Eq. 1 to 4 are relate to analysis of the network and Eq. 5 relates to simulating the scenarios).

For visualizing the results of FCM analysis in regards to state of each income group's network, Visone software is used and the results are presented in next chapter of the report.

[15] Visual Basic Editor

Equation		Description
Eq. 1	$D = \frac{\sum C_i C_j}{N}$	Density (D) is calculated by dividing the number of actual connections (C_i C_j) by the number of total possible connections. It is an indicator of connectivity.
Eq. 2	$Ct_i = O_i + I_i$	Centrality (Ct) is the sum of a concept's in- and out-degrees (I and O respectively). It denotes the individual importance of a concept (Reckien et al. 2013) in respect to other concepts in the network.
Eq. 3	$O_i = \sum_{k=1}^{k} \bar{w}_{ik}$	O_i is the out-degree of a concept. It is calculated by adding up the absolute weights of all outgoing connections of a particular concept. It is a measure of the strength of the influence of one concept C_i on other concepts in the network. In other words, it is the row sum of absolute values of a variable in the adjacency matrix (Özesmi and Özesmi 2004).
Eq. 4	$I_i = \sum_{k=1}^{k} \bar{w}_{ki}$	I_i is the in-degree of a concept. It is calculated by adding up the absolute weights of all incoming connections of a concept. It is a measure of the dependency of a concept on other concepts in the network, i.e. the column sum of absolute values of a variable.
Eq. 5	$A_i^{(k+1)} = \left(A_i^{(k)} + \sum_{\substack{j=1 \\ j \neq i}}^{N} A_j^{(k)} w_{ji} \right)$	Eq. 5 enables scenarios to be built (Özesmi and Özesmi 2004; Kok 2009). The state vector A of the baseline scenario is normally created by initially setting the state values of all the concepts to 1 (hypothetically, other initial values are possible if proper reasoning is provided, e.g. by asking stakeholders to gauge the importance of the

Figure 8: FCM analysis Equations
Source: (Olazabal & Reckien 2015, P. 157)

3.3.3. FCM scenario simulation

The final part of research is identifying the suitable heat wave adaptation option for each income group based on their social Cognitive map (the research main objective) by testing and simulating different scenarios in FCMAPPER software.

FCM scenario analysis (Eq. 5 in table 11) enables the dynamics of the state vector A to be calculated. This vector is the most important output of FCM. This vector can be calculated by focusing on the effect that each concept has on the other concepts in the network over a number of iterations or time steps (k) (normally 20-30 iterations) (Kok, 2009). "*Scenario generation has been recognized as one of the most valuable applications of FCM in general and in environmental management in particular*" (Kok, 2009; Jetter & Schweinfort, 2011 cited in Olazabal & Reckien, 2015, P. 158).

Three different scenarios are simulated and tested for each income groups:

- Investment and Development In NYC Public Health Sector
- Investment and Development in NYC Water and Electricity System
- Investment and Development In NYC Transit Sector

The selected concepts and their fixed value for simulating three scenarios in FCMAPPER is presented in table 13 to table 16.
According to Olazabal & Reckien (2015), the selected value must be between 0 to 1. The selected values for concepts in regards to health issues is mainly 0.1 which means by implementing the scenario the effect of that concepts would reduce to minimum level but still affect the system. For the concepts with 0 value, the effect of concepts is completely removed. Value 1 represent the maximum effect and 0.9 means the effect of concept is increased through implementing the scenario but not in maximum level.
It should be considered that all these number represent a cause and effect relationships and any comparison about intensity of these relationship is not possible. For instance the value 0.9 compare to value 0.1 does not mean the effect of first value is 9 time bigger than the smaller one.

According to Olazabal & Reckien (2015), the selected concepts based on simulated scenario would be fixed to the selected value through 30 iteration in FCMAPPER, and the change in other concepts would be assessed and compare with the current state of system (which all the concepts value are 1 in FCMAPPER that means no change is simulated).

Subject of simulated scenarios for In Poverty Group					
Public Health Sector		**Water and Electricity System**		**Transit Sector**	
Concept	**Value**	**Concept**	**Value**	**Concept**	**Value**
Anxiousness	0.1	Drought	0.1	Transportation usage	1
Asthma	0.1	Water shortage	0.1	Intolerable subway/transit platforms	0
Cardiac arrest	0.1	Blackout/Power shortage	0	Subway failures	0
Death	0.1	Water line problem	0		
Fatigue	0.1				
Children death	0.1				
Elderly death	0.1				
Heat stroke	0.1				
Hyperthermia	0.1				
Illness	0.1				
Migraine	0.1				
Skin cancer	0.1				

Table 13: Selected concepts and their value for scenario simulation in FCMAPPER for In Poverty Group
Source: Own draft

Subject of simulated scenarios for Low Income Group					
Public Health Sector		**Water and Electricity System**		**Transit Sector**	
Concept	**Value**	**Concept**	**Value**	**Concept**	**Value**
Anxiousness	0.1	Conserving water	1	Subway delays	0
Asthma	0.1	Drought	0.1	Intolerable subway/transit platforms	0
Harmful for children	0.1	Water shortage	0.1	Overheated cars	0.1
Death	0.1	Blackout/Power shortage	0		
Depression	0.1	Non-functional elevators	0		
Fatigue	0.1				
Harmful for disabled	0.1				
Harmful for elderly	0.1				
Heat stroke	0.1				
Illness	0.1				
Spread of infections	0.1				

Table 14: Selected concepts and their value for scenario simulation in FCMAPPER for Low Income Group
Source: Own draft

Subject of simulated scenarios for Middle Income Group					
Public Health Sector		**Water and Electricity System**		**Transit Sector**	
Concept	**Value**	**Concept**	**Value**	**Concept**	**Value**
Anxiousness	0.1	Water pollution	0.1	Asphalt melting	0
Asthma	0.1	Water shortage	0.1	Transportation failure	0
Cabin fever	0.1	Drought	0.1	More traffic	0.1
Death	0.1	Low water pressure	0	Intolerable platforms	0
Depression	0.1	Blackout/Power shortage	0	Delays	0
Faint	0.1	Electronics damage	0	Overheated cars	0.1
Fatigue	0.1				
Health of elderly	0.9				
Heat stroke	0.1				
Illness	0.1				
Pestilence	0.1				
Skin cancer	0.1				

Table 15: Selected concepts and their value for scenario simulation in FCMAPPER for Middle Income Group
Source: Own draft

Subject of simulated scenarios for High Income Group					
Public Health Sector		**Water and Electricity System**		**Transit Sector**	
Concept	**Value**	**Concept**	**Value**	**Concept**	**Value**
Asthma	0.1	Draught	0.1	Destroyed roads	0
Death	0.1	Water shortage	0.1	Infrastructure damage	0
Fatigue	0.1	Blackout/Power shortage	0	Intolerable subway/transit platforms	0
Harmful for elderly	0.1	Decreased fire hydrant pressure	0	Less comfortable commute	0
Cardiac arrest	0.1			More accidents	0.1
Heat stroke	0.1				
Hyperthermia	0.1				
Illness	0.1				
People & animals cooling off problem	0.1				

Table 16: Selected concepts and their value for scenario simulation in FCMAPPER for High Income Group
Source: Own draft

4. RESULTS AND DISCUSSION

In this chapter of the report, the results of the analysis as described in last section and the discussion with respect to research objectives are presented. First the distribution of different income groups (in the research sample) is discussed and the results of statistical analysis and FCM analysis are presented in next two sections.

4.1. Distribution of sample's different income groups in New York City

The distribution of defined income groups (in research samples) in different boroughs of New York City is shown in Figure 9.

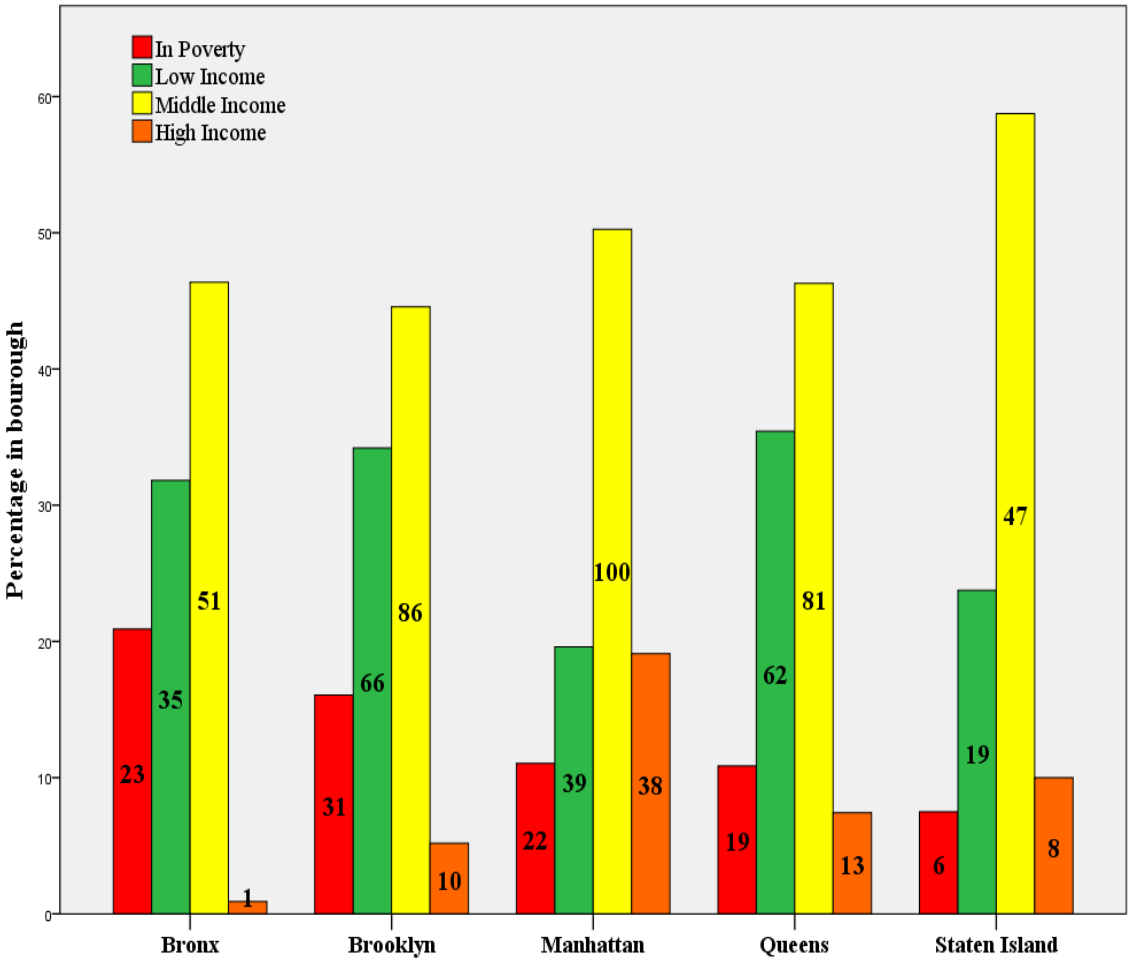


Figure 9: Distribution of different income groups in New York City.
(The numbers inside the bar represent the number of respond in data base)
Source: Own draft

As it is presented in figure 9, the middle income group has the greatest share in all boroughs and after that low income groups and in poverty groups. The high income group has the lowest share in all boroughs. There is only one records related to high income groups in Bronx and it has the highest share of in poverty groups which is completely similar to the results of American Community Survey (ACS) presented in section 3.1 (table 4).

4.2. Statistical analysis results

In this section of reports, the results of statistical analysis with respects to research objectives are presented.

4.2.1. Past impacts of heat waves

Impacts of heat waves experienced by citizens in the past according to different subjects is evaluated based on citizen's statement. The question is "*In the past 10 years, are they experience any damage in regards to different subjects (Damage to your property, lost income, Health-related damage, Other, No harm)*? The results for each income group is presented in table 17.

Income Group		Damage to your property	Lost income, e.g. due to not being able to go to work	Health-related damage	Other, such as ...	No harm	Total
In Poverty	Count	0	3	26	12	66	100
	% within Group	0.0%	3.0%	26.0%	12.0%	66.0%	100%
Low Income	Count	7	16	36	22	152	219
	% within Group	3.2%	7.3%	16.4%	10.0%	69.4%	100%
Middle Income	Count	15	18	63	37	249	362
	% within Group	4.1%	5.0%	17.4%	10.2%	68.8%	100%
High Income	Count	4	4	15	11	44	70
	% within Group	5.7%	5.7%	21.4%	15.7%	62.9%	100%
Total	Count	26	41	140	82	511	751

Table 17: Impacts of heat waves in the past (experienced by different income groups)
Source: Own draft.

As it shows in the table 17 (highlighted cells in red), the majority of citizens (more than 62% in all income groups), express that they didn't experience any harm from heat waves in the past 10 years.

Figure 10, shows the share of income groups in different type of negative impacts caused by heat waves within citizens who express they experience some type of harm from heat waves in past 10 years.
As it is presented in the figure 10, the major part of negative impacts experience by all income groups is in regards to health related issues. Within the category 'others' which has the second highest share in all income groups, citizens mostly mention the city infrastructure failures and power black outs. Health related damages has the highest share in in poverty groups compare to other income groups while damage to property is not mentioned at all by in poverty groups. Damages related to lost income has the highest share in low income groups.

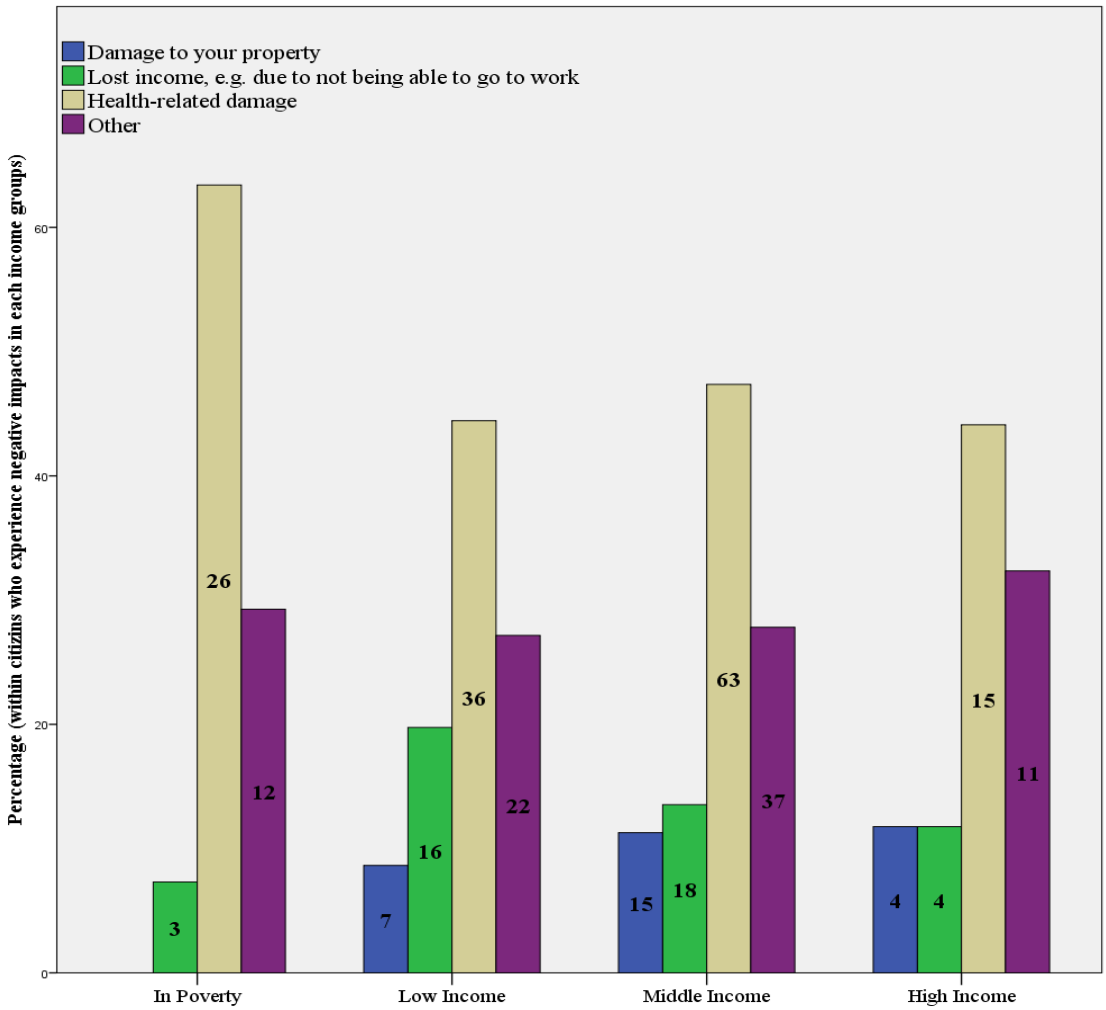


Figure 10: Negative Impacts of heat waves in the past (experienced by different income groups)
(The numbers inside the bar represent the number of respond in data base)
Source: Own draft.

4.2.2. Future impacts of heat waves

For evaluating different income groups' concerns about future impacts of heat waves, first, different income groups' expressions in regards to the question about "*how much they are generally worried about future impacts of heat waves in next 20 years*?" are analysed. The results are presented in figure 11.

According to figure11, the majority of citizens in all income groups (more that 72 % in all income groups) are somewhat or very worried about future impacts of heat waves. Among the citizens which are very worried in each income group, in poverty group (30.6%) and low income group (28.5%) have higher share compare to middle income group (21.1%) and high income group (24.3%) while among citizens which are somewhat worried in each income group, high income group (54.3%) and middle income group (51.8%) have higher share compare to low income group (45.7%) and in poverty group (44.5%).

According to these results, in lower income groups (in poverty and low income) more people are very worried about future impacts of heat waves compare to groups with higher income (middle income and high income groups).

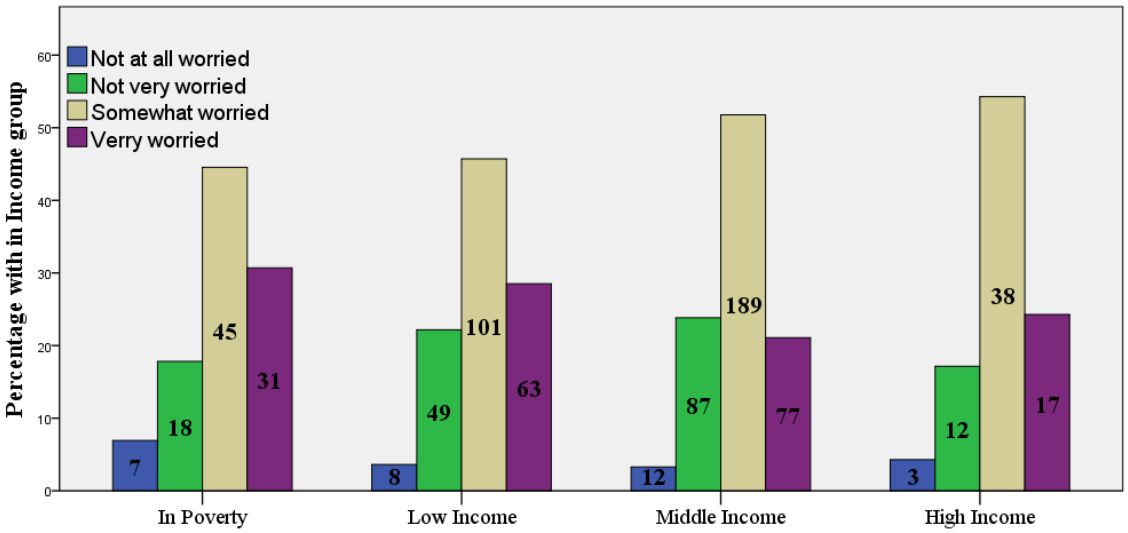


Figure 11: Different income groups' level of concerns about future impacts of heat waves
(The numbers inside the bar represent the number of respond in data base)
Source: Own draft.

In next step, to have a better understanding about different income groups' concerns about future impacts of heat waves, expected intensity of negative impacts of heat waves on different subjects according to citizens' statement are evaluated. The question is " *How much do they think the impacts of heat waves will harm different subjects (you personally, your family, your community, your borough, NYC in general, Future generation, plant & animal, public property, people's private property)*? This step's results are presented in figure 12 and figure 13.These results are presented in table format in appendix (section 7.2).

According to figure 12 and 13, almost in all evaluated subjects, Among the citizens which stated very severe harms in each income groups, in poverty groups and low income groups have higher share compare to middle income group and high income group while the results is almost opposite among citizens who stated not very severe harms in each income groups.

