Chapter 4 – DATABASE MANAGEMENT ARCHITECTURE

As it is explained in Chapter 2, in case of a crisis realized by NATO, the NATO requesting body will summon a multi-national fleet based upon the impact of the crisis, and access to all relevant databases will be created to align with the resources provided by NATO nations. Using this information, the NARATs will be generated and delivered to the air transport authority as task requests. The NARATs will be implicitly connected to all helicopter related data files available in NATO systems. The helicopter tasking and routing will be done by the DST and the databases will be updated by considering the current status of the crisis situation. A conceptual architecture is depicted in Figure 4.1.

At the stage of designing the data model of the DST, capabilities needed for operational reasons are first reviewed and summarized as follows:

- Robustness;
- Speed (Quasi real-time performance);
- Accessibility to accurate data on a real-time basis;
- Standardization;
- Inter- operability;
- Flexibility;
- Re-planning possibility;
- Capability to deal with randomness, fuzziness and incompleteness;
- What-if analysis capability;
- Alternative solutions with respect to different objective functions under various assumptions;
- Provision of a realistic applicable solution; and
- Prioritisation of capabilities.

Based upon these design requirements, the catalogue, mission and task databases are developed in accordance with the general flow depicted in Figure 4.2.

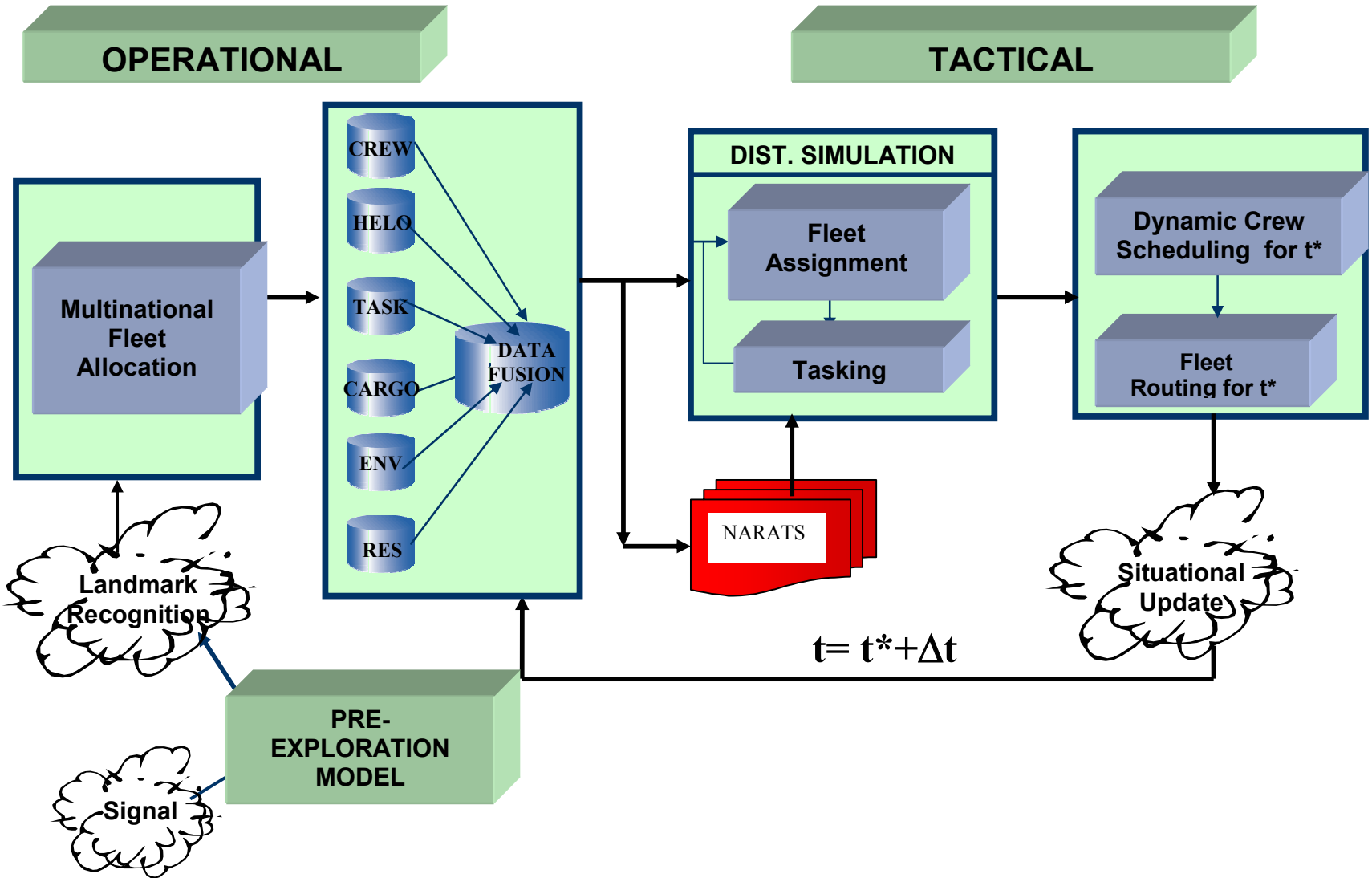

Figure 4.1: A Conceptual Architecture of the DST.