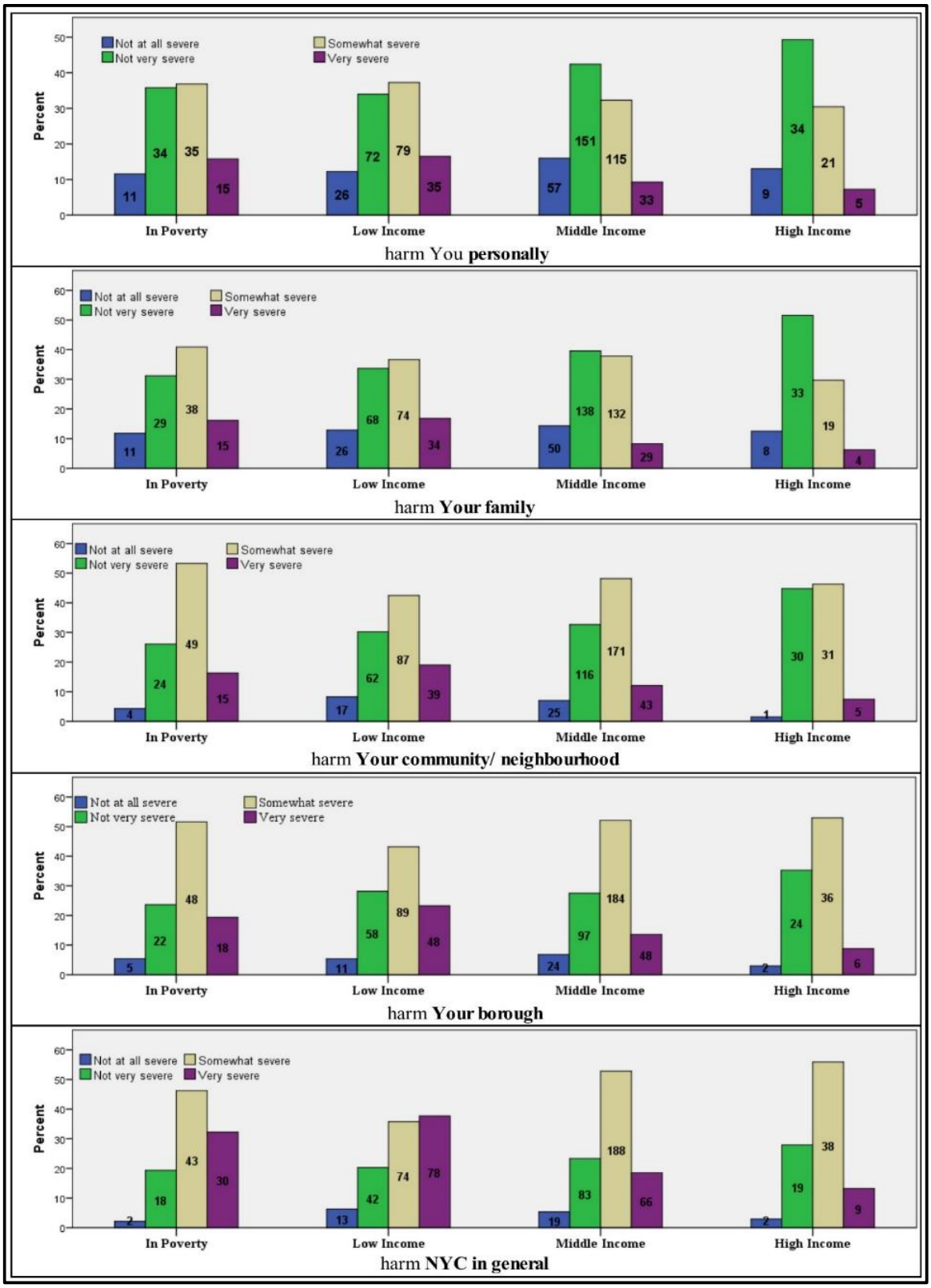


Figure 12: Different income groups concerns about future impacts of heat waves based on different subjects. (The numbers inside the bar represent the number of respond in data base)
Source: Own draft

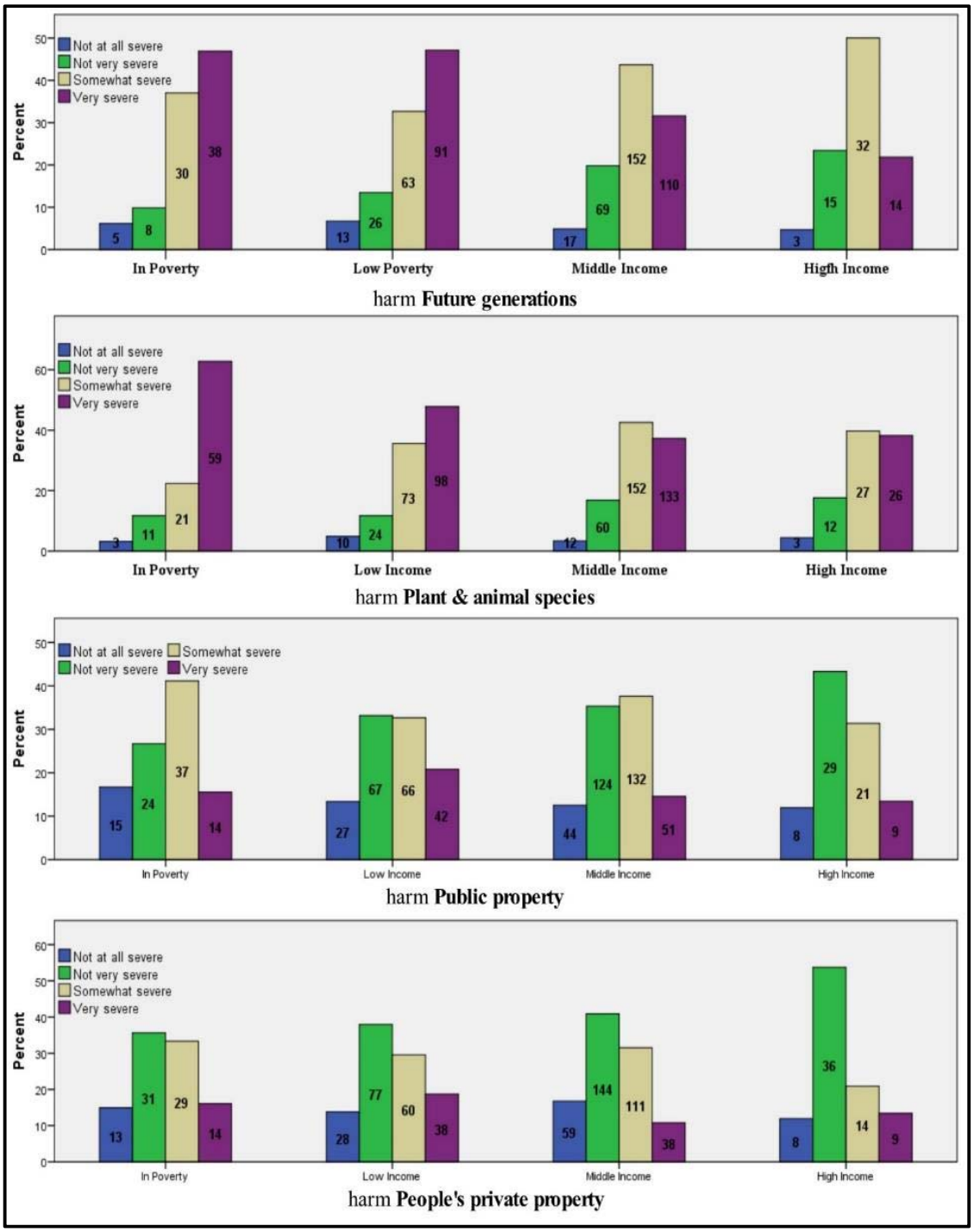


Figure 13: Different income groups concerns about future impacts of heat waves based on different subjects. (The numbers inside the bar represent the number of respond in data base)
Source: Own draft

As it explained in research methodology (section 3.3.1), In next step, to identify the significant differences across research income groups in regards to future impacts of heat waves, the Kruskal-Wallis H-Test is used. The results of this analysis is presented in table 18.

Subject	Chi-Square	Asymp. Sig.
Personal Life	12.661	.005
Family	10.283	.016
Community/ neighbourhood	5.033	.169
Borough	5.033	.169
NYC in general	16.184	.001
Future generations	16.724	.001
Plant & animal species	16.782	.001
Public property (e.g. roads, schools, public buildings)	1.584	.663
People's private property (e.g. homes, cars, boats)	5.082	.166

Table 18: Results of Kruskal-Wallis H-Test in regards to future impacts of heat waves.
(The highlighted text in red, shows the significant differences between income groups which "*Asymp. Sig.*" value is less than 0.05); Source: Own draft.

According to results to table 18, there is significant differences between four income groups in regards to these subjects (highlighted in red in table 18):

- Personal life
- Family
- New York City in general
- Future generation
- Plant & animal species

As it explained in research methodology (section 3.3.1), Mann-Whitney U-test is used to identify the exact location of significant differences between different income groups. The results of this test is presented in table 19.

According to table 19, there is not any significant differences between middle income groups and high income groups in regards to all evaluated subjects. The results is almost similar between in poverty groups and low income groups except for "*plant & animals species*" subject. According to the analysis results, all the identified significant differences are located between lower income groups (in poverty and low income group in one side) and higher income groups (middle income groups and high income groups on the other side).

According to the results of this section, in regards to negative impacts of heat waves in the future(which are analysed in this research), citizens with lower income (in poverty and low income) are more concerned compare to middle income and high income groups.

Subject	Location of significant differences (between income groups)		Mann-Whitney- U	Z-score	Asymp. Sig.
Personal life	In poverty	Low Income Group	9981.000	-.130	0.896
		Middle Income Group	14616.500	-2.154	0.031
		High Income Group	2751.500	-1.862	0.063
	Low Income	Middle Income Group	32334.000	-3.019	0.003
		High Income Group	6085.000	-2.214	0.027
	Middle Income Group	High Income Group	12034.500	-.282	0.778
Family	In poverty	Low Income Group	9150.000	-.376	0.707
		Middle Income Group	14061.500	-2.104	0.035
		High Income Group	2348.500	-2.380	0.017
	Low Income	Middle Income Group	31587.000	-2.154	0.031
		High Income Group	5313.000	-2.265	0.023
	Middle Income Group	High Income Group	10291.000	-1.067	0.286
New York City in general	In poverty	Low Income Group	9621.000	-.007	0.995
		Middle Income Group	13882.000	-2.612	0.009
		High Income Group	2490.000	-2.500	0.012
	Low Income	Middle Income Group	31329.500	-3.175	0.001
		High Income Group	5667.000	-2.555	0.011
	Middle Income Group	High Income Group	11523.500	-.689	0.491
Future generation	In poverty	Low Income Group	7672.500	-.260	0.795
		Middle Income Group	11739.500	-2.502	0.012
		High Income Group	1906.500	-2.924	0.003
	Low Income	Middle Income Group	28845.500	-2.898	0.004
		High Income Group	4730.5	-2.995	0.003
	Middle Income Group	High Income Group	10084.0	-1.284	0.199
Plant & animal species	In poverty	Low Income Group	8328.5	-2.076	0.038
		Middle Income Group	12830.5	-3.782	0.000
		High Income Group	2445.0	-2.803	0.005
	Low Income	Middle Income Group	32844.0	-2.178	0.029
		High Income Group	6238.5	-1.402	0.161
	Middle Income Group	High Income Group	12071.0	-0.077	0.938

Table 19: Results of Mann-Whitney U-test in regards to future impacts of heat waves.
(The highlighted text in red, shows the location of significant differences between income groups which "*Asymp. Sig.*" value is less than 0.05); Source: Own draft.

4.2.3. Heat wave adaptation

For evaluating different income groups in regards to heat wave adaptation issues, first, different income groups' access to air conditioning as one of the major adaptation tools to impacts of heat waves is analysed. The results for this step is presented in figure 14.

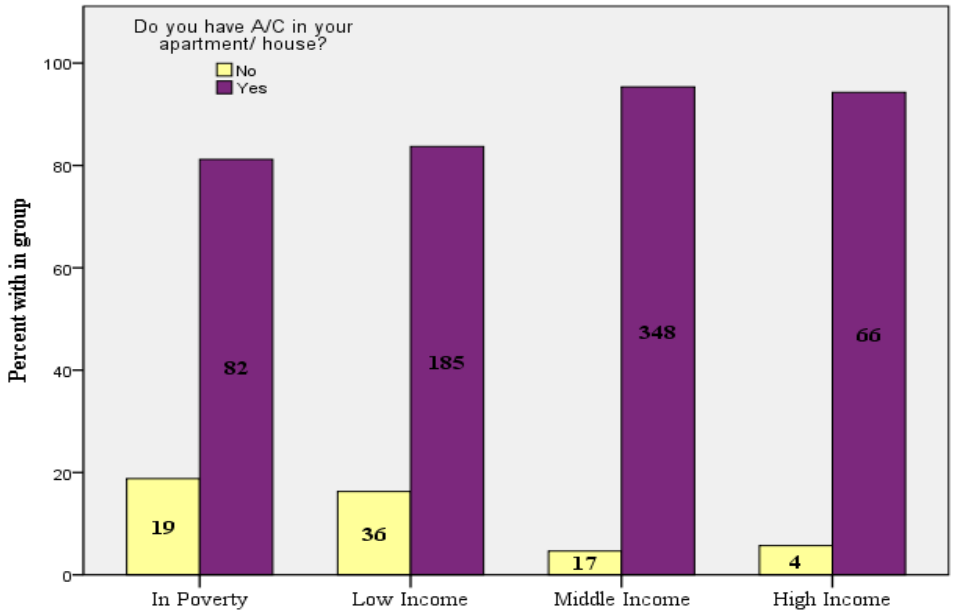


Figure 14: Access to air conditioning devices (A/C) across different income groups.
(The numbers inside the bar represent the number of respond in data base)
Source: Own draft

As it presented in figure 14, the majority of citizens (more than 80 % in all income groups stated that they have access to air conditioning devices. It should be considered that among citizens who doesn't have access to A/C In poverty and low income groups have a higher share compared to middle and high income groups. the results are almost similar and confirm the results of the research by Rosenzweig, Solecki, Degaetano, et al. (2011) which shows approximately 84 % of housing units had some form of indoor air conditioning in New York City.

In next step, different income group's expressions about citizens' responsibility in regards to adaptation issues are analysed. The question is "*Do they think citizens themselves should be doing more or less to protect themselves from the impacts of heat waves?"* The results are presented in figure 15.

According to figure15 the majority of citizens in each income groups (more than 68%) state that citizens should be more or much more responsible in heat wave adaptation issues.
Among the citizens which state that citizens should be much more responsible in each income group, in poverty group (27.72) and low income group (19.9%) have higher share compare to middle income group (17.5%) and high income group (10%) while among citizens which stated that citizens currently doing enough in each income group, high income group (28.6%) and middle income group (28.8%) have higher share compare to low income group (23.98%) and in poverty group (24.75%).
According to these results, in lower income groups (in poverty and low income) more people think citizens should be much more responsible in regards to impacts of heat waves compare to groups with higher income (middle income and high income groups).

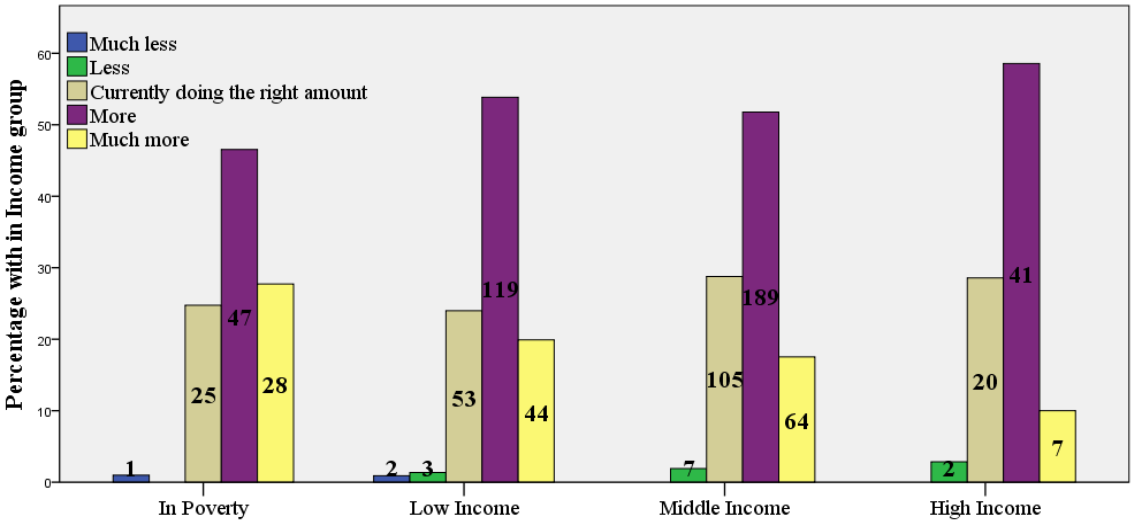


Figure 16: Different income groups expressions about citizens' responsibility in regards to adaptation issues. (The numbers inside the bar represent the number of respond in data base); Source: Own draft

In next step, to have a better understanding about different income groups' perception about importance of different urban sectors in regards to heat wave adaptation, different income groups' statements are evaluated. The results of this step is presented in figure 16 and figure 17. These results are presented in table format in appendix (section 7.3).

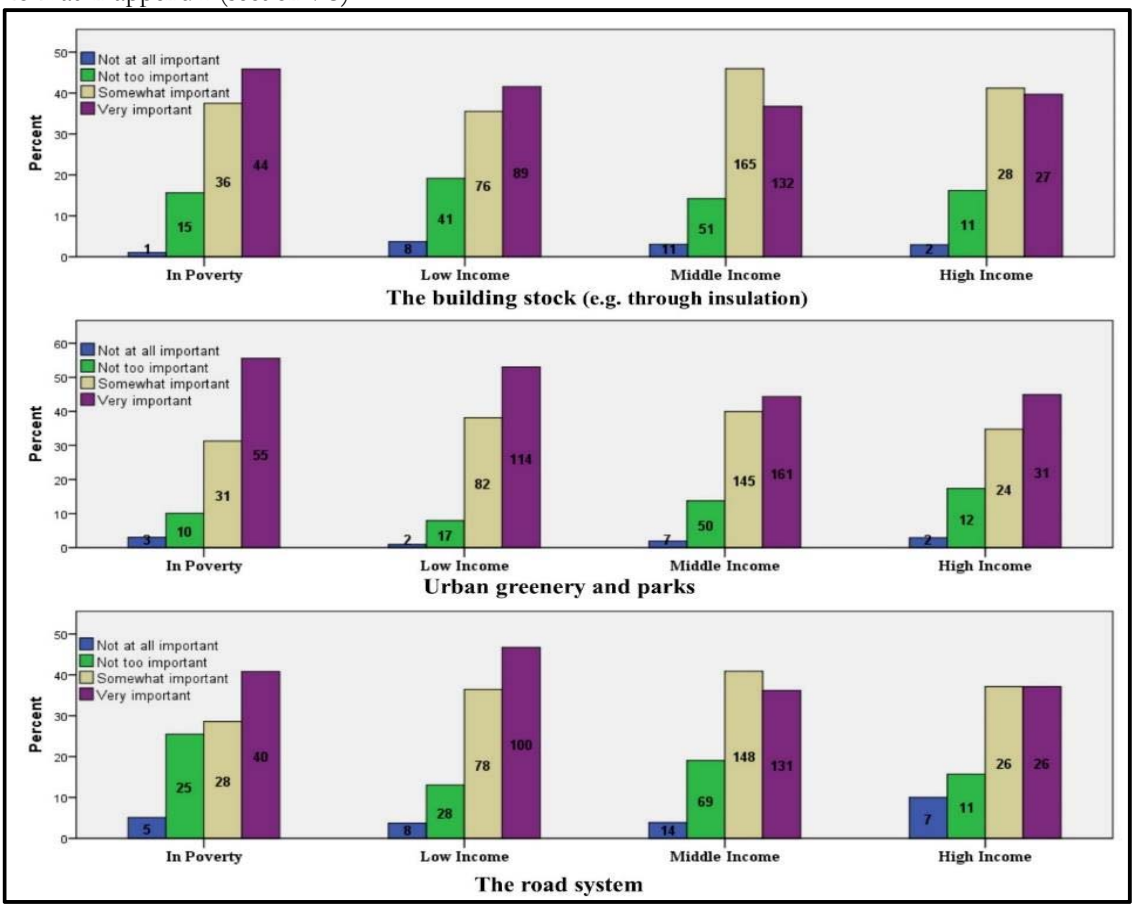


Figure 15: Importance of different urban sectors in heat wave adaptation based on income groups' perception. (The numbers inside the bar represent the number of respond in data base); Source: Own draft.

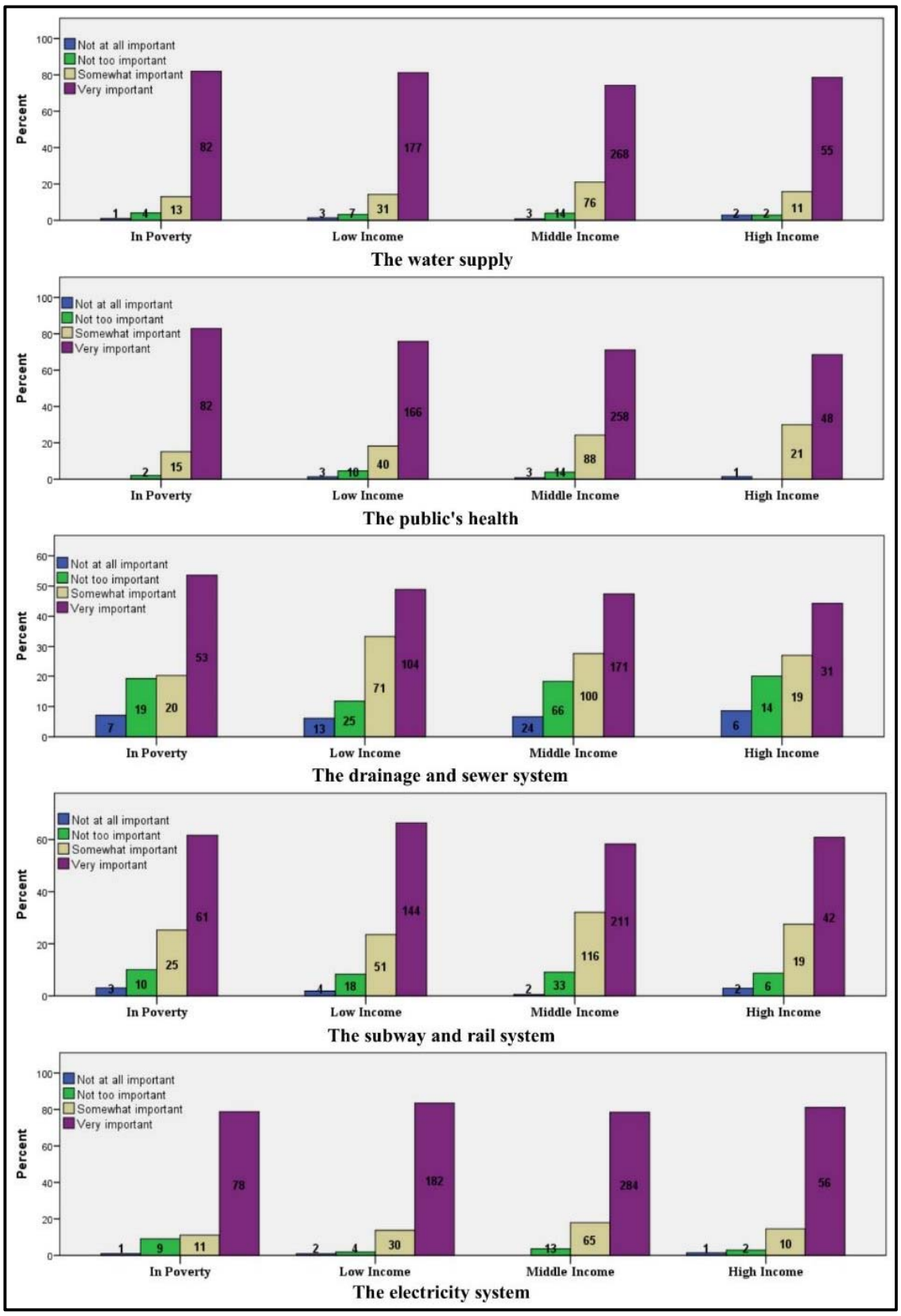


Figure 17: Importance of different urban sectors in heat wave adaptation based on income groups' perception. (The numbers inside the bar represent the number of respond in data base); Source: Own draft.

According to figure 16 and figure 17, majority of citizens in all income groups stated that the evaluated urban sectors are very important or somewhat important. Almost in all evaluated urban sectors, among the citizens which stated the sector is very important in each income groups, in poverty groups and low income groups have higher share compare to middle income group and high income group.

As it explained in research methodology (section 3.3.1), In next step, to identify the significant differences across research income groups in regards to importance of different urban sectors in heat wave adaptation, the Kruskal-Wallis H-Test is used. The results of this analysis is presented in table 20.

Urban Sectors	Chi-Square	Asymp. Sig.
The water supply	4.542	0.209
The public's health	6.561	0.087
The drainage and sewer system	2.001	0.572
The subway and rail system	2.683	0.443
The electricity system	2.530	0.470
The building stock, e.g. through insulation	1.782	0.619
Urban greenery and parks	8.384	0.039
The road system	7.675	0.053

Table 20: Results of Kruskal-Wallis H-Test in regards to Importance of different urban sectors in heat wave adaptation (The highlighted text in red, shows the significant differences between income groups which "*Asymp. Sig.*" value is less than 0.05); Source: Own draft.

According to results to table 20, there is significant differences between four income groups in regards to importance of "*Urban greenery and parks*" (highlighted in red in table 20.
As it explained in research methodology (section 3.3.1), Mann-Whitney U-test is used to identify the exact location of significant differences between different income groups. The results of this test is presented in table 21.

Urban Sector	Location of significant differences (between income groups)		Mann-Whitney-U	Z-score	Asymp. Sig.
Urban greenery and parks	In poverty	Low Income Group	10627.0	-0.023	0.981
		Middle Income Group	16054.5	-1.773	0.076
		High Income Group	2999.5	-1.473	0.141
	Low Income	Middle Income Group	34670.0	-2.462	0.014
		High Income Group	6466.0	-1.777	0.076
	Middle Income Group	High Income Group	12256.5	-0.305	0.761

Table 21: Results of Mann-Whitney U-test in regards to importance of urban sectors in heat wave adaptation. (The highlighted text in red, shows the location of significant differences between income groups which "*Asymp. Sig.*" value is less than 0.05); Source: Own draft.

According to table 21, the significant difference between income groups in regards to "*Urban greenery and parks*" is located between Low Income group and middle income groups which is highlighted in the table. The results shows that this urban sector is more important for lower income groups compare to middle income groups.

4.3. FCM analysis results

In this section, the results of FCM analysis are presented in two main part.
In the first part the general results and discussion about different income groups' cognitive maps' state with respect to impacts of heat wave are presented. The second parts mainly focuses on results of FCM scenario analysis results.

4.3.1. Income groups' cognitive maps state

According to results of FCM analysis, the general info about different income groups' cognitive maps (aggregated FCM for each income group with same number of respondents) in regards to impacts of heat wave in New York City is presented in table 22.

Income Group	Density	Total Nr. Connections	Total Nr. Factors(concepts)
In Poverty	0.108	389	60
Low Income	0.119	416	59
Middle Income	0.102	474	68
High Income	0.094	295	56

Table 22: General results of FCM analysis in regards to income groups' cognitive map
Source: Own draft

As it presented in the table 22, the middle income groups cognitive map has the highest number of concepts as is almost the most complex network compare to other groups while the high income groups has the lowest number of concepts and lowest density. The In poverty and low income groups almost have the similar number of concepts but the low income groups cognitive map has the highest density between all research income groups. The results of Different income groups' cognitive maps visualization (with respects to Centrality of concepts) is presented through figure 18 to figure 21.

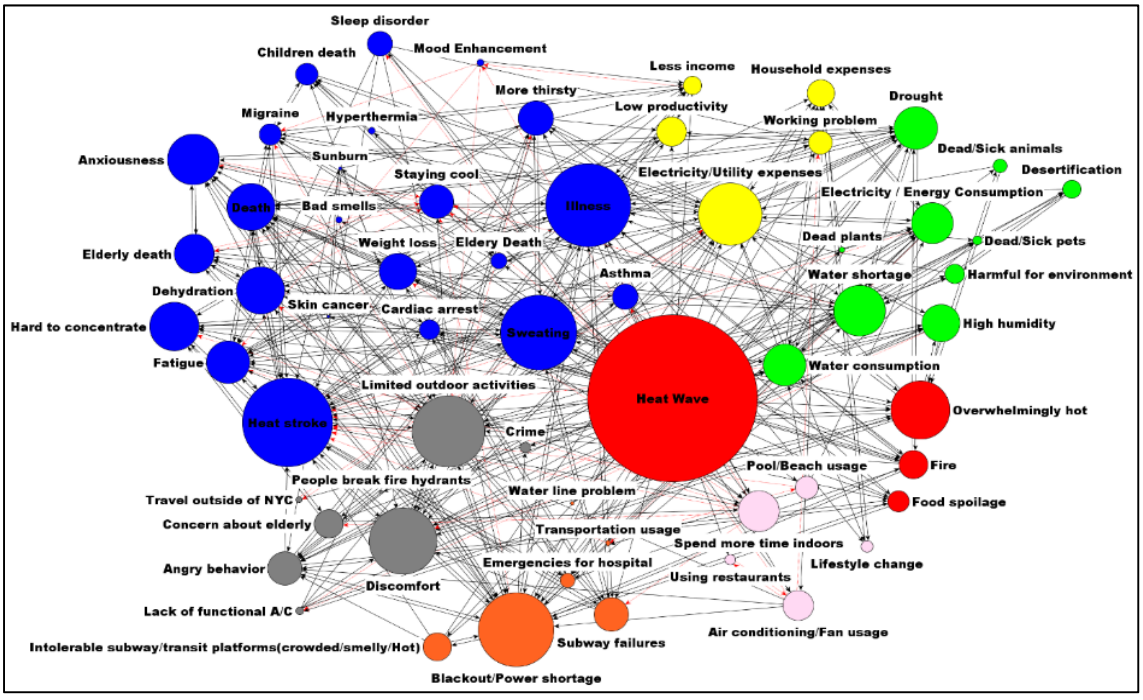


Figure 18: In Poverty Group's Cognitive map Visualization (with respect to Centrality)
(Legend: Health Aspect, Economic Aspect, Energy & Natural resources, Hazard & Damages, Life style , City Infrastructure, Social Aspect); Source: own draft

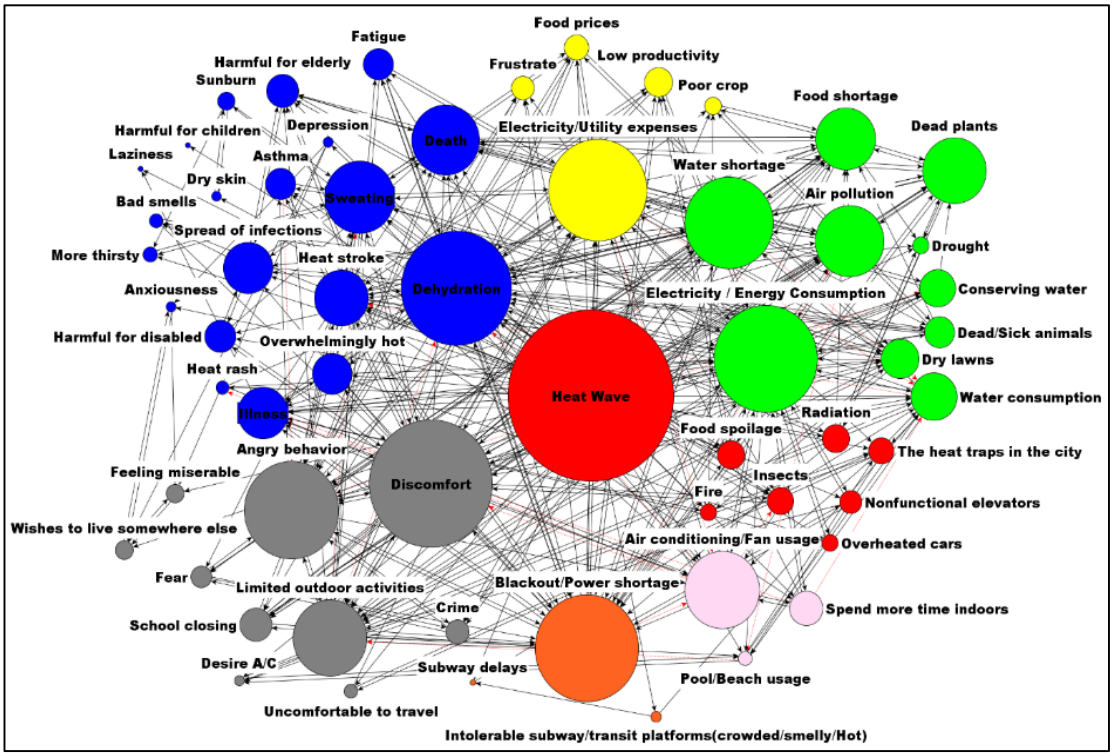


Figure 19: Low income Group's Cognitive map Visualization (with respect to Centrality)
(Legend: Health Aspect, Economic Aspect, Energy & Natural resources, Hazard & Damages, Life style , City Infrastructure, Social Aspect); Source: own draft

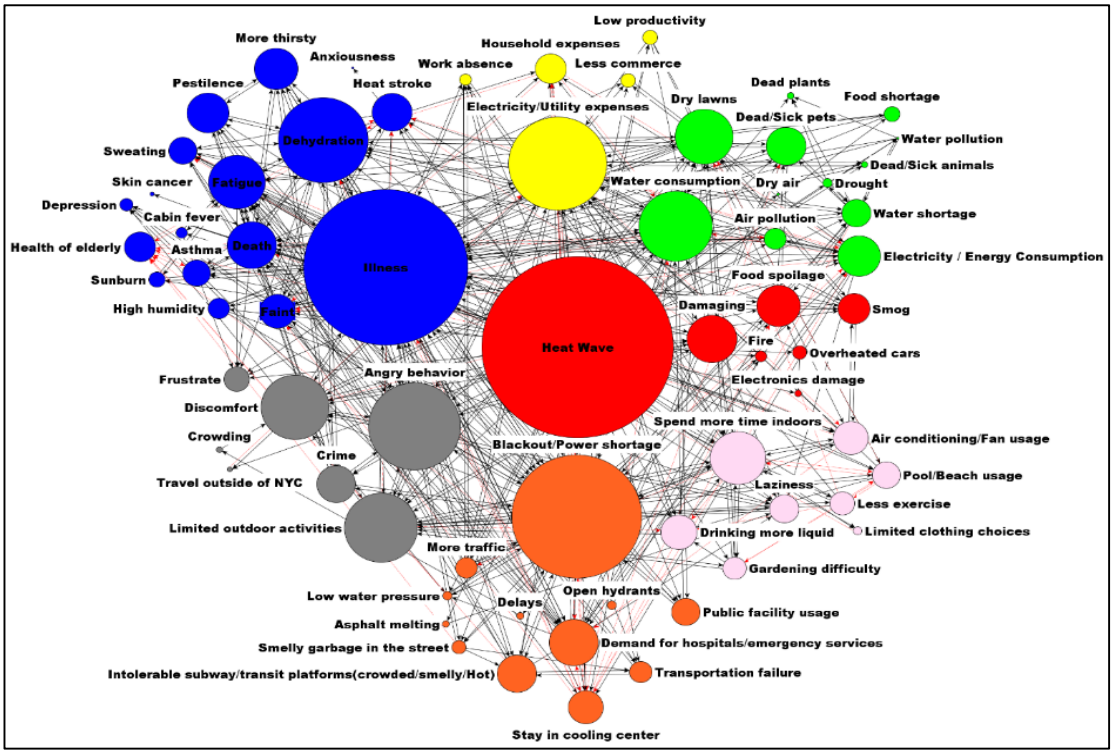


Figure 20: Middle income Group's Cognitive map Visualization (with respect to Centrality)
(Legend: Health Aspect, Economic Aspect, Energy & Natural resources, Hazard & Damages, Life style , City Infrastructure, Social Aspect); Source: own draft

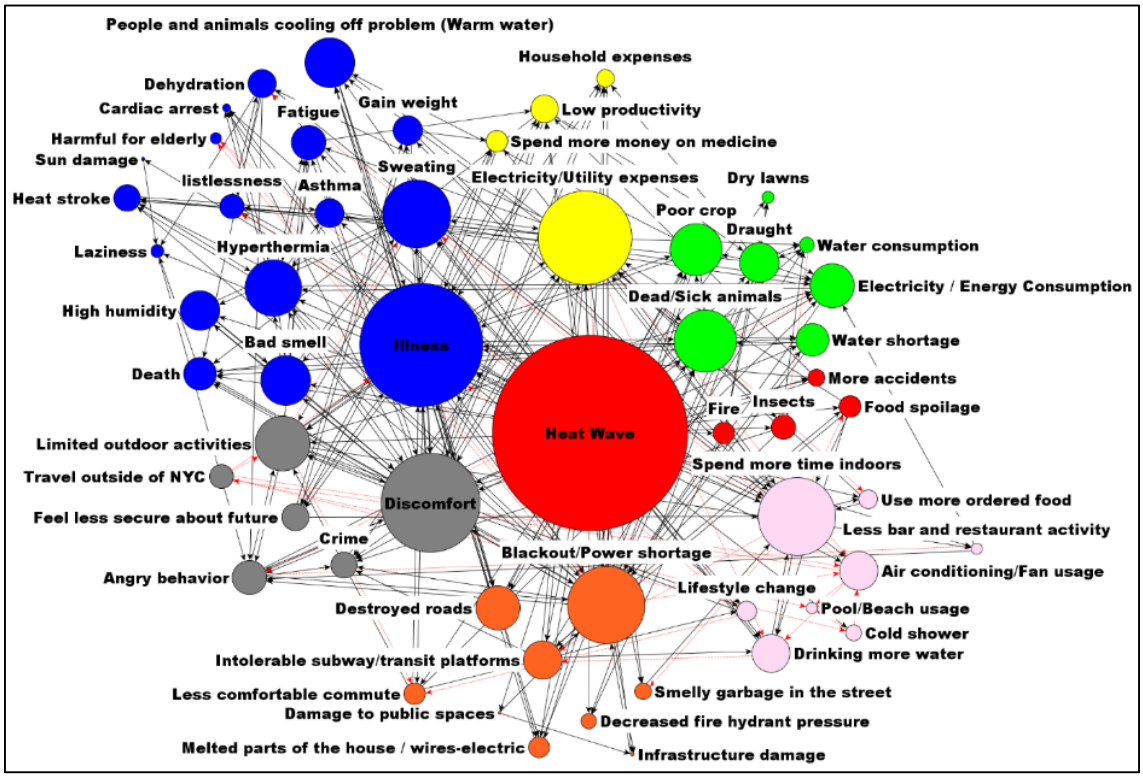


Figure 21: High income Group's Cognitive map Visualization (with respect to Centrality) (Legend: Health Aspect, Economic Aspect, Energy & Natural resources, Hazard & Damages, Life style , City Infrastructure, Social Aspect); Source: own draft

As it is presented in figure 19 to 21, the health aspect have the highest share in the concepts in all income groups' cognitive maps. In regards to in poverty groups, hazard and damage aspect has the lowest share of concepts. In low income group's map, life style aspect has the lowest share of concepts while in middle income group and high income groups' maps, economic aspects has the lowest share.

To have a better understanding in regards to different income groups cognitive maps, in next three sections the results of FCM analysis in regards to FCM three main indices (In-degree, Out-degree and Centrality) are presented. These results are presented in table format in appendix (section 7.4).

4.3.1.1. In-degree

The results of FCM analysis in regards to in-degree indices for different income groups are presented in figure 22 to figure 25. In-degree value shows the level of dependency of a concepts to other concepts in the network.

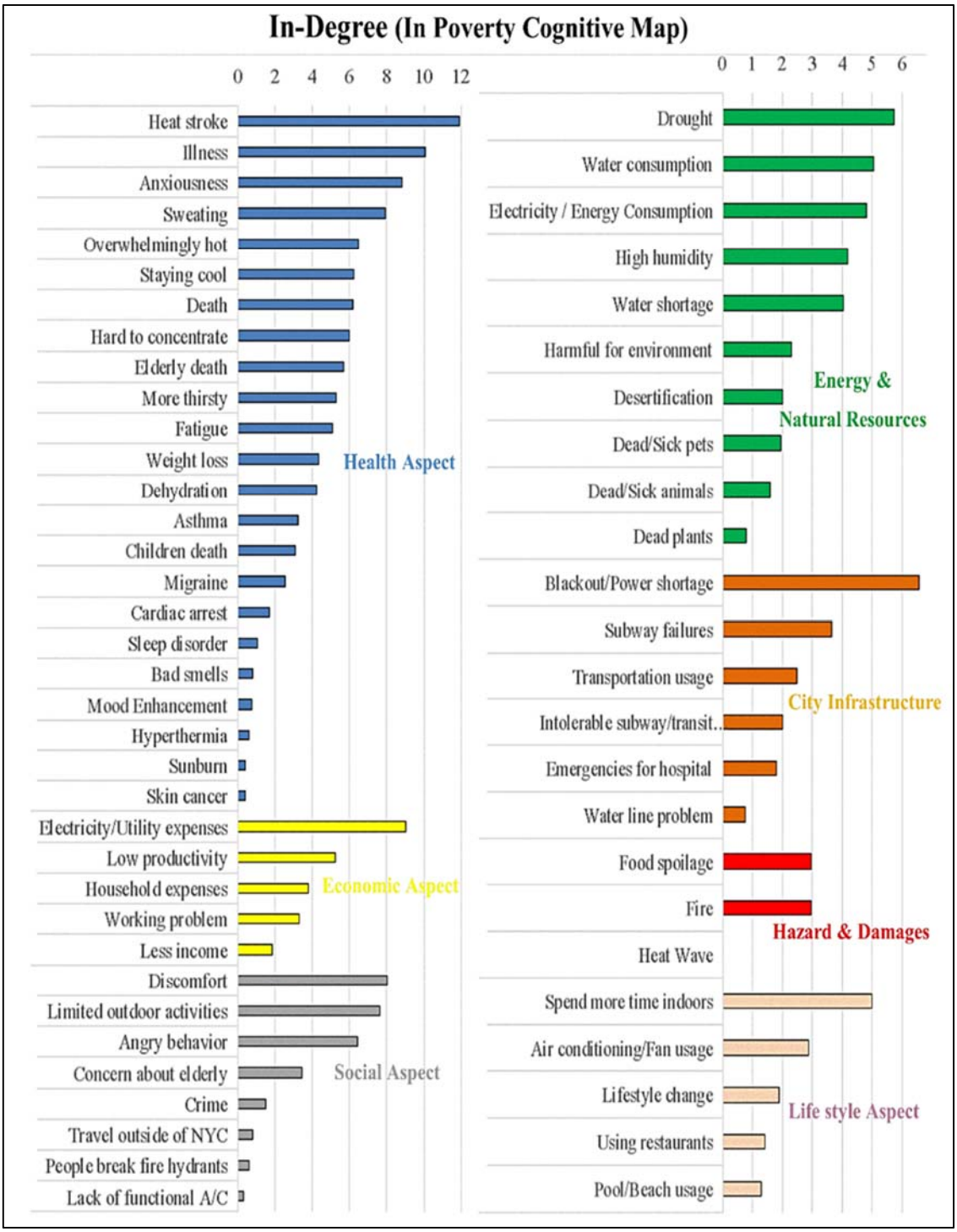


Figure 22: In-degree results for in Poverty Group
(The scale in right side and left side is not the same)
Source: Own draft.

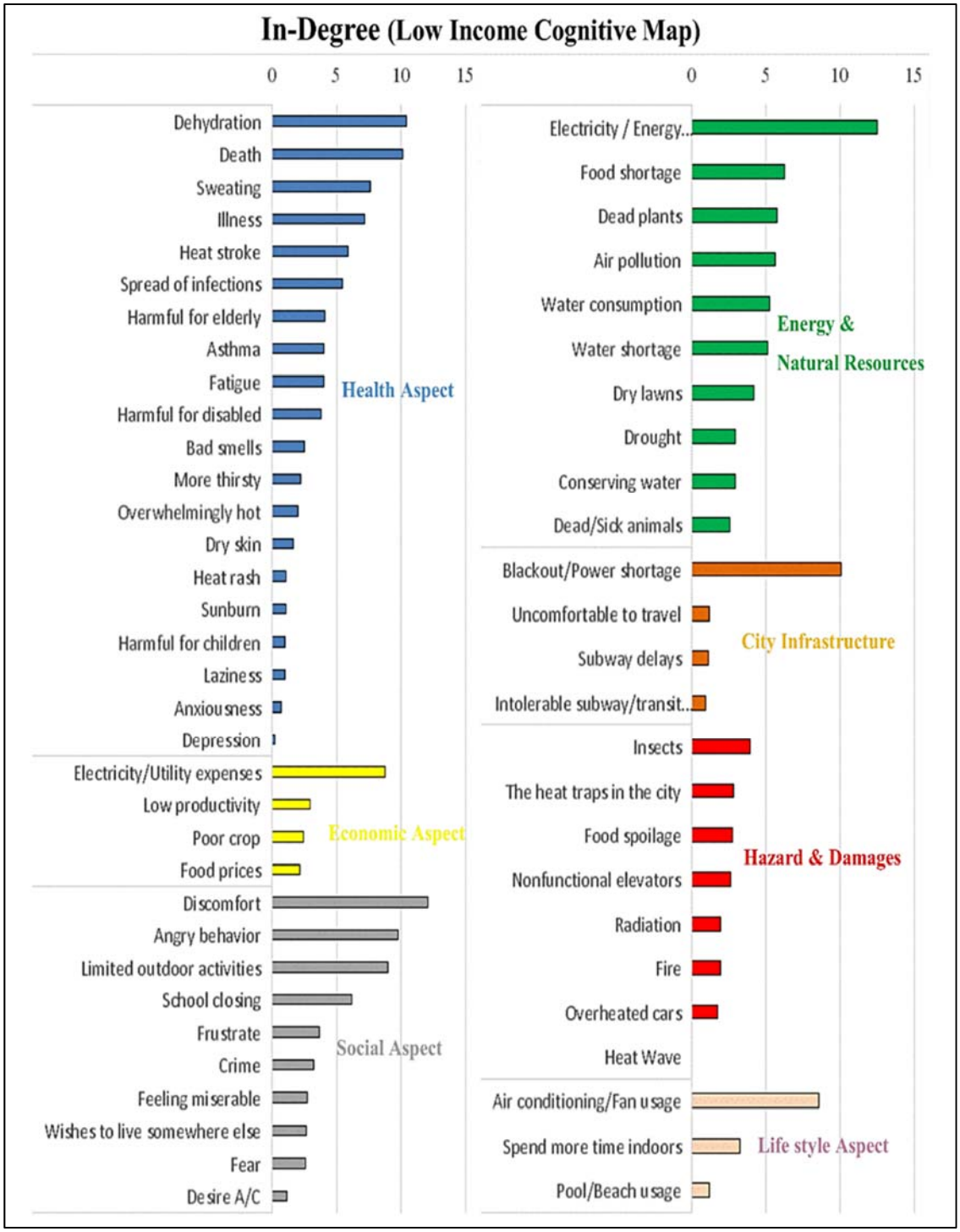


Figure 23: In-degree results for low income Group
(The scale in right side and left side is not the same)
Source: Own draft.