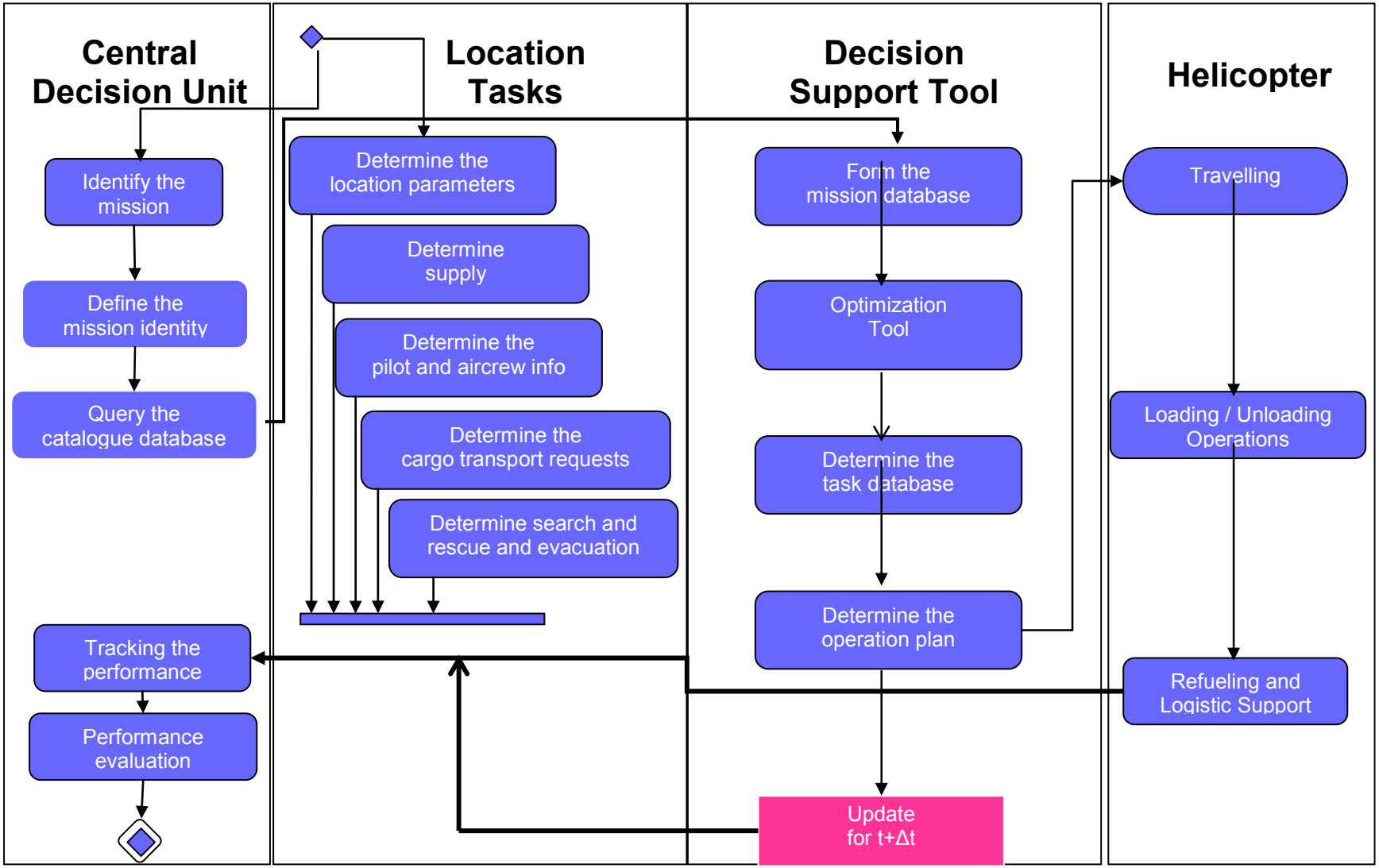

Figure 4.2: General Flow of the DST.

4.1 PRINCIPLES OF DATA MODELING

At this point, it is attempted to design the database management system of the intended decision support system by employing relational data modeling approach. Relational data model organizes and represents data in the form of tables or relations. (Hansen and Hansen, 1996) The term relation refers to a two-dimensional table of data. In other words, according to the model, information is arranged in columns and rows. The term relation, rather than matrix is used here because data values in the table are not homogeneous. A relation has a unique name and represents a particular entity. Each row of a relation, referred to as a tuple, is a collection of facts about a particular individual of that entity. In other words, a tuple represents an instance of the entity represented by the relation; that is, the tuples are the rows of the relation. The columns of a relation hold values of attributes that are associated with each entity instance. (Maurer et al., 1998) Each column in the relation is an attribute of the relation, and the set of all possible values that an attribute may have is the domain of the attribute. (Hansen and Hansen, 1996)

The specification of a relation schema must include the declaration of at least one key. A key is a set of attributes whose values uniquely determine a single entity. For a relational table, each row must have a distinct value for its set of key attributes. (Riccardi, 2001) While a relation may have two or more candidate keys, one must be selected and designated as the primary key in the database schema. When the primary key values of one relation appear in other relations, they are termed foreign keys, which may duplicate occurrences in a relation, while primary keys may not. (Maurer et al., 1998)