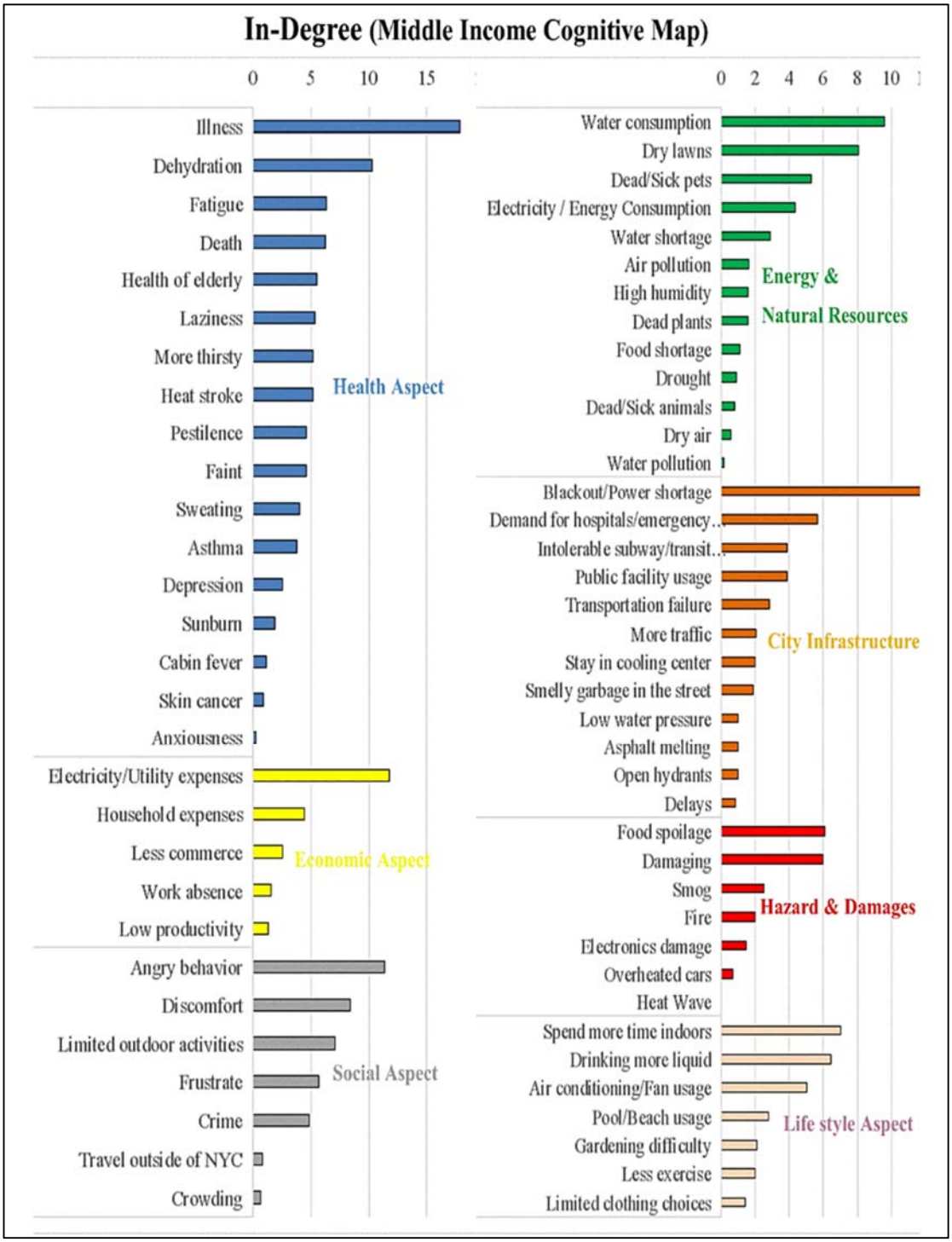


Figure 24: In-degree results for middle income Group
(The scale in right side and left side is not the same)
Source: Own draft.

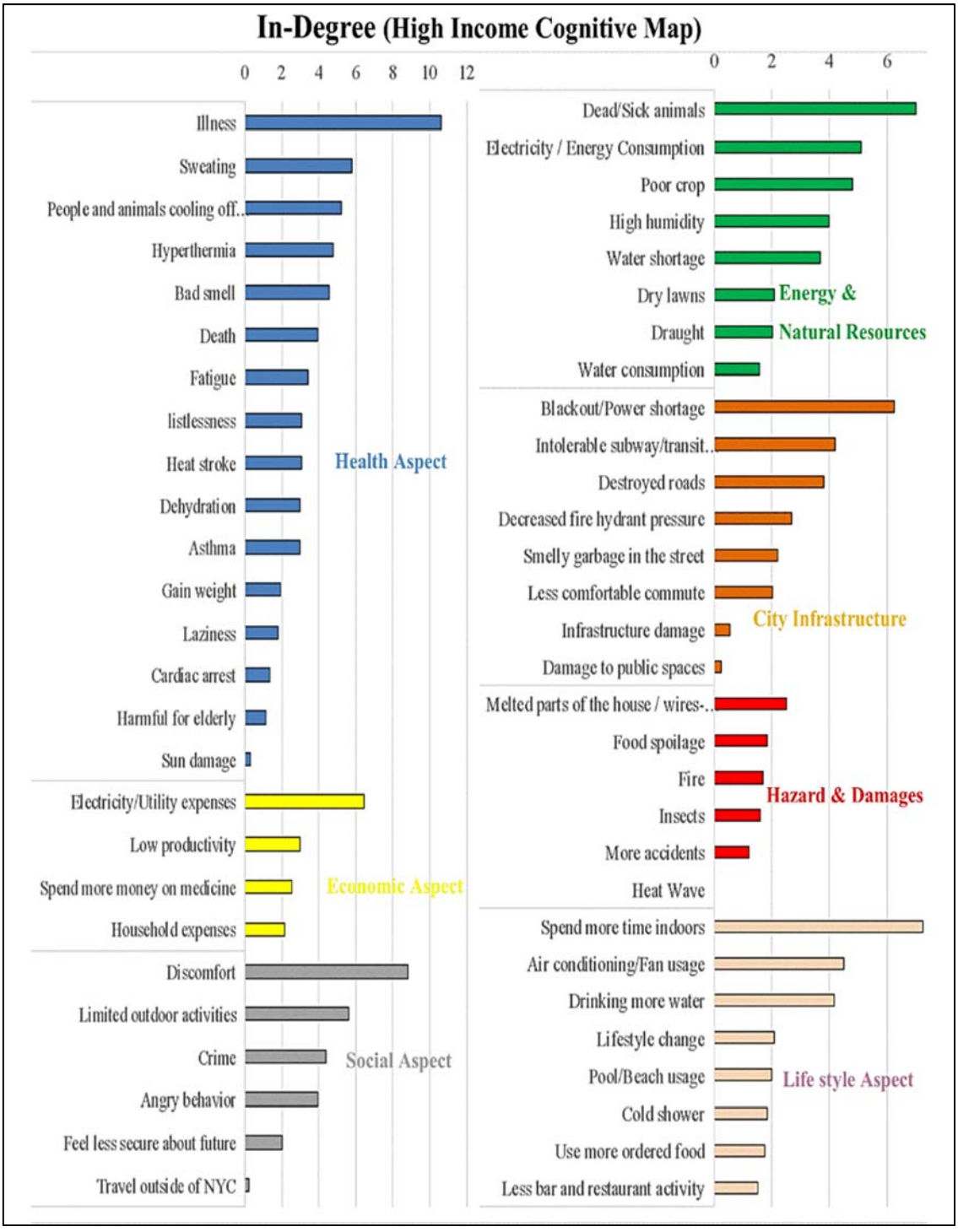


Figure 25: In-degree results for high income Group
(The scale in right side and left side is not the same)
Source: Own draft.

To have a better understanding about similarity and differences between income groups in regards to In-Degree values, the three concepts with highest in-degree value (with respect to defined Aspects) are presented in table 23.

In-degree								
Concept Groups	Income Groups							
	In Poverty		Low Income		Middle Income		High Income	
	Concept	Value	Concept	Value	Concept	Value	Concept	Value
Health Aspect	Heat stroke	11.93	Dehydration	10.44	Illness	17.83	Illness	10.6
	Illness	10.08	Death	10.14	Dehydration	10.26	Sweating	5.81
	Anxiousness	8.8	Sweating	7.62	Fatigue	6.3	People and animals cooling off problem	5.2
Economic Aspect	Electricity/Utility expenses	9	Electricity/Utility expenses	8.73	Electricity/ Utility expenses	11.79	Electricity/ Utility expenses	6.45
	Low productivity	5.25	Low productivity	2.95	Household expenses	4.4	Low productivity	2.97
	Household expenses	3.8	Poor crop	2.48	Less commerce	2.5	Spend more money on medicine	2.55
Social Aspect	Discomfort	8.03	Discomfort	12.07	Angry behaviour	11.34	Discomfort	8.81
	Limited outdoor activities	7.63	Angry behaviour	9.76	Discomfort	8.4	Limited outdoor activities	5.63
	Angry behaviour	6.45	Limited outdoor activities	8.97	Limited outdoor activities	7.08	Crime	4.4
Energy & Natural Resources	Drought	5.73	Electricity / Energy Consumption	12.51	Water consumption	9.61	Dead/Sick animals	7
	Water consumption	5.04	Food shortage	6.2	Dry lawns	8.08	Electricity / Energy Consumption	5.11
	Electricity / Energy Consumption	4.82	Dead plants	5.73	Dead/Sick pets	5.3	Poor crop	4.8
City Infrastructure	Blackout/Power shortage	6.59	Blackout/Power shortage	10.05	Blackout/Power shortage	11.76	Blackout/Power shortage	6.26
	Subway failures	3.65	Uncomfortable to travel	1.15	Demand for hospitals/emergency services	5.68	Intolerable subway/transit platforms(crowded/smelly/Hot)	4.2

	Transportation usage	2.5	Subway delays	1.1	Intolerable subway/transit platforms	3.91	Destroyed roads	3.8
Hazard & Damages	Food spoilage	2.98	Insects	3.9	Food spoilage	6.1	Melted parts of the house / wires-electric	2.5
	Fire	2.96	The heat traps in the city	2.79	Damaging	6	Food spoilage	1.85
	Heat Wave	0	Food spoilage	2.7	Smog	2.51	Fire	1.7
Life style Aspect	Spend more time indoors	5	Air conditioning /Fan usage	8.53	Spend more time indoors	7.03	Spend more time indoors	7.24
	Air conditioning /Fan usage	2.88	Spend more time indoors	3.23	Drinking more liquid	6.45	Air conditioning /Fan usage	4.5
	Lifestyle change	1.9	Pool/Beach usage	1.14	Air conditioning /Fan usage	5.06	Drinking more water	4.16

Table 23: Different income group comparison with respect to In-degree value
Source: Own drafts

According to figure 22 to 25 and In-degree comparison table 23, in regards to health aspect, "*Heat stroke*" and "*Dehydration*" concepts have the highest in-degree in In Poverty and Low income groups cognitive map while "*Illness*" concept has the highest in-degree value in both Middle and High income groups.

In regards to economic aspects, "*Electricity/Utility expenses*" concept has the highest in-degree value in all income groups' cognitive maps.

In regards to social aspect, "*Discomfort*" concept has the highest in-degree in all income groups' maps except Middle income group which "*Discomfort*" has the second highest in-degree after "*Angry behaviour*".

In regards to energy and natural resources aspect, concepts with highest in-degree are totally different across research income groups.

"*Blackout/Power shortage*" concept has the highest in-degree with respect to city infrastructure aspect in all four income groups' cognitive maps.

In regards to hazard and damages aspect, "*Food spoilage*" has the highest in-degree in In Poverty and Middle income groups, while "*Insects*" and "*Melted parts of the house*" have the highest in-degree in Low income and High income group's Cognitive maps.

Finally in regards to Life style aspect, "*Spend more time indoors*" has the highest in-degree in all income groups except in Low Income group's map which it has the second highest in-degree value after "*Air conditioning/Fan usage*".

4.3.1.2. Out-Degree

The results of FCM analysis in regards to Out-degree indices for different income groups are presented in figure 26 to figure 29. Out-degree value shows the strength of each concepts in regards to influencing the other concepts in the network.

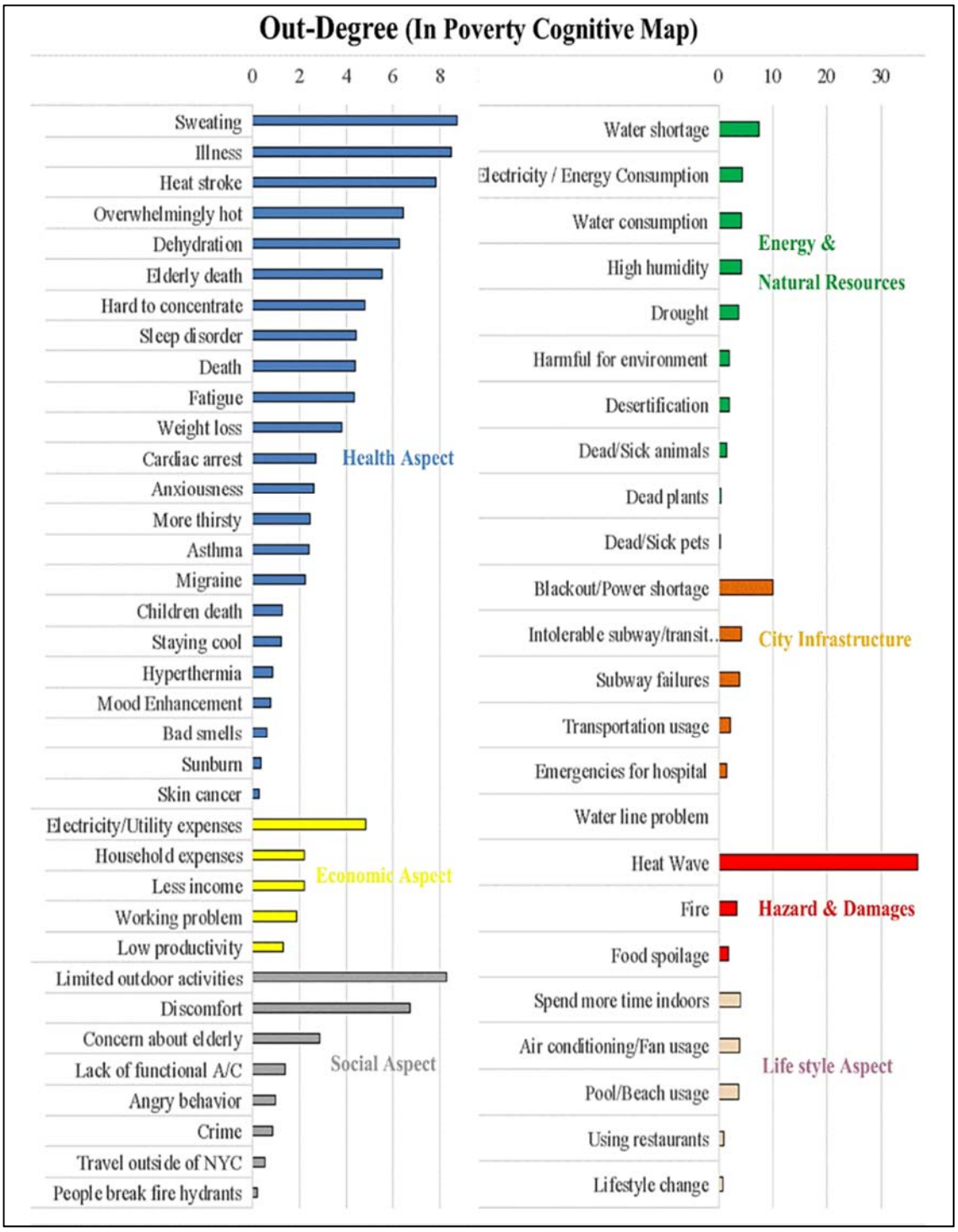


Figure 26: Out-degree results for in Poverty Group
(The scale in right side and left side is not the same)
Source: Own draft

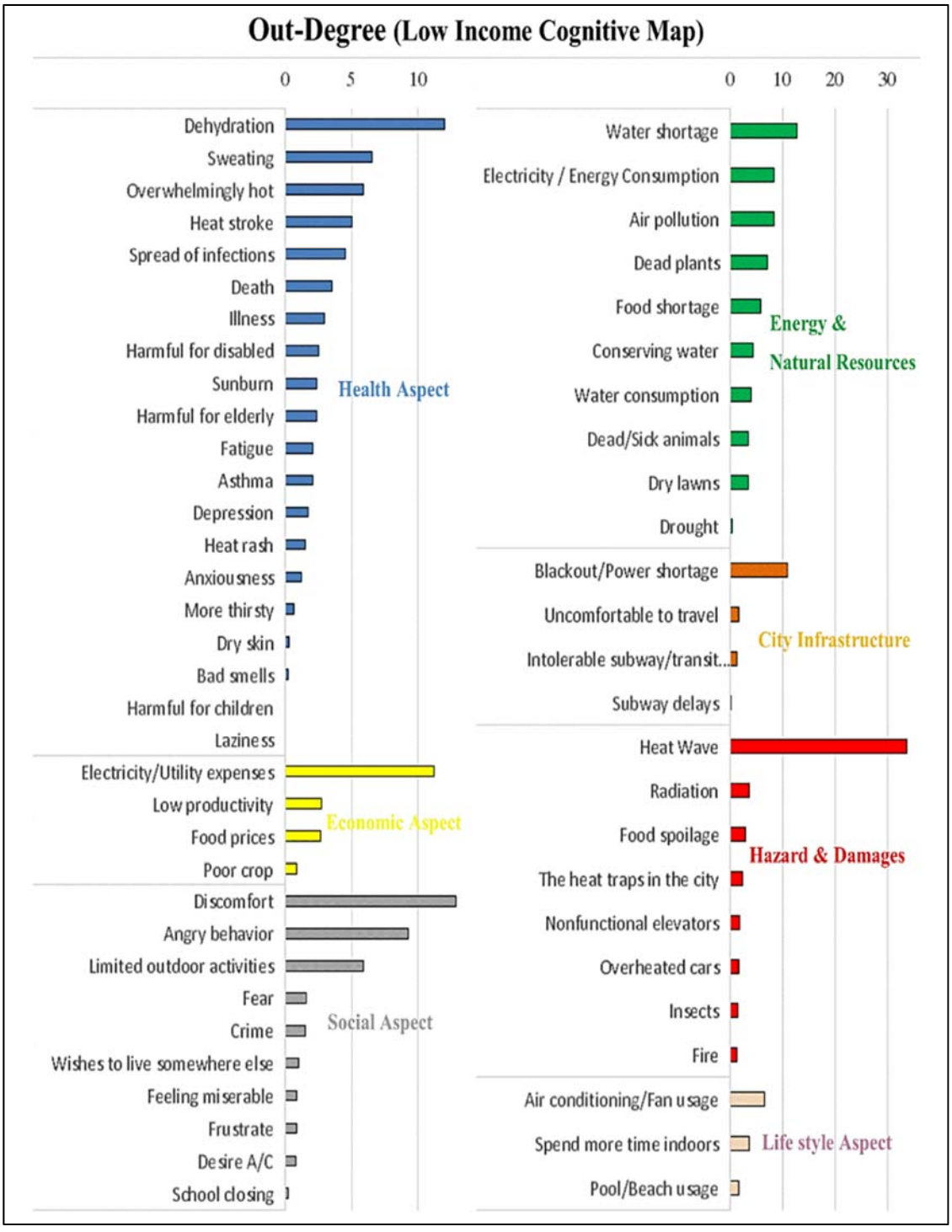


Figure 27: Out-degree results for low Income Group
(The scale in right side and left side is not the same)
Source: Own draft

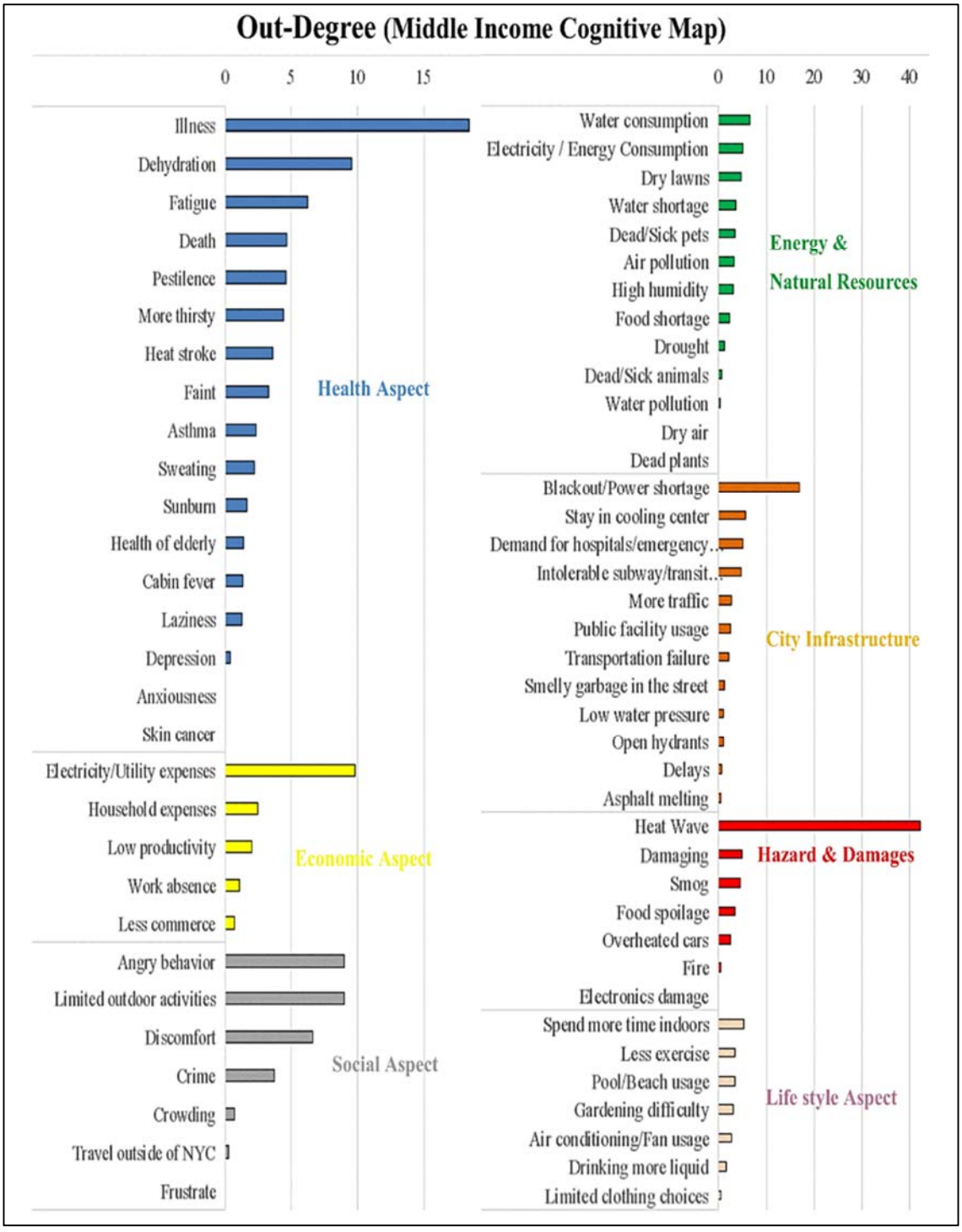


Figure 28: Out-degree results for middle Income Group
(The scale in right side and left side is not the same)
Source: Own draft

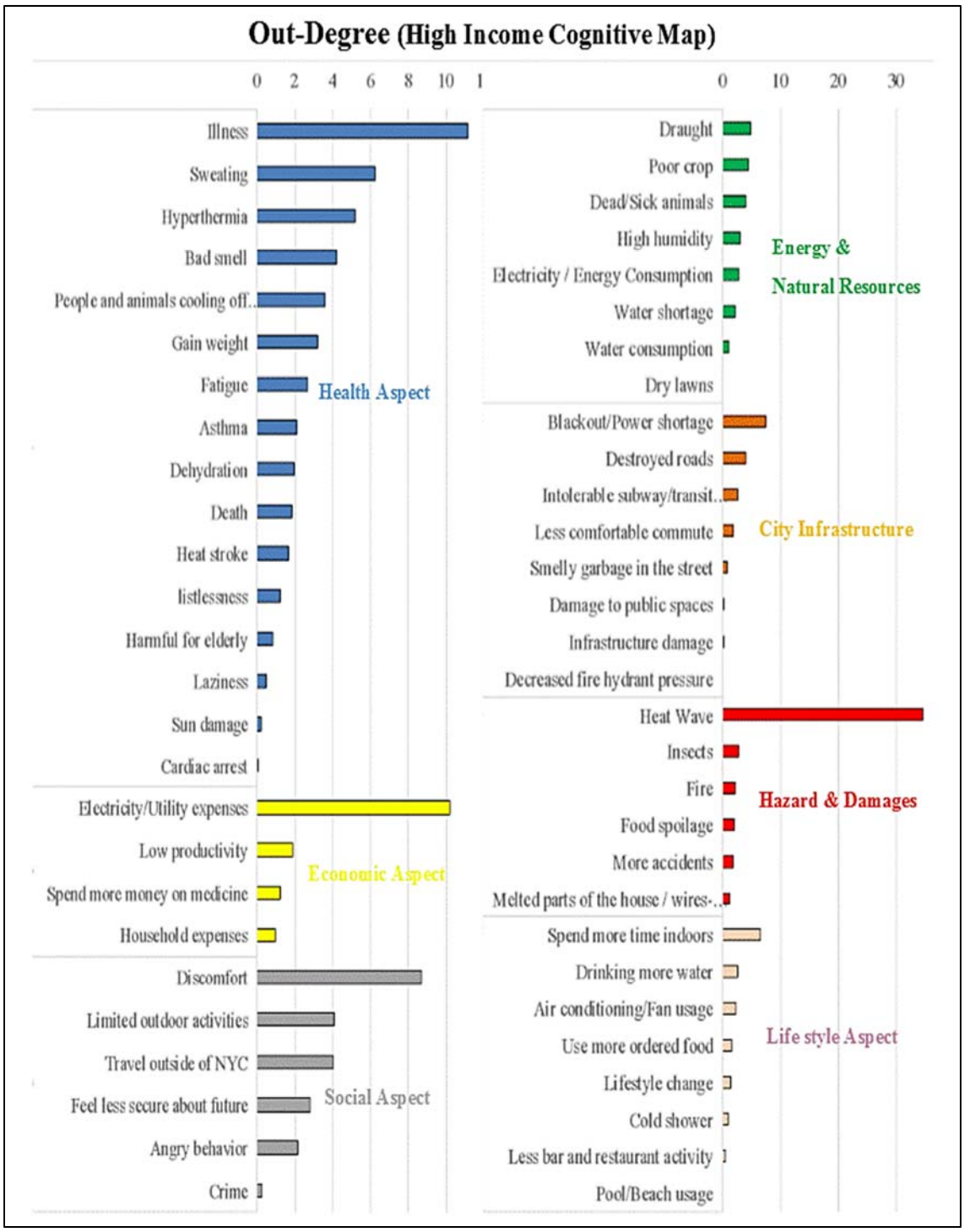


Figure 29: Out-degree results for high Income Group
(The scale in right side and left side is not the same)
Source: Own draft

To have a better understanding about similarity and differences between income groups in regards to Out-degree, the three concepts with highest out-degree value (with respect to defined Aspects) are presented in table 24.

Out-degree								
Concept Groups	Income Groups							
	In Poverty		Low Income		Middle Income		High Income	
	Concept	Value	Concept	Value	Concept	Value	Concept	Value
Health Aspect	Sweating	8.75	Dehydration	11.95	Illness	18.43	Illness	11.16
	Illness	8.49	Sweating	6.56	Dehydration	9.55	Sweating	6.23
	Heat stroke	7.84	Overwhelmingly hot	5.92	Fatigue	6.21	Hyperthermia	5.17
Economic Aspect	Electricity/Utility expenses	4.83	Electricity/Utility expenses	11.18	Electricity/Utility expenses	9.85	Electricity/Utility expenses	10.19
	Household expenses	2.2	Low productivity	2.76	Household expenses	2.5	Low productivity	1.9
	Less income	2.2	Food prices	2.7	Low productivity	2.01	Spend more money on medicine	1.21
Social Aspect	Limited outdoor activities	8.3	Discomfort	12.82	Angry behaviour	9	Discomfort	8.67
	Discomfort	6.73	Angry behaviour	9.28	Limited outdoor activities	8.98	Limited outdoor activities	4.1
	Concern about elderly	2.85	Limited outdoor activities	5.89	Discomfort	6.6	Travel outside of NYC	4.05
Energy & Natural Resources	Water shortage	7.37	Water shortage	12.73	Water consumption	6.64	Draught	4.94
	Electricity / Energy Consumption	4.36	Electricity / Energy Consumption	8.41	Electricity / Energy Consumption	5.08	Poor crop	4.4
	Water consumption	4.26	Air pollution	8.3	Dry lawns	4.71	Dead/Sick animals	4
City Infrastructure	Blackout/Power shortage	9.96	Blackout/Power shortage	10.93	Blackout/Power shortage	16.89	Blackout/Power shortage	7.46
	Intolerable subway/transit platforms	4.2	Uncomfortable to travel	1.59	Stay in cooling centre	5.74	Destroyed roads	4
	Subway failures	3.8	Intolerable subway/transit platforms	1.2	Demand for hospitals/emergency services	5.17	Intolerable subway/transit platforms	2.55
Hazard & Damages	Heat Wave	36.69	Heat Wave	33.55	Heat Wave	42.21	Heat Wave	34.62
	Fire	3.36	Radiation	3.6	Damaging	5	Insects	2.7

	Food spoilage	1.73	Food spoilage	2.88	Smog	4.5	Fire	2.1
Life style Aspect	Spend more time indoors	4.05	Air conditioning /Fan usage	6.51	Spend more time indoors	5.33	Spend more time indoors	6.53
	Air conditioning /Fan usage	3.85	Spend more time indoors	3.55	Less exercise	3.45	Drinking more water	2.55
	Pool/Beach usage	3.7	Pool/Beach usage	1.6	Pool/Beach usage	3.38	Air conditioning /Fan usage	2.35

Table 24: Different income group comparison with respect to Out-degree value
Source: Own drafts

According to figure 26 to 29 and Out-degree comparison table 24, in regards to health aspect, "*Sweating*" and "*Dehydration*" concepts have the highest out-degree in In Poverty and Low income group cognitive maps while "*Illness*" has the highest out-degree value in both Middle and High income groups' cognitive maps which is very similar to the results of In-degree for this aspect.
In regards to economic aspects, "*Electricity/Utility expenses*" concept has the highest out-degree value in all income groups' cognitive maps which is completely similar to the results of In-Degree for this aspect.
In regards to social aspect, "*Discomfort*" has the highest out-degree in both Low income and High income groups' maps while it has the second highest out-degree in In-Poverty group's map after "*Limited outdoor activities*".
In regards to energy and natural resources aspect, "*Water shortage*" has the highest out-degree in both In-Poverty and Low income groups and "*water consumption*" and "*Drought*" have the highest out-degree in Middle income and High income groups.
"*Blackout/Power shortage*" concept has the highest out-degree with respect to city infrastructure aspect in all four income groups' cognitive maps which is totally similar to the results of In-degree for this aspect.
In regards to hazard and damages aspect, "*Heat wave*" has the highest out-degree in all income groups and the second and third highest concepts are completely different in all income groups.
Finally in regards to Life style aspect, "*Spend more time indoors*" has the highest out-degree in all income groups except in Low income group's map which it has the second highest out-degree value after "*Air conditioning/Fan usage*". The results of out-degree for this aspect is completely similar to the results of in-degree.

4.3.1.3. Centrality

The results of FCM analysis in regards to Centrality indices for different income groups are presented in figure 30 to figure 33. Centrality value, shows the individual importance of concepts in the network.

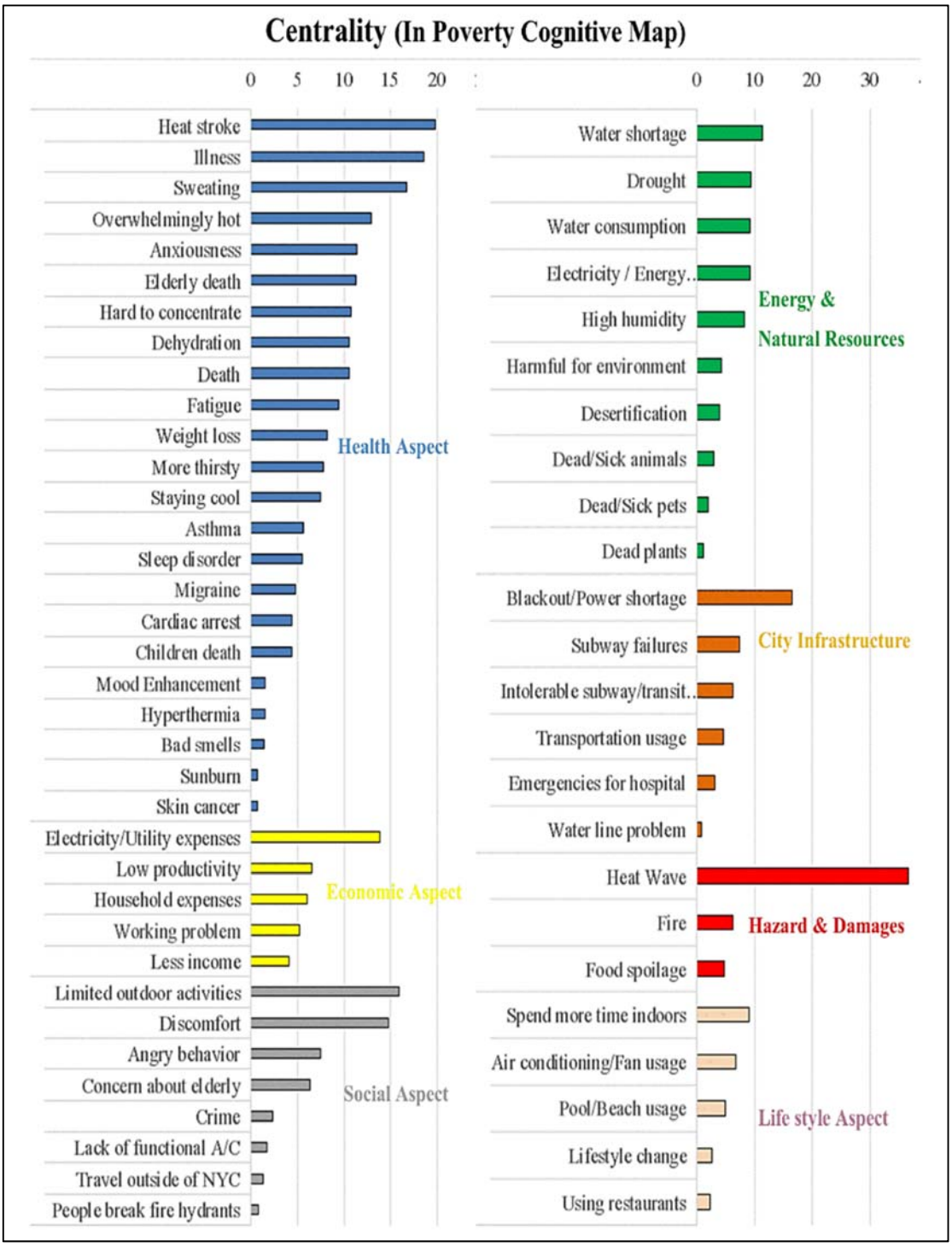


Figure 30: Centrality results for in poverty Group
(The scale in right side and left side is not the same)
Source: Own draft

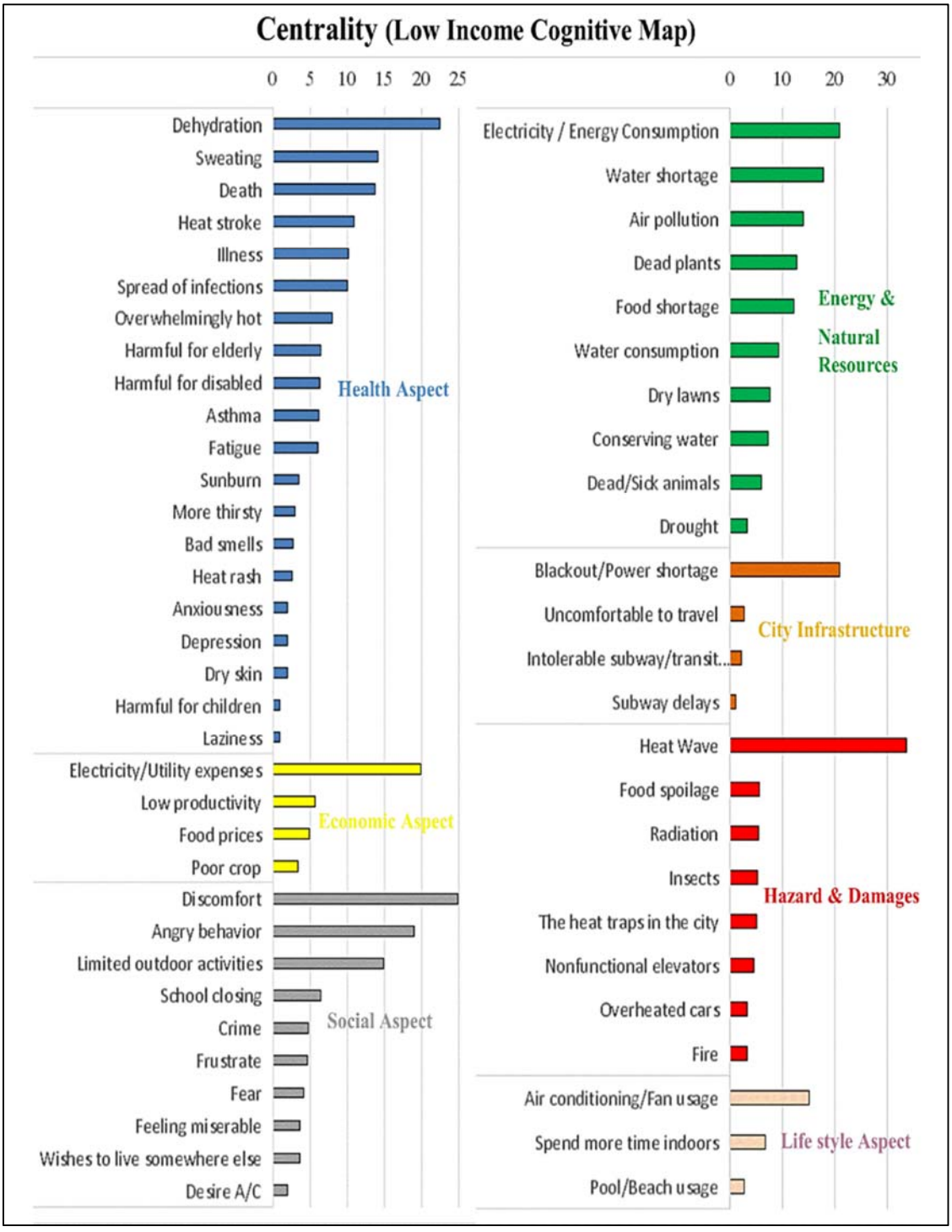


Figure 31: Centrality results for low income Group
(The scale in right side and left side is not the same)
Source: Own draft

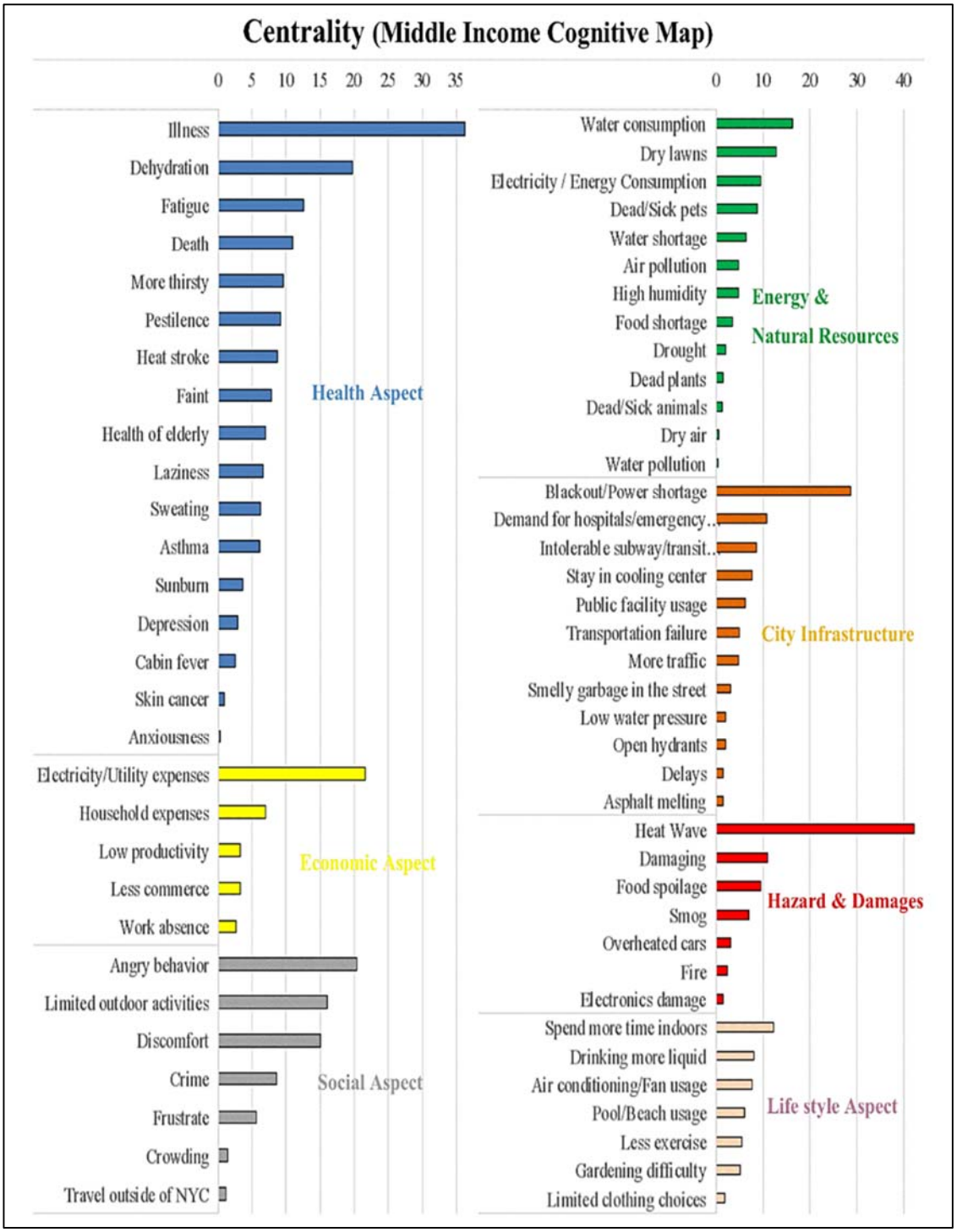


Figure 32: Centrality results for middle income Group
(The scale in right side and left side is not the same)
Source: Own draft

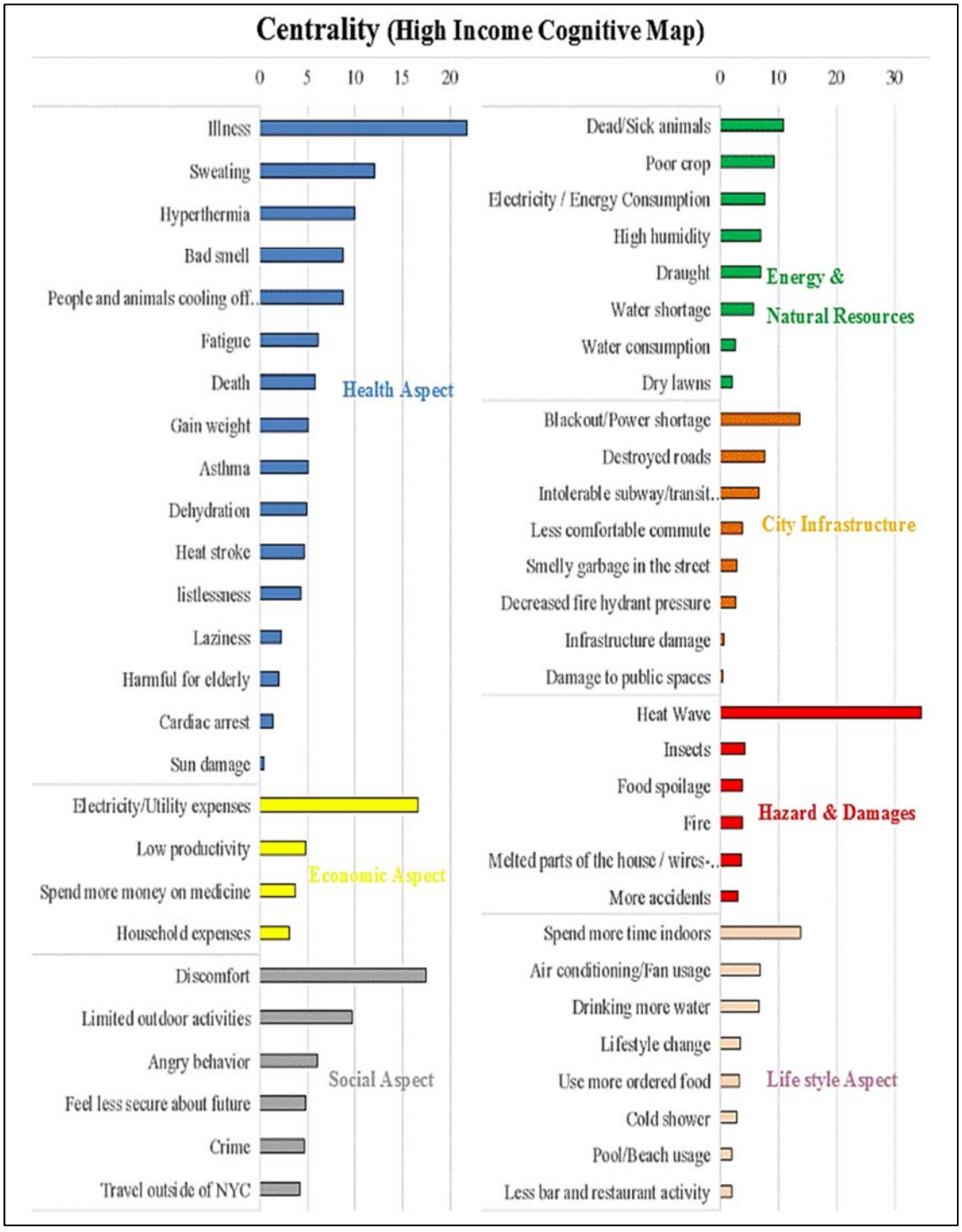


Figure 33: Centrality results for high income Group
(The scale in right side and left side is not the same)
Source: Own draft

To have a better understanding about similarity and differences between income groups in regards to Centrality, the three concepts with highest Centrality value (with respect to defined Aspects) are presented in table 25.

Centrality								
Concept Groups	Income Groups							
	In Poverty		Low Income		Middle Income		High Income	
	Concept	Value	Concept	Value	Concept	Value	Concept	Value
Health Aspect	Heat stroke	19.77	Dehydration	22.39	Illness	36.26	Illness	21.76
	Illness	18.57	Sweating	14.18	Dehydration	19.8	Sweating	12.04
	Sweating	16.7	Death	13.7	Fatigue	12.51	Hyperthermia	9.94
Economic Aspect	Electricity/ Utility expenses	13.83	Electricity/ Utility expenses	19.91	Electricity/ Utility expenses	21.64	Electricity/ Utility expenses	16.65
	Low productivity	6.55	Low productivity	5.71	Household expenses	6.9	Low productivity	4.87
	Household expenses	6	Food prices	4.9	Low productivity	3.28	Spend more money on medicine	3.76
Social Aspect	Limited outdoor activities	15.93	Discomfort	24.89	Angry behaviour	20.34	Discomfort	17.48
	Discomfort	14.76	Angry behaviour	19.03	Limited outdoor activities	16.05	Limited outdoor activities	9.73
	Angry behaviour	7.42	Limited outdoor activities	14.86	Discomfort	15	Angry behaviour	6.06
Energy & Natural Resources	Water shortage	11.39	Electricity / Energy Consumption	20.92	Water consumption	16.25	Dead/Sick animals	11
	Drought	9.44	Water shortage	17.86	Dry lawns	12.8	Poor crop	9.2
	Water consumption	9.31	Air pollution	13.92	Electricity / Energy Consumption	9.45	Electricity / Energy Consumption	7.79
City Infrastructure	Blackout/Power shortage	16.55	Blackout/Power shortage	20.98	Blackout/Power shortage	28.65	Blackout/Power shortage	13.71
	Subway failures	7.45	Uncomfortable to travel	2.74	Demand for hospitals/e	10.84	Destroyed roads	7.8

					mergency services			
	Intolerable subway/transit platforms	6.2	Intolerable subway/transit platforms	2.1	Intolerable subway/transit platforms	8.61	Intolerable subway/transit platforms	6.75
Hazard & Damages	Heat Wave	36.69	Heat Wave	33.55	Heat Wave	42.21	Heat Wave	34.62
	Fire	6.32	Food spoilage	5.58	Damaging	11	Insects	4.3
	Food spoilage	4.71	Radiation	5.5	Food spoilage	9.6	Food spoilage	3.86
Life style Aspect	Spend more time indoors	9.05	Air conditioning/Fan usage	15.04	Spend more time indoors	12.36	Spend more time indoors	13.77
	Air conditioning /Fan usage	6.73	Spend more time indoors	6.78	Drinking more liquid	8.05	Air conditioning/Fan usage	6.85
	Pool/Beach usage	5	Pool/Beach usage	2.74	Air conditioning/Fan usage	7.79	Drinking more water	6.71

Table 25: Different income group comparison with respect to Centrality value

According to figure 30 to 33 and Centrality comparison table 25, in regards to health aspect, "*Heat stroke*" and "*Dehydration*" have the highest Centrality in In Poverty and Low income group cognitive maps while "*Illness*" has the highest centrality value in both Middle and High income groups' cognitive maps.

In regards to economic aspects, "*Electricity/Utility expenses*" has the highest centrality value in all income groups' cognitive maps.

In regards to social aspect, "*Discomfort*" has the highest centrality in both Low income and High income groups' maps while it has the second highest centrality in In-Poverty group's map after "*Limited outdoor activities*".

In regards to energy and natural resources aspect, concepts with highest Centrality are totally different across research income groups.

"*Blackout/Power shortage*" concept has the highest centrality with respect to city infrastructure aspect in all four income groups' cognitive maps. While the second highest concepts is completely different across research income groups, the third one is *"Intolerable subway/transit platforms*" which is the same across all income groups.

In regards to hazard and damages aspect, "*Heat wave*" has the highest Centrality in all income groups. While the second highest concepts are completely different across all income groups' cognitive maps, the third one is "*Food Spoilage*" in all of them except Middle income group.

Finally in regards to Life style aspect, "*Spend more time indoors*" has the highest Centrality in all income groups' maps except in Low income group which it has the second highest out-degree value after "*Air conditioning/Fan usage*".

4.3.2. FCM scenario simulation results

As it is explained in research methodology (chapter 3), three different scenarios are simulated and tested for each income groups:

- Investment and Development In NYC Public Health Sector
- Investment and Development in NYC Water and Electricity System
- Investment and Development In NYC Transit Sector

In next sections the results of scenario simulation for each income groups are presented. The effect of each scenario on all the network and the differences between these scenarios in regards to their positive and negative impacts on each income group's cognitive maps is discussed in these sections.

4.3.2.1. Results of FCM scenario simulation for in poverty group

The effect of each scenario (in 30 iteration) on major concepts in the poverty group's cognitive map with respect to defined aspects (concept groups) is presented in figure 34. The results for each concept is presented with a number between +4 (highest positive change compare to steady state) and -4 (highest negative change compare to steady state) which is the results of FCMAPPER software.

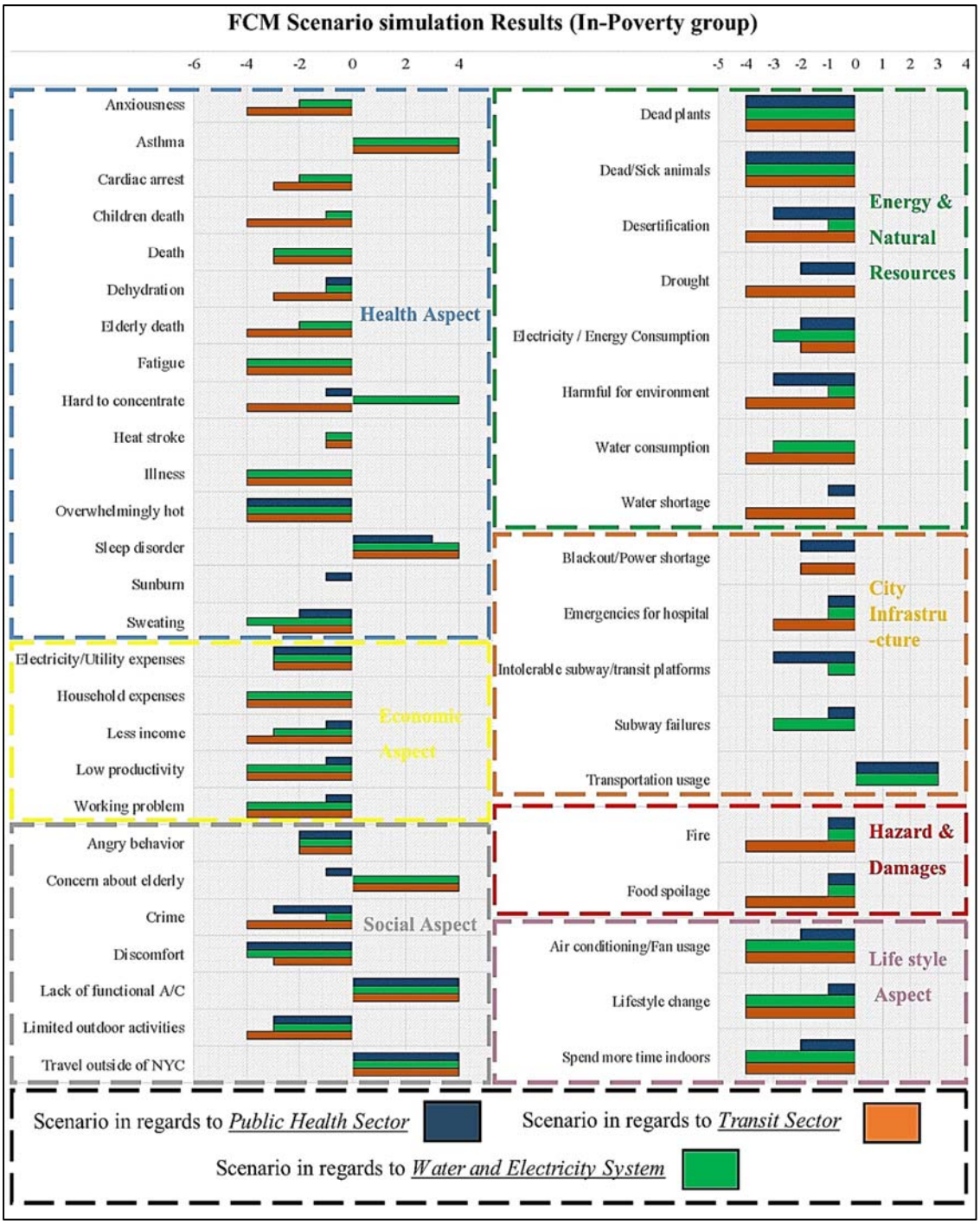


Figure 34: Results of FCM scenario simulation for in poverty group
Source: Own draft

According to figure 34, scenario in regards to transit sector seems to have the strongest effect on in poverty group's cognitive maps. To have a better understanding about these scenarios effects on in poverty group's network, and comparing them with each other, positive and negative change in regards to each aspects are merged and presented in figure 35. The negative number in the figure 35 shows the decrease in negative impacts (concepts) and positive numbers shows the increase in negative impacts with respect to each aspect.

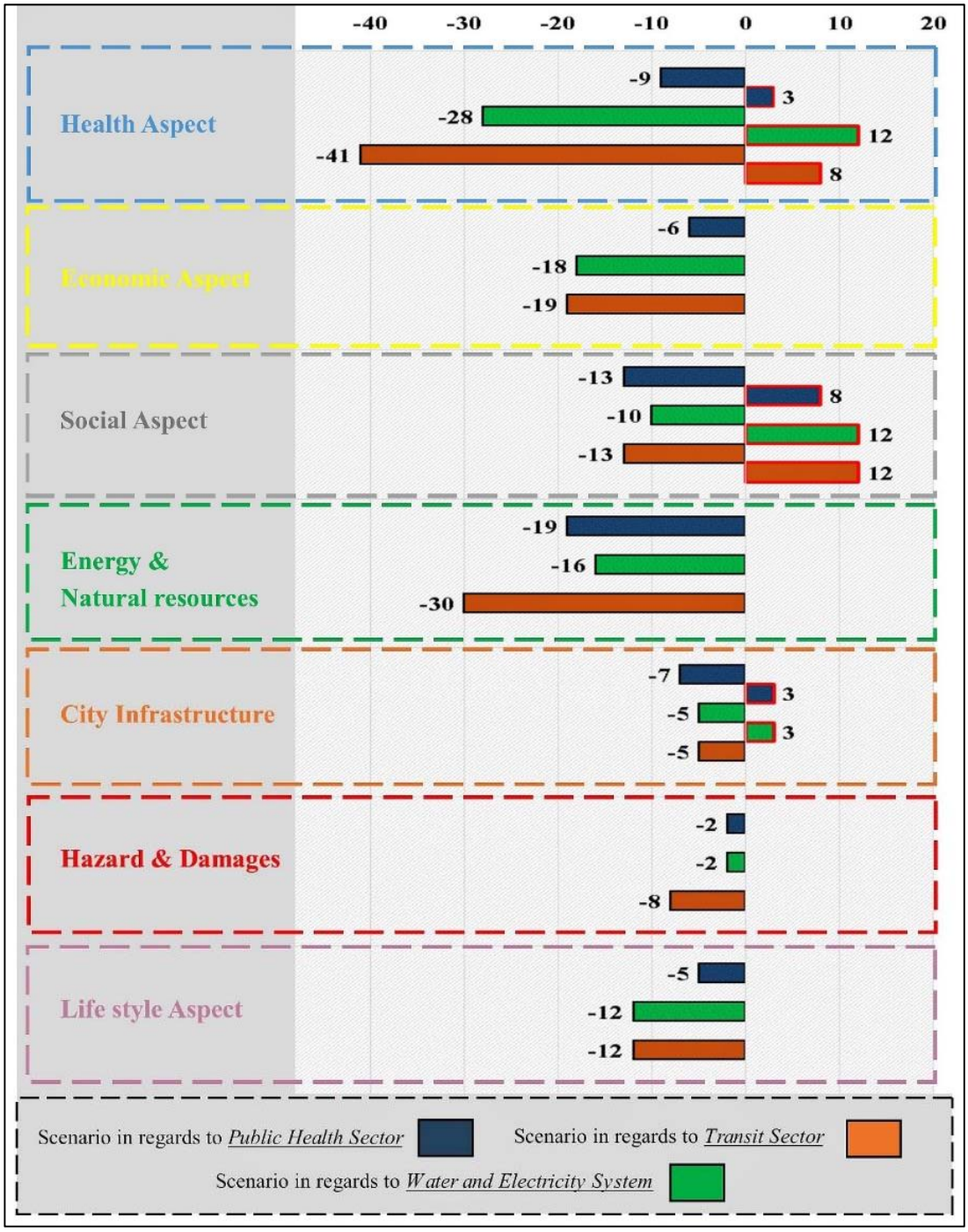


Figure 35: Comparing different scenario's effects on in poverty groups with respect to different aspects (concepts Group). Source: Own draft

According to figure 35, scenario about transit sector shows the strongest positive impacts (by decreasing negative concepts strongly in FCM scenario simulation) in regards to "health aspect", "economic aspect" , "energy and natural resources" and "hazard and damages". Scenario about public health sector shows the strongest positive impacts in regards to "social aspects". In regards to "Life style aspect", scenarios about both transit sector and water and electricity system shows similar positive impacts.

4.3.2.2. Results of FCM scenario simulation for low income group

The effect of each scenario (in 30 iteration) on low income group's cognitive map with respect to defined aspects (concept groups) is presented in figure 36. The results for each concepts is presented with a number between +4 (highest positive change compare to steady state) and -4 (highest negative change compare to steady state) which is the results of FCMAPPER software.

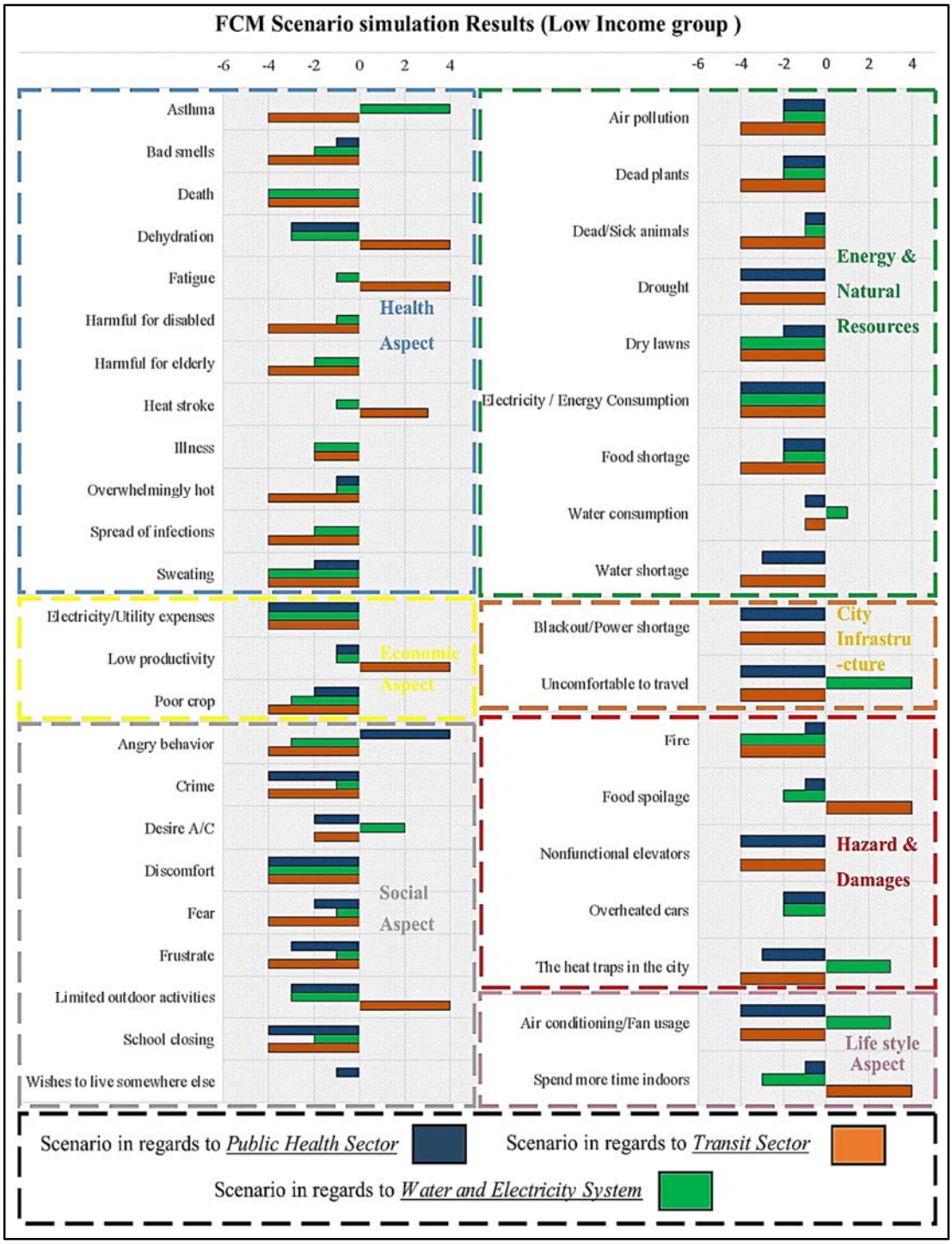


Figure 36: Results of FCM scenario simulation for low income group
Source: Own draft

To have a better understanding about these scenarios effects on low income groups, and comparing them with each other, positive and negative change in concepts with respects to each aspects are merged and presented in figure 37. The negative number in the figure 37 shows the decrease in negative impacts (concepts) and positive numbers shows the increase in negative impacts.

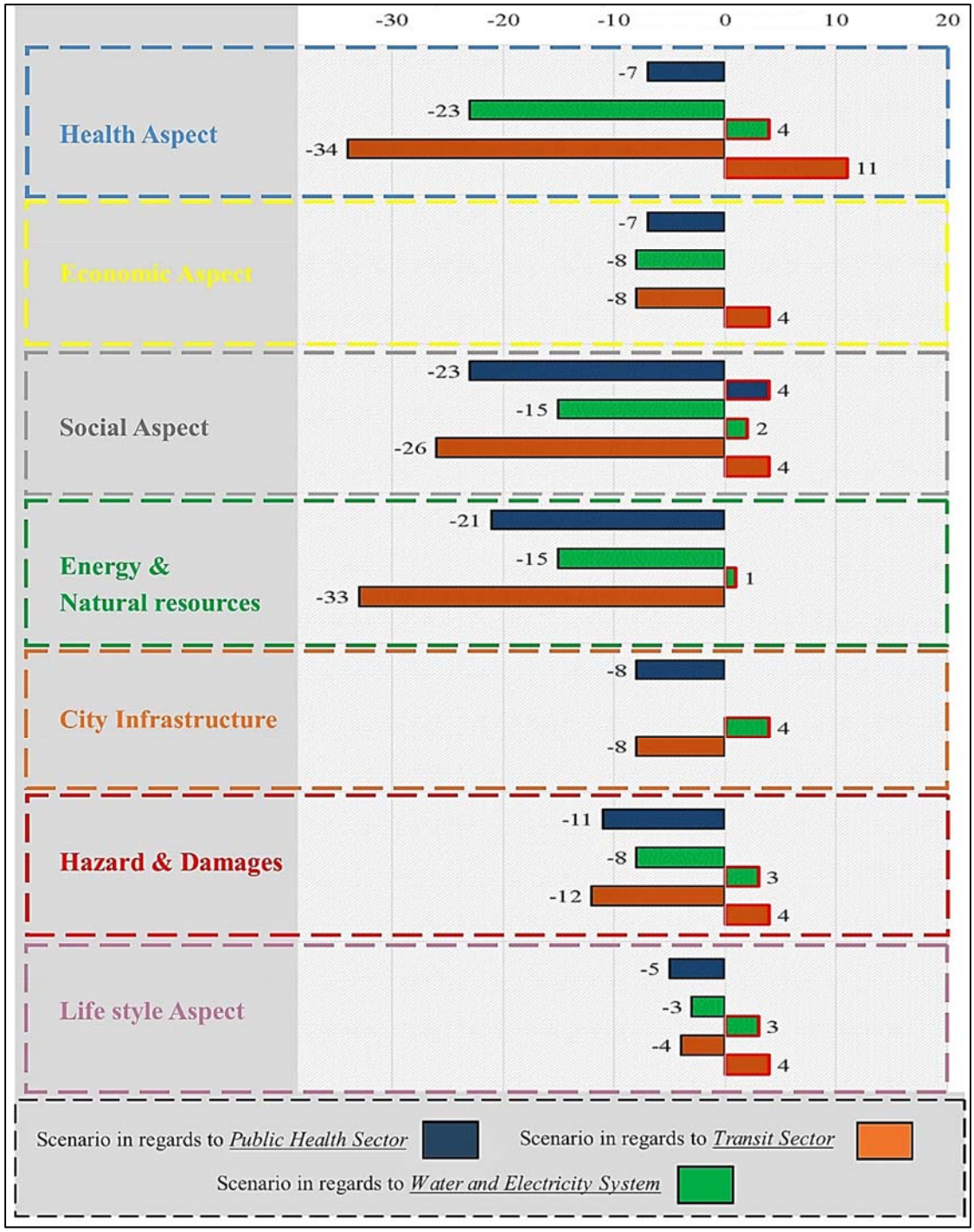


Figure 37: Comparing different scenario's effects on low income groups with respect to different aspects (concepts Group). Source: Own draft

As it presented in figure 37, in regards to "health aspect", "social aspect" and "energy and natural resources" scenario with focus on transit sector has the strongest positive effect on low income group while in regards to "hazard and damages" and "life style aspect", scenario which focuses on public health has the strongest positive effect according to simulation results. It should be considered that due to the definition of concepts which are mainly include negative impacts, the negative numbers in the figures represent the positive effects by decreasing these negative impacts while positive numbers represent negative effect by increasing these negative impacts.

4.3.2.3. Results of FCM scenario simulation for middle income group

The effect of each scenario (in 30 iteration) on middle income group's cognitive map with respect to defined aspects (concept groups) is presented in figure 38. The results for each concepts is presented with a number between +4 (highest positive change compare to steady state) and -4 (highest negative change compare to steady state) which is the results of FCMAPPER software.

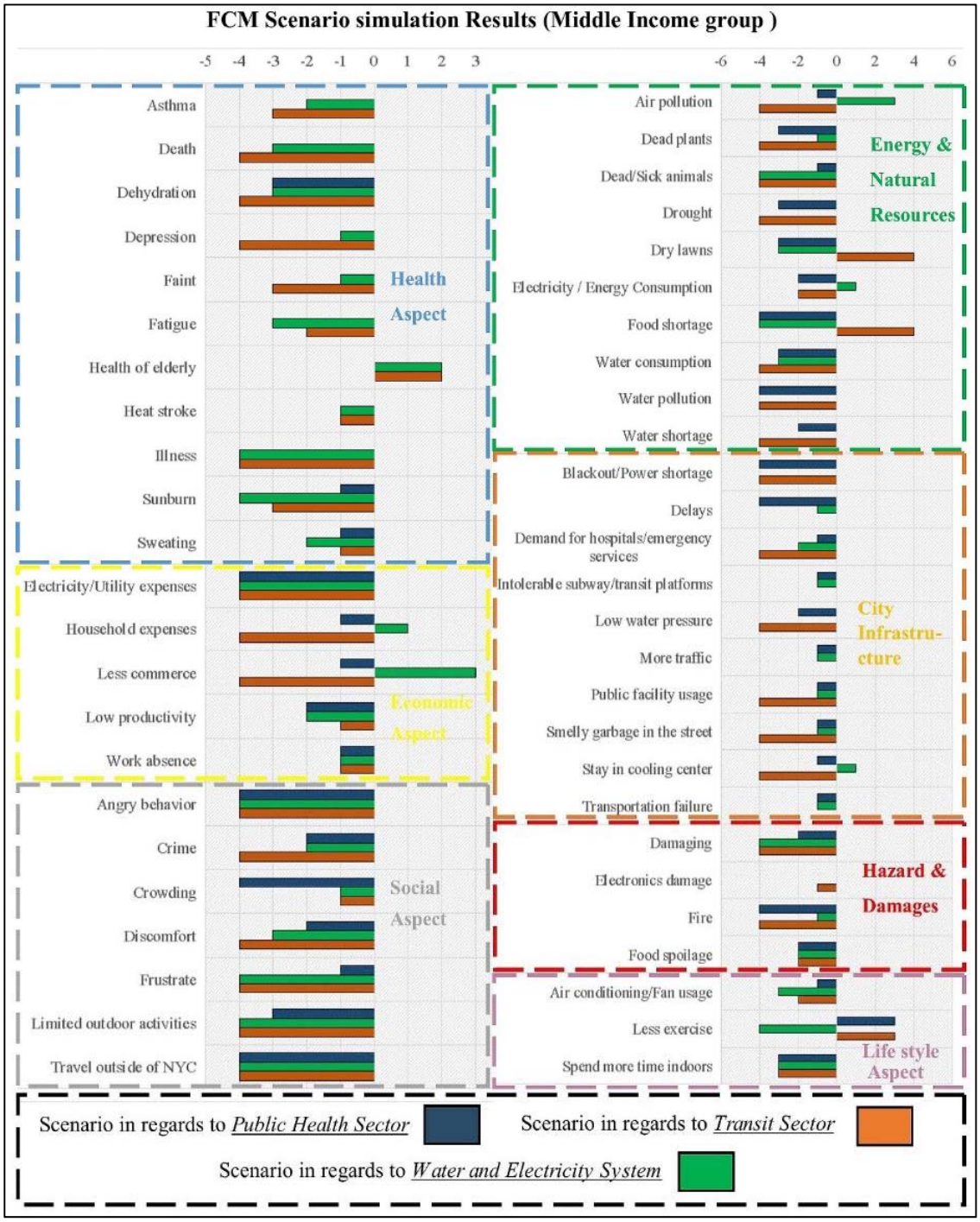


Figure 38: Results of FCM scenario simulation for middle income group
Source: Own draft

To have a better understanding about these scenarios effects on middle income groups, positive and negative change in concepts with respects to each aspects are merged and presented in figure 39. The negative number in the figure 39 shows the decrease in negative impacts (concepts) and positive numbers shows the increase in negative impacts.

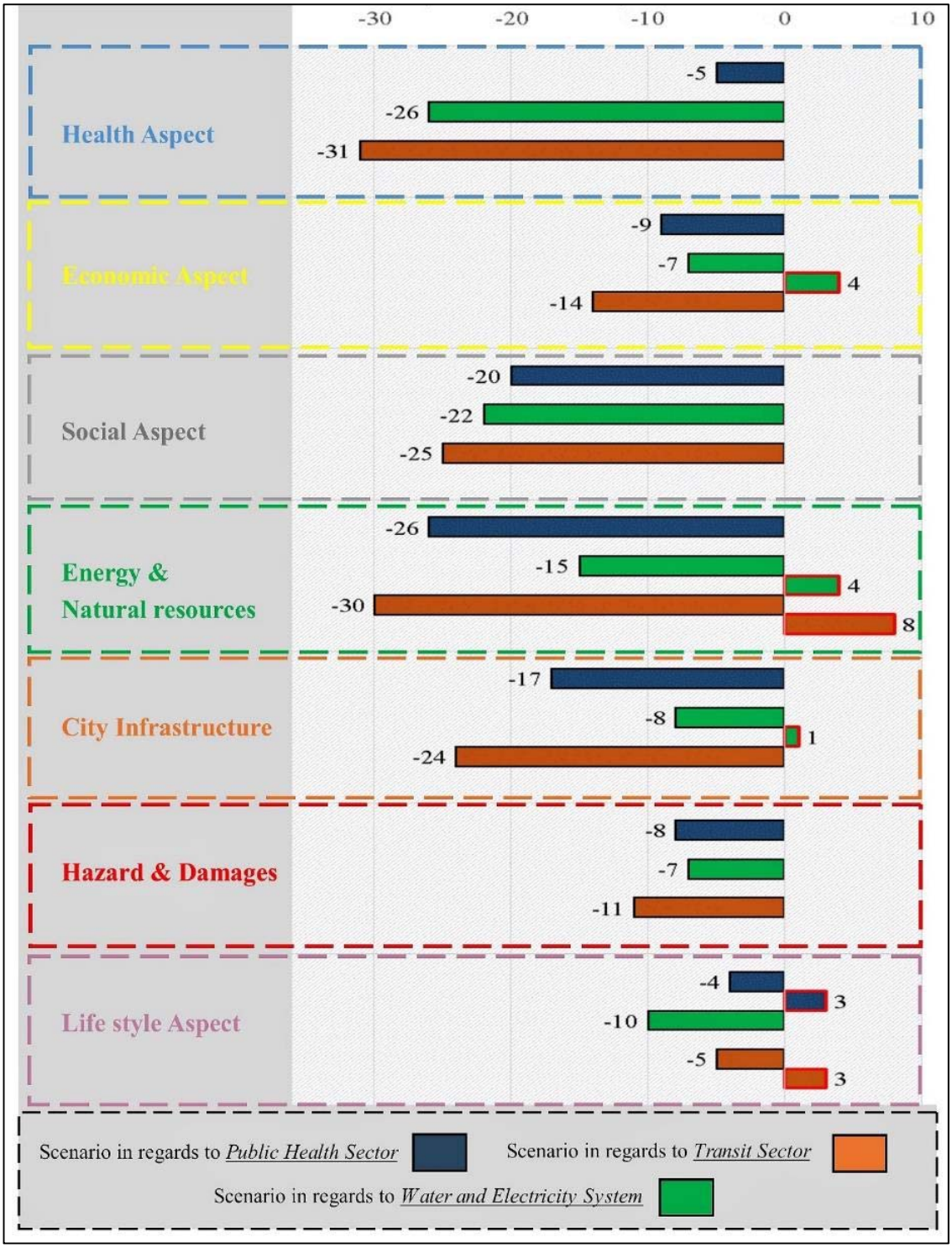


Figure 39: Comparing different scenario's effects on middle income groups with respect to different aspects (concepts Group). Source: Own draft

According to figure 39, similar to the results of in poverty group, scenario which focuses on transit sector shows the strongest positive impacts in regards to "health aspect", "economic aspect" , "social aspect", "city infrastructure" and "hazard and damages". Scenario about public health sector shows the strongest positive impacts in regards to "energy and natural resources" while the scenarios which focuses on water and electricity system shows the strongest positive effect on "Life style aspect".

4.3.2.4. Results of FCM scenario simulation for high income group

The effect of each scenario (in 30 iteration) on high income group's cognitive map with respect to defined aspects (concept groups) is presented in figure 40. The results for each concepts is presented with a number between +4 (highest positive change compare to steady state) and -4 (highest negative change compare to steady state) which is the results of FCMAPPER software.

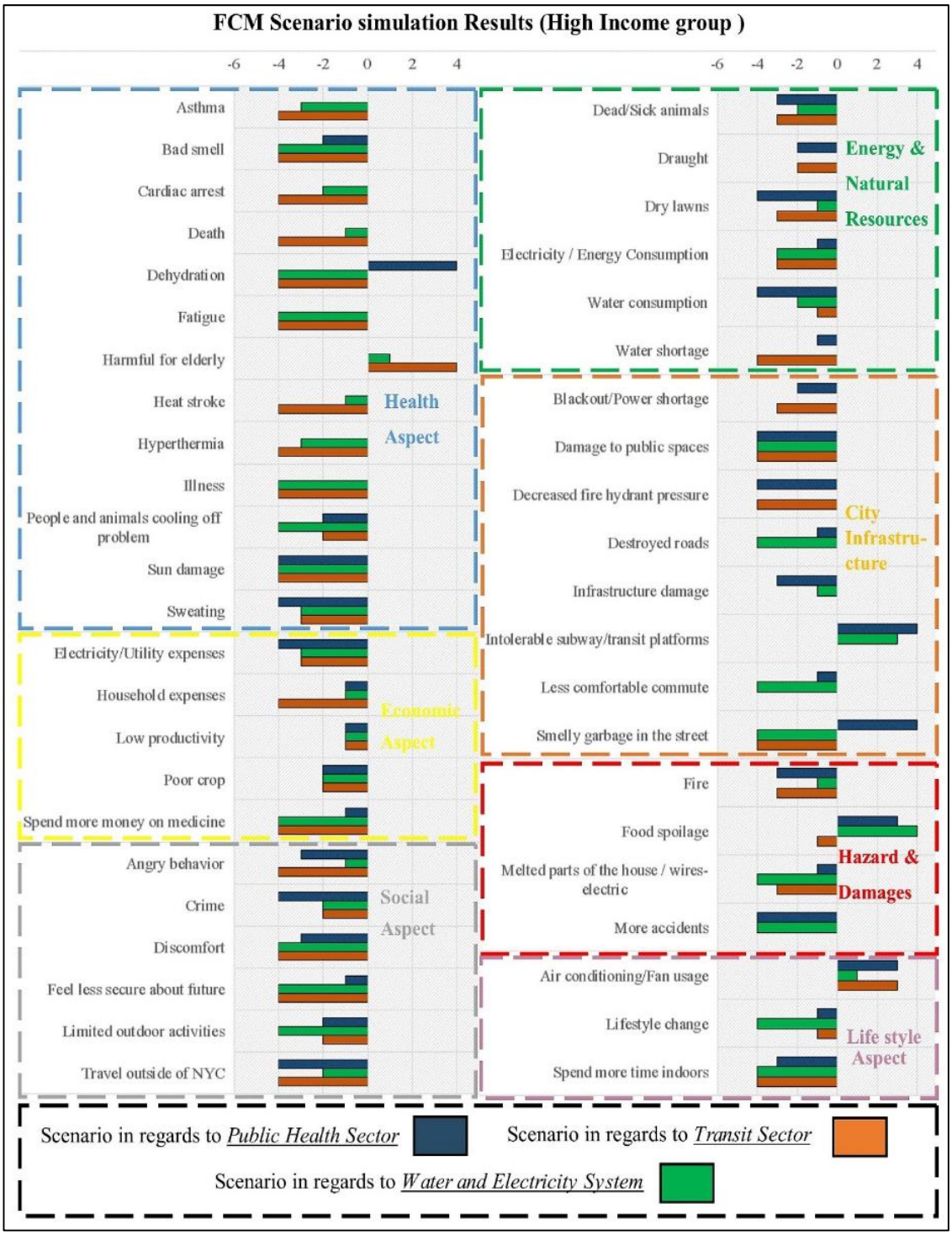


Figure 40: Results of FCM scenario simulation for high income group
Source: Own draft

To have a better understanding about these scenarios effects on high income groups, positive and negative change in concepts with respects to each aspects are merged and presented in figure 41. The negative number in the figure 41 shows the decrease in negative impacts (concepts) and positive numbers shows the increase in negative impacts.

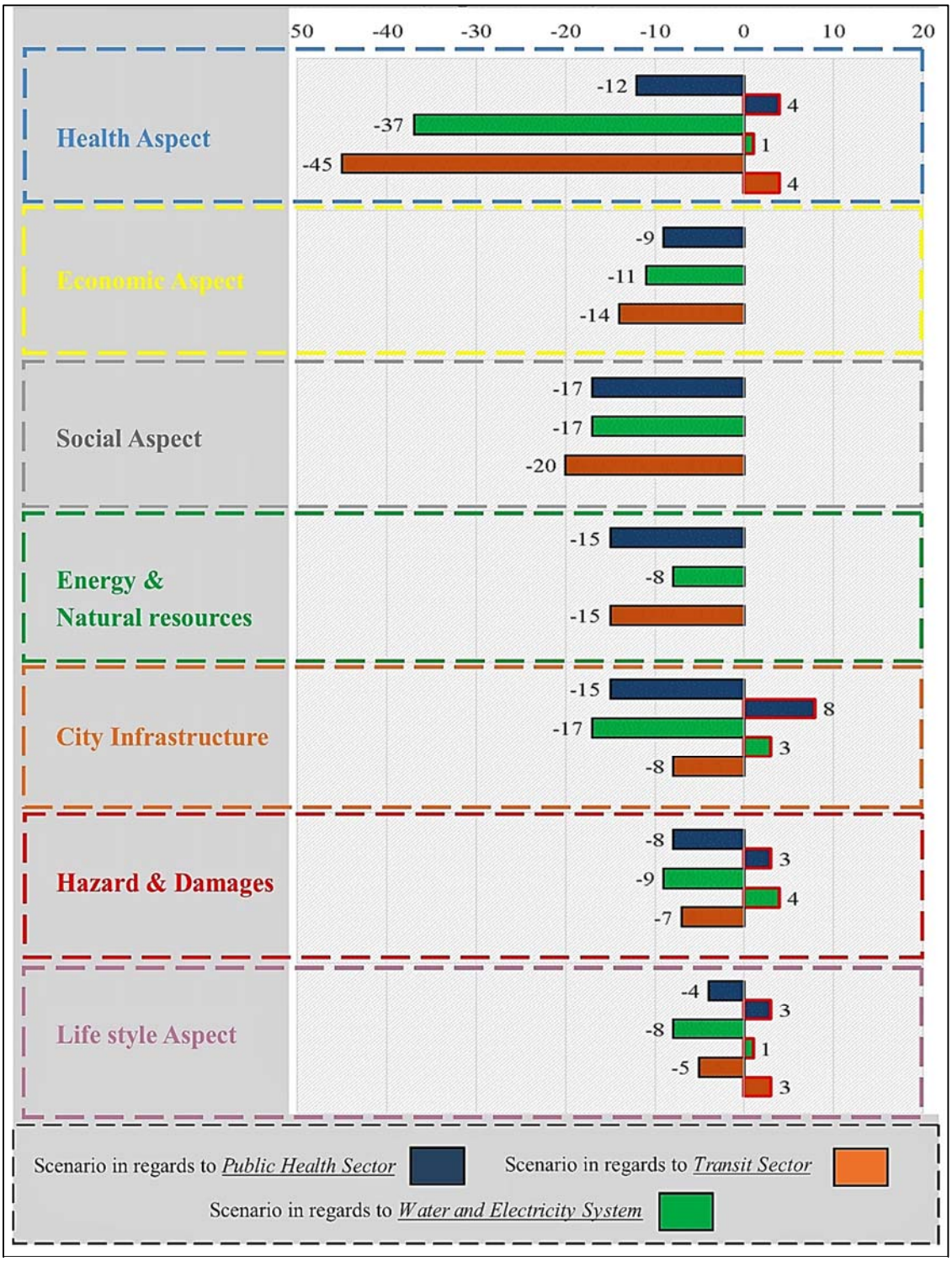


Figure 41: Comparing different scenario's effects on high income groups with respect to different aspects (concepts group). Source: Own draft

According to figure 41, scenario which focuses on transit sector shows the strongest positive impacts in regards to "health aspect", "economic aspect" , "social aspect", "city infrastructure" and "hazard and damages" furthermore they have the strongest positive impacts in regards to "energy and natural resources" together with scenario about public health sector. Scenario which focuses on water and electricity system shows the strongest positive effect in regards to both "city infrastructure" and "life style aspects".

4.3.2.5. Comparison across different income groups with respect to final results of FCM scenario simulation

Figure 42, shows the results of merging all the positive and negative value of change (number between -4 and +4) for all the concepts to provide a general overview of effect of each scenario on research income groups. It should be considered that the negative number in the figure 42 shows the decrease in negative impacts (concepts) and positive numbers shows the increase in negative impacts.

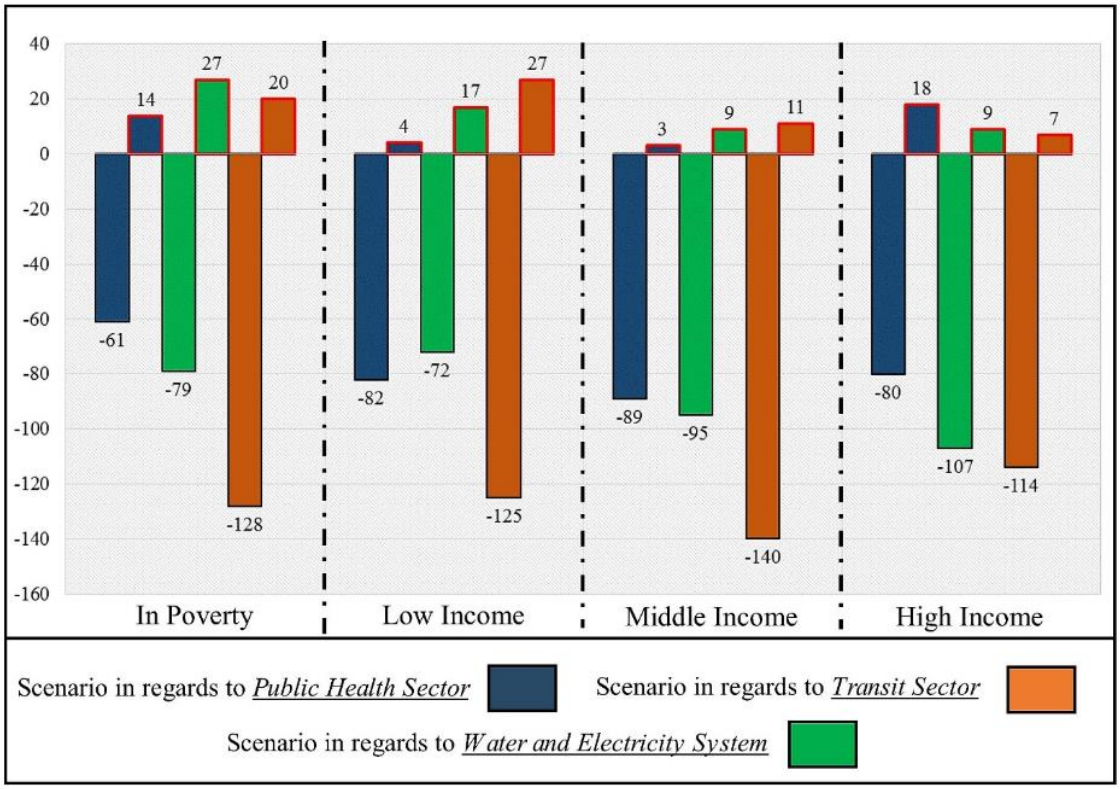


Figure 42: Comparison across different income groups with respect to final results of FCM scenario simulation
Source: Own draft

According to figure 42, it could be concluded that all 3 scenarios have overall positive impacts for middle and high income groups, but mixed impacts for low and poverty group. Scenario in regards to transit sector shows the strongest positive effect in all income groups. The results of FCM scenario simulation for that scenario in regards to water and electricity system has stronger positive effect on poverty and high income groups compare to the scenario in regards to public health sector while the results for low income groups is opposite. These two scenarios have almost the same effect on middle income groups according to the results.

5. CONCLUSION

In this chapter the results of all the research analysis with respect to research objective are concluded. This chapter include three main section. In section one the results in regards to statistical analysis with respect to related research objective is presented. Section two focuses on FCM analysis results with respect to related research objective. In section three the research limitation are discussed.

5.1. Statistical analysis (sub objective 1 and 2)

According to detail discussion in research methodology, descriptive statistics and non-parametric statistical analysis (Kruskal-Wallis H-Test and Mann-Whitney U-test) are selected to answer research questions in regards to first two research objectives. The conclusion according to the results of statistical analysis with respect to these objectives is presented in table 26.

Sub-Objective 1
To Identify main differences across different income groups in NYC in regards to the past and future impacts of heat waves
***What are the main differences across different income groups in regards to their experience about past impacts of Heat Waves*?** According to the research results, more than half of the citizens (more than 60%) in all income groups, express that they didn't experience any harm from heat waves in the past 10 years. Among citizens who experience negative impacts of heat waves, the pattern in all income groups is the same and health related damage and financial damages is highlighted in all income group's statements.
What are the main differences across different income groups in regards to their concerns about future impacts of Heat Wave? According to the descriptive statistic results, the majority of citizens (more than 70%) in all income groups express that they are very worried about future impacts of heat waves. According to the results of non-parametric statistical analysis, there is a significant differences between two low income groups (in poverty group and low income group) in one side and two higher income groups (middle income group and high income group) on the other side, in regards to future impacts of heat waves in New York city. According to these results, it can be concluded that citizens with lower income are more concern about future negative impacts of heat waves in New York city compare to middle class and high income group.
Sub-Objective 2
To Identify the main differences across different income groups in NYC in regards to orientation of future HW adaptation practices
What are the main differences, across different income groups in regards to their opinion about citizens' responsibility in HW adaptation practices in NYC? According to research results, the majority of citizens (more than 68%) in each income group believed that citizens should be more responsible in heat wave adaptation issues. According to these results, in lower income groups (in poverty and low income) more people think citizens should be much more responsible in regards to impacts of heat waves compare to groups with higher income (middle income and high income groups).

What are the main differences, across different income groups in regards to their opinion about the important urban sector(s) in the future HW adaptation practices in NYC?
According to the research results, all the urban sectors which analysed in the research (The water supply, The public's health, The drainage and sewer system, The subway and rail system, The electricity system, Urban greenery and parks, The road system, The building stock) are very important for majority of citizens in all income groups. It should be considered that, just in regards to "*Urban greenery and park*", there is a significant different between low income group and middle income group. According to results, it can be concluded that among different urban sectors, "*Urban greenery and park*" is more important for low income groups compare to higher income groups.

Table 26: Research conclusion in regards to sub objective 1 and 2

5.2. FCM analysis (sub objective 3 and 4)

According to detail discussion in chapter 3, FCM analysis is used to answer research questions in regards to last two research objectives. The conclusion according to the results of FCM analysis with respect to these objectives is presented in table 27.

Sub-Objective 3
To capture the citizens' Cognitive Maps in regards to impacts of HW across different income groups in NYC
What are the main elements (concepts and relation between them) in each income groups' cognitive maps in regards to impacts of heat waves in NYC?
According to results of FCM analysis about centrality, In regards to in poverty group's map, concepts about "*Heat stroke*", "*Electricity/Utility expenses*", "*Limited outdoor activities*", "*Discomfort*" and "*Blackout/Power shortage*" are the main elements. In low income group's map, concepts about "*Dehydration*", "*Discomfort*", "*Angry behaviour*", "*Electricity/Energy consumption*", "*Water shortage*" and *"Blackout/ Power shortage*" are the main elements. In Middle income group's map, concepts about "*Illness*", "*Dehydration*", "*Electricity/Energy consumption*", "*Angry behaviour*", "*Limited outdoor activities*", "*Water consumption*" and *"Blackout/ Power shortage*" are the main elements. In High income group's map, concepts about "*Illness*", "*Electricity/Utility expenses*", "*Discomfort*", "*Blackout/ Power shortage*" and "*Spend more time indoors"* are the main elements.
What are the main differences between different income groups' cognitive maps structure in regards to impacts of heat waves in NYC?
According to the research results, the middle income groups cognitive map has the highest number of concepts as it is almost the most complex network compare to other groups while the high income groups has the lowest number of concepts and lowest density. The In poverty and low income groups almost have the similar number of concepts but the low income groups cognitive map has the highest density between all research income groups.

It should be considered that different income groups' cognitive maps, share so many similar concepts and the main differences is in regards to priority of concepts with respect to FCM indices' value (Centrality, In-degree and Out-degree).
Sub-Objective 4
To Identify the suitable HW adaptation options for each income groups with respect to their cognitive maps in NYC
How Different adaptation options affects different income groups in NYC, with respects to their cognitive maps about Heat wave impacts?   The scenario about transit sector shows the strongest positive impacts on concepts related to "*Health aspect*", "*Economic aspect*", "*Energy and Natural resources*" and "*Hazard and damages*". Scenario about public health sector shows the strongest positive impacts in regards to "S*ocial aspects*". In regards to "*Life style aspect*", scenarios about both transit sector and water and electricity system shows similar positive impacts.   In regards to low income group, scenario with focus on transit sector has the strongest positive effect on concepts related to "*Health aspect*", "*Social aspect*" and "*Energy and Natural resources*" while in regards to "*Hazard and Damages*" and "*Life style aspect*", scenario which focuses on public health has the strongest positive effect.   In regards to middle income groups, scenario which focuses on transit sector shows the strongest positive impacts on concepts related to "*Health aspect*", "*Economic aspect*", "*Social aspect*", "*City infrastructure*" and "*Hazard and Damages*". Scenario about public health sector shows the strongest positive impacts in regards to "*Energy and Natural resources*" while the scenarios which focuses on water and electricity system shows the strongest positive effect on "*Life style aspect*".   In regards to high income group, scenario which focuses on transit sector shows the strongest positive impacts on concepts related to "*Health aspect*", "*Economic aspect*" , "*Social aspect*", "*City infrastructure*" and "*Hazard and Damages*". This scenario have the strongest positive impacts in regards to "*Energy and Natural resources*" together with scenario about public health sector. Scenario which focuses on water and electricity system shows the strongest positive effect on concepts related to both "*City infrastructure*" and "*Life style aspects*".
What are the suitable HW adaptation options for each income groups with respect to citizens' cognitive maps in NYC?   According to results of FCM scenario analysis, it could be concluded that adaptation options which focus on "*Transit sector*" are the most suitable adaption options for all income groups in New York city with respects to different income groups' cognitive maps.   Adaptation options which focus on "*Water and Electricity system*" are the second suitable adaptation options for in poverty group and high income group in New York city with respect to these groups' cognitive maps.   Adaptation options which focus on "*Public Health sector*" are the second suitable adaptation options for low income group in New York city.

Table 27: Research conclusion in regards to sub objective 3 and 4

According to the conclusion, the main objective of the research which is ***"To identify the suitable adaptation options for different income groups impacted by Heat waves in New York City"*** is obtained. The results of this research provide a useful overview for policy maker in regards to differences across different income groups in New York City about the impacts of heat waves. Furthermore this research provide a framework for assessing the heat wave adaptation scenario in New York City with respect to different income groups cognitive maps.

5.3. Research limitation

In regards to statistical analysis results validation, the main limitation is the research data samples size which is quite small (762) compare to population of New York City (which projected to be 8,405,837 in 2013 according to ACS). But it should be considered that the research data set is a rich dataset with more than 60 variables in regards to different subjects which at least can provide a useful overview of differences between various income groups in New York City for policy maker.

The other limitation is in regards to gathering the FCM basic data through online interview which increase the risk of misunderstanding and mistake especially about the relation between concepts. According to Özesmi & Özesmi (2004) and Olazabal & Reckien (2015), face to face interview method is suggested as suitable method for gathering FCM basic data which minimize the misunderstanding risk about the concepts and their relations. Although it is important to note that online interview increase the possibility to include more participant with different characteristics in the FCM sample and can provide more comprehensive overview of whole population cognitive map and will increase the spatial scope of sampling data due to include participant from all over the New York city area.

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7. APPENDIX

7.1. Poverty threshold (in $) for New York City (in 2013)

Size of family unit	Related children under 18 years								
	None	One	Two	Three	Four	Five	Six	Seven	Eight or more
1	12,119								
2	15,600	16,057							
3	18,222	18,751	18,769						
4	24,028	24,421	23,624	23,707					
5	28,977	29,398	28,498	27,801	27,376				
6	33,329	33,461	32,771	32,110	31,128	30,545			
7	38,349	38,588	37,763	37,187	36,115	34,865	33,493		
8	42,890	43,269	42,490	41,807	40,839	39,610	38,331	38,006	
9	51,594	51,844	51,154	50,575	49,625	48,317	47,134	46,842	45,037

Table 28: Poverty threshold (in $) for New York City (in 2013)
Source: (DeNavas-Walt & Proctor, 2014)

7.2. Results of evaluating different income group concerns about future impacts of heat waves (with respect to define subjects)

		In Poverty		Low Income		Middle Income		High Income	
		Count	Column N %	Count	Column N %	Count	Column N %	Count	Column N %
Impacts will harm You ***personally***	Not at all severe	11	11.6%	26	12.3%	57	16.0%	9	13.0%
	Not very severe	34	35.8%	72	34.0%	151	42.4%	34	49.3%
	Somewhat severe	35	36.8%	79	37.3%	115	32.3%	21	30.4%
	Very severe	15	15.8%	35	16.5%	33	9.3%	5	7.2%
	Total	95	100.0%	212	100.0%	356	100.0%	69	100.0%
Impacts will harm ***Your family***	Not at all severe	11	11.8%	26	12.9%	50	14.3%	8	12.5%
	Not very severe	29	31.2%	68	33.7%	138	39.5%	33	51.6%
	Somewhat severe	38	40.9%	74	36.6%	132	37.8%	19	29.7%
	Very severe	15	16.1%	34	16.8%	29	8.3%	4	6.3%
	Total	93	100.0%	202	100.0%	349	100.0%	64	100.0%
Impacts will harm ***Your community/ neighbourhood***	Not at all severe	4	4.3%	17	8.3%	25	7.0%	1	1.5%
	Not very severe	24	26.1%	62	30.2%	116	32.7%	30	44.8%
	Somewhat severe	49	53.3%	87	42.4%	171	48.2%	31	46.3%
	Very severe	15	16.3%	39	19.0%	43	12.1%	5	7.5%
	Total	92	100.0%	205	100.0%	355	100.0%	67	100.0%
Impacts will harm ***Your borough***	Not at all severe	5	5.4%	11	5.3%	24	6.8%	2	2.9%
	Not very severe	22	23.7%	58	28.2%	97	27.5%	24	35.3%
	Somewhat severe	48	51.6%	89	43.2%	184	52.1%	36	52.9%
	Very severe	18	19.4%	48	23.3%	48	13.6%	6	8.8%
	Total	93	100.0%	206	100.0%	353	100.0%	68	100.0%
Impacts will harm ***NYC in general***	Not at all severe	2	2.2%	13	6.3%	19	5.3%	2	2.9%
	Not very severe	18	19.4%	42	20.3%	83	23.3%	19	27.9%
	Somewhat severe	43	46.2%	74	35.7%	188	52.8%	38	55.9%
	Very severe	30	32.3%	78	37.7%	66	18.5%	9	13.2%
	Total	93	100.0%	207	100.0%	356	100.0%	68	100.0%
Impacts will harm ***Future generations***	Not at all severe	5	6.2%	13	6.7%	17	4.9%	3	4.7%
	Not very severe	8	9.9%	26	13.5%	69	19.8%	15	23.4%
	Somewhat severe	30	37.0%	63	32.6%	152	43.7%	32	50.0%
	Very severe	38	46.9%	91	47.2%	110	31.6%	14	21.9%
	Total	81	100.0%	193	100.0%	348	100.0%	64	100.0%
Impacts will harm ***Plant & animal species***	Not at all severe	3	3.2%	10	4.9%	12	3.4%	3	4.4%
	Not very severe	11	11.7%	24	11.7%	60	16.8%	12	17.6%
	Somewhat severe	21	22.3%	73	35.6%	152	42.6%	27	39.7%
	Very severe	59	62.8%	98	47.8%	133	37.3%	26	38.2%
	Total	94	100.0%	205	100.0%	357	100.0%	68	100.0%

Table 29: Different income groups concerns about future impacts of heat waves based on different subjects; Source: Own draft

7.3. Results of evaluating Importance of different urban sectors in heat wave adaptation based on income groups' perception

		In Poverty	Low Income	Middle Income	High Income
The water supply	Not at all important	1.0%	1.4%	0.8%	2.9%
	Not too important	4.0%	3.2%	3.9%	2.9%
	Somewhat important	13.0%	14.2%	21.1%	15.7%
	Very important	82.0%	81.2%	74.2%	78.6%
	Total	100.0%	100.0%	100.0%	100.0%
The public's health	Not at all important	0.0%	1.4%	0.8%	1.4%
	Not too important	2.0%	4.6%	3.9%	0.0%
	Somewhat important	15.2%	18.3%	24.2%	30.0%
	Very important	82.8%	75.8%	71.1%	68.6%
	Total	100.0%	100.0%	100.0%	100.0%
The drainage and sewer system	Not at all important	7.1%	6.1%	6.6%	8.6%
	Not too important	19.2%	11.7%	18.3%	20.0%
	Somewhat important	20.2%	33.3%	27.7%	27.1%
	Very important	53.5%	48.8%	47.4%	44.3%
	Total	100.0%	100.0%	100.0%	100.0%
The subway and rail system	Not at all important	3.0%	1.8%	0.6%	2.9%
	Not too important	10.1%	8.3%	9.1%	8.7%
	Somewhat important	25.3%	23.5%	32.0%	27.5%
	Very important	61.6%	66.4%	58.3%	60.9%
	Total	100.0%	100.0%	100.0%	100.0%
The electricity system	Not at all important	1.0%	0.9%	0.0%	1.4%
	Not too important	9.1%	1.8%	3.6%	2.9%
	Somewhat important	11.1%	13.8%	18.0%	14.5%
	Very important	78.8%	83.5%	78.5%	81.2%
	Total	100.0%	100.0%	100.0%	100.0%
The building stock, e.g. through insulation	Not at all important	1.0%	3.7%	3.1%	2.9%
	Not too important	15.6%	19.2%	14.2%	16.2%
	Somewhat important	37.5%	35.5%	46.0%	41.2%
	Very important	45.8%	41.6%	36.8%	39.7%
	Total	100.0%	100.0%	100.0%	100.0%
Urban greenery and parks	Not at all important	3.0%	0.9%	1.9%	2.9%
	Not too important	10.1%	7.9%	13.8%	17.4%
	Somewhat important	31.3%	38.1%	39.9%	34.8%
	Very important	55.6%	53.0%	44.4%	44.9%
	Total	100.0%	100.0%	100.0%	100.0%
The road system	Not at all important	5.1%	3.7%	3.9%	10.0%
	Not too important	25.5%	13.1%	19.1%	15.7%
	Somewhat important	28.6%	36.4%	40.9%	37.1%
	Very important	40.8%	46.7%	36.2%	37.1%
	Total	100.0%	100.0%	100.0%	100.0%

Table 30: Importance of different urban sectors in heat wave adaptation based on income groups' perception; Source: Own draft

7.4. Results of FCM analysis

7.4.1. In poverty group

Groups	Concept	In-degree	Out-degree	Centrality
Health Aspect	Anxiousness	8.80	2.60	11.39
	Asthma	3.25	2.40	5.65
	Bad smells	0.80	0.60	1.40
	Cardiac arrest	1.70	2.70	4.40
	Children death	3.08	1.25	4.33
	Death	6.16	4.37	10.53
	Dehydration	4.26	6.29	10.55
	Elderly death	5.71	5.53	11.24
	Fatigue	5.10	4.34	9.44
	Hard to concentrate	6.00	4.80	10.80
	Heat stroke	11.93	7.84	19.77
	Hyperthermia	0.60	0.85	1.45
	Illness	10.08	8.49	18.57
	Migraine	2.56	2.24	4.80
	Mood Enhancement	0.75	0.75	1.50
	More thirsty	5.30	2.43	7.73
	Overwhelmingly hot	6.50	6.45	12.95
	Skin cancer	0.38	0.25	0.63
	Sleep disorder	1.04	4.43	5.47
	Staying cool	6.24	1.20	7.44
	Sunburn	0.38	0.34	0.72
	Sweating	7.95	8.75	16.70
	Weight loss	4.35	3.80	8.15
Economic Aspect	Electricity/Utility expenses	9.00	4.83	13.83
	Household expenses	3.80	2.20	6.00
	Less income	1.85	2.20	4.05
	Low productivity	5.25	1.30	6.55
	Working problem	3.30	1.88	5.18
Social Aspect	Angry behaviour	6.45	0.97	7.42
	Concern about elderly	3.45	2.85	6.30
	Crime	1.50	0.85	2.35
	Discomfort	8.03	6.73	14.76
	Lack of functional A/C	0.30	1.40	1.70
	Limited outdoor activities	7.63	8.30	15.93

	People break fire hydrants	0.60	0.20	0.80
	Travel outside of NYC	0.80	0.50	1.30
Energy & Natural Resources	Dead plants	0.80	0.35	1.15
	Dead/Sick animals	1.60	1.40	3.00
	Dead/Sick pets	1.95	0.01	1.96
	Desertification	2.00	2.00	4.00
	Drought	5.73	3.71	9.44
	Electricity / Energy Consumption	4.82	4.36	9.18
	Harmful for environment	2.30	2.00	4.30
	High humidity	4.20	4.10	8.30
	Water consumption	5.04	4.26	9.31
	Water shortage	4.03	7.37	11.39
City Infrastructure	Blackout/Power shortage	6.59	9.96	16.55
	Emergencies for hospital	1.80	1.40	3.20
	Intolerable subway/transit platforms (crowded/smelly/Hot)	2.00	4.20	6.20
	Subway failures	3.65	3.80	7.45
	Transportation usage	2.50	2.15	4.65
	Water line problem	0.75	0.00	0.75
Hazard & Damages	Fire	2.96	3.36	6.32
	Food spoilage	2.98	1.73	4.71
	Heat Wave	0.00	36.69	36.69
Life style Aspect	Air conditioning/Fan usage	2.88	3.85	6.73
	Lifestyle change	1.90	0.70	2.60
	Pool/Beach usage	1.30	3.70	5.00
	Spend more time indoors	5.00	4.05	9.05
	Using restaurants	1.40	0.98	2.38

Table 31: Results of FCM analysis for in poverty group;
Source: Own draft

7.4.2. Low income group

Groups	Concept	In-degree	Out-degree	Centrality
Health Aspect	Anxiousness	0.75	1.25	2.00
	Asthma	4.03	2.10	6.13
	Bad smells	2.55	0.21	2.76
	Death	10.14	3.56	13.70
	Dehydration	10.44	11.95	22.39
	Depression	0.25	1.75	2.00
	Dry skin	1.65	0.30	1.95
	Fatigue	4.00	2.10	6.10
	Harmful for children	1.00	0.00	1.00
	Harmful for disabled	3.80	2.50	6.30
	Harmful for elderly	4.08	2.40	6.47
	Heat rash	1.10	1.50	2.60
	Heat stroke	5.90	5.01	10.91
	Illness	7.16	2.94	10.10
	Laziness	1.00	0.00	1.00
	More thirsty	2.25	0.70	2.95
	Overwhelmingly hot	2.06	5.92	7.98
	Spread of infections	5.50	4.50	10.00
	Sunburn	1.10	2.40	3.50
	Sweating	7.62	6.56	14.18
Economic Aspect	Electricity/Utility expenses	8.73	11.18	19.91
	Food prices	2.20	2.70	4.90
	Low productivity	2.95	2.76	5.71
	Poor crop	2.48	0.90	3.37
Social Aspect	Angry behaviour	9.76	9.28	19.03
	Crime	3.23	1.50	4.73
	Desire A/C	1.20	0.80	2.00
	Discomfort	12.07	12.82	24.89
	Fear	2.60	1.60	4.20
	Feeling miserable	2.75	0.90	3.65
	Frustrate	3.70	0.90	4.60
	Limited outdoor activities	8.97	5.89	14.86
	School closing	6.21	0.24	6.45
	Wishes to live somewhere else	2.65	1.00	3.65
Energy & Natural resources	Air pollution	5.62	8.30	13.92
	Conserving water	2.88	4.35	7.22
	Dead plants	5.73	7.07	12.81
	Dead/Sick animals	2.51	3.50	6.01
	Drought	2.90	0.35	3.25
	Dry lawns	4.15	3.50	7.65

	Electricity / Energy Consumption	12.51	8.41	20.92
	Food shortage	6.20	5.89	12.09
	Water consumption	5.22	4.07	9.29
	Water shortage	5.12	12.73	17.86
City Infrastructure	Blackout/Power shortage	10.05	10.93	20.98
	Intolerable subway/transit platforms(crowded/smelly/Hot)	0.90	1.20	2.10
	Subway delays	1.10	0.01	1.11
	Uncomfortable to travel	1.15	1.59	2.74
Hazard and Damages	Fire	1.90	1.35	3.25
	Food spoilage	2.70	2.88	5.58
	Heat Wave	0.00	33.55	33.55
	Insects	3.90	1.45	5.35
	Non-functional elevators	2.60	1.90	4.50
	Overheated cars	1.75	1.55	3.30
	Radiation	1.90	3.60	5.50
	The heat traps in the city	2.79	2.35	5.14
Life style Aspect	Air conditioning/Fan usage	8.53	6.51	15.04
	Pool/Beach usage	1.14	1.60	2.74
	Spend more time indoors	3.23	3.55	6.78

Table 32: Results of FCM analysis for low income group
Source: Own draft

7.4.3. Middle income group

Groups	Concept	In-degree	Out-degree	Centrality
Health Aspect	Anxiousness	0.20	0.00	0.20
	Asthma	3.75	2.33	6.08
	Cabin fever	1.10	1.35	2.45
	Death	6.27	4.67	10.94
	Dehydration	10.26	9.55	19.80
	Depression	2.50	0.41	2.91
	Faint	4.56	3.27	7.83
	Fatigue	6.30	6.21	12.51
	Health of elderly	5.53	1.41	6.93
	Heat stroke	5.15	3.60	8.75
	Illness	17.83	18.43	36.26
	Laziness	5.30	1.25	6.55
	More thirsty	5.21	4.40	9.61
	Pestilence	4.60	4.61	9.21
	Skin cancer	0.90	0.00	0.90
	Sunburn	1.90	1.65	3.55
	Sweating	4.01	2.20	6.21
Economic Aspect	Electricity/Utility expenses	11.79	9.85	21.64
	Household expenses	4.40	2.50	6.90
	Less commerce	2.50	0.70	3.20
	Low productivity	1.28	2.01	3.28
	Work absence	1.55	1.10	2.65
Social Aspect	Angry behaviour	11.34	9.00	20.34
	Crime	4.86	3.73	8.59
	Crowding	0.65	0.70	1.35
	Discomfort	8.40	6.60	15.00
	Frustrate	5.65	0.00	5.65
	Limited outdoor activities	7.08	8.98	16.05
	Travel outside of NYC	0.80	0.30	1.10
Energy & Natural Resources	High humidity	1.60	3.15	4.75
	Air pollution	1.64	3.23	4.87
	Dead plants	1.57	0.00	1.57
	Dead/Sick animals	0.80	0.60	1.40
	Dead/Sick pets	5.30	3.50	8.80
	Drought	0.88	1.17	2.04
	Dry air	0.60	0.00	0.60
	Dry lawns	8.08	4.71	12.80
	Electricity / Energy Consumption	4.37	5.08	9.45
	Food shortage	1.10	2.40	3.50
	Water consumption	9.61	6.64	16.25

	Water pollution	0.14	0.37	0.51
	Water shortage	2.87	3.54	6.40
City Infrastructure	Asphalt melting	1.00	0.50	1.50
	Blackout/Power shortage	11.76	16.89	28.65
	Delays	0.85	0.75	1.60
	Demand for hospitals/emergency services	5.68	5.17	10.84
	Intolerable subway/transit platforms(crowded/smelly/Hot)	3.91	4.70	8.61
	Low water pressure	1.02	1.02	2.04
	More traffic	2.04	2.70	4.74
	Open hydrants	1.00	1.00	2.00
	Public facility usage	3.88	2.45	6.33
	Smelly garbage in the street	1.88	1.26	3.14
	Stay in cooling center	1.98	5.74	7.71
	Transportation failure	2.85	2.10	4.95
Hazard and Damages	Damaging	6.00	5.00	11.00
	Electronics damage	1.50	0.00	1.50
	Fire	2.00	0.50	2.50
	Food spoilage	6.10	3.50	9.60
	Heat Wave	0.00	42.21	42.21
	Overheated cars	0.70	2.45	3.15
	Smog	2.51	4.50	7.01
Life style Aspect	Air conditioning/Fan usage	5.06	2.72	7.79
	Drinking more liquid	6.45	1.60	8.05
	Gardening difficulty	2.10	3.05	5.15
	Less exercise	2.00	3.45	5.45
	Limited clothing choices	1.40	0.50	1.90
	Pool/Beach usage	2.78	3.38	6.16
	Spend more time indoors	7.03	5.33	12.36

Table 33: Results of FCM analysis for middle income group

Source: Own draft

7.4.4. High income group

Groups	Concept	In-degree	Out-degree	Centrality
Health Aspect	Asthma	3.00	2.10	5.10
	Bad smell	4.58	4.22	8.80
	Cardiac arrest	1.37	0.02	1.39
	Death	3.96	1.85	5.81
	Dehydration	3.00	1.96	4.96
	Fatigue	3.41	2.67	6.09
	Gain weight	1.95	3.20	5.15
	Harmful for elderly	1.15	0.85	2.00
	Heat stroke	3.05	1.65	4.70
	Hyperthermia	4.77	5.17	9.94
	Illness	10.60	11.16	21.76
	Laziness	1.80	0.50	2.30
	listlessness	3.05	1.25	4.30
	People and animals cooling off problem (Warm water)	5.20	3.60	8.80
	Sun damage	0.30	0.20	0.50
	Sweating	5.81	6.23	12.04
Economic Aspect	Electricity/Utility expenses	6.45	10.19	16.65
	Household expenses	2.13	0.95	3.07
	Low productivity	2.97	1.90	4.87
	Spend more money on medicine	2.55	1.21	3.76
Social Aspect	Angry behaviour	3.93	2.13	6.06
	Crime	4.40	0.25	4.65
	Discomfort	8.81	8.67	17.48
	Feel less secure about future	2.02	2.80	4.82
	Limited outdoor activities	5.63	4.10	9.73
	Travel outside of NYC	0.20	4.05	4.25
Energy & Natural resources	High humidity	4.00	3.00	7.00
	Dead/Sick animals	7.00	4.00	11.00
	Draught	2.03	4.94	6.97
	Dry lawns	2.10	0.00	2.10
	Electricity / Energy Consumption	5.11	2.68	7.79
	Poor crop	4.80	4.40	9.20
	Water consumption	1.58	1.05	2.63
	Water shortage	3.70	2.10	5.80
City Infrastructure	Blackout/Power shortage	6.26	7.46	13.71
	Damage to public spaces	0.25	0.22	0.47
	Decreased fire hydrant pressure	2.70	0.00	2.70
	Destroyed roads	3.80	4.00	7.80

	Infrastructure damage	0.55	0.10	0.65
	Intolerable subway/transit platforms (crowded/smelly/Hot)	4.20	2.55	6.75
	Less comfortable commute	2.02	1.80	3.82
	Smelly garbage in the street	2.20	0.75	2.95
Hazard & Damages	Fire	1.70	2.10	3.80
	Food spoilage	1.85	2.01	3.86
	Heat Wave	0.00	34.62	34.62
	Insects	1.60	2.70	4.30
	Melted parts of the house / wires-electric	2.50	1.20	3.70
	More accidents	1.20	1.80	3.00
Life style Aspect	Air conditioning/Fan usage	4.50	2.35	6.85
	Cold shower	1.85	1.00	2.85
	Drinking more water	4.16	2.55	6.71
	Less bar and restaurant activity	1.50	0.50	2.00
	Lifestyle change	2.10	1.40	3.50
	Pool/Beach usage	2.00	0.00	2.00
	Spend more time indoors	7.24	6.53	13.77
	Use more ordered food	1.75	1.60	3.35

Table 34: Results of FCM analysis for high income group
Source: Own draft