There are three basic integrity constraints in database design. The Entity Integrity is summed such that no key attribute of any row in a relation may have a null value. However, the Referential Integrity requires that either every foreign key must be null, or its value must be the actual value of a key in another relation. The third constraint is Functional Dependencies. This constraint provides a means for defining additional constraints on a relational schema. The essential idea is that a tuple's value in one attribute uniquely determines the tuple's value in another attribute. (Hansen and Hansen, 1996)

The relationships are transformed into relational model in three different ways depending on the relationship's cardinality. In One-to-Many relationship types, the relation describing the object on the many side of the relationship receives the foreign key column that points to the other object. However, in transforming Many-to-Many relationships, an intersection relation is created between two tables. The intersection relation is also a table, which includes the key fields of both related tables. (Hansen and Hansen, 1996) The third type relationship is One-to-One relationships. In transforming this type, both tables must include the other's key. (Riccardi, 2001)

4.2 THE STRUCTURE OF THE DATABASE MANAGEMENT SYSTEM

The database developed in this study for the decision support system which contains three main parts is depicted in Figure 4.3: Catalogue Database, Mission Database, and Task Database. In the optimization process, the main flow starts from the Catalogue Database, which is updated by central NATO units, and Catalogue Database is queried to form the Mission Database. Mission Database is updated by central NATO units and domestic units. Optimization tool takes the Mission Database and carries out the task of determining the assignments. Task database is the result of the optimization process and it is queried to build the task assignment reports.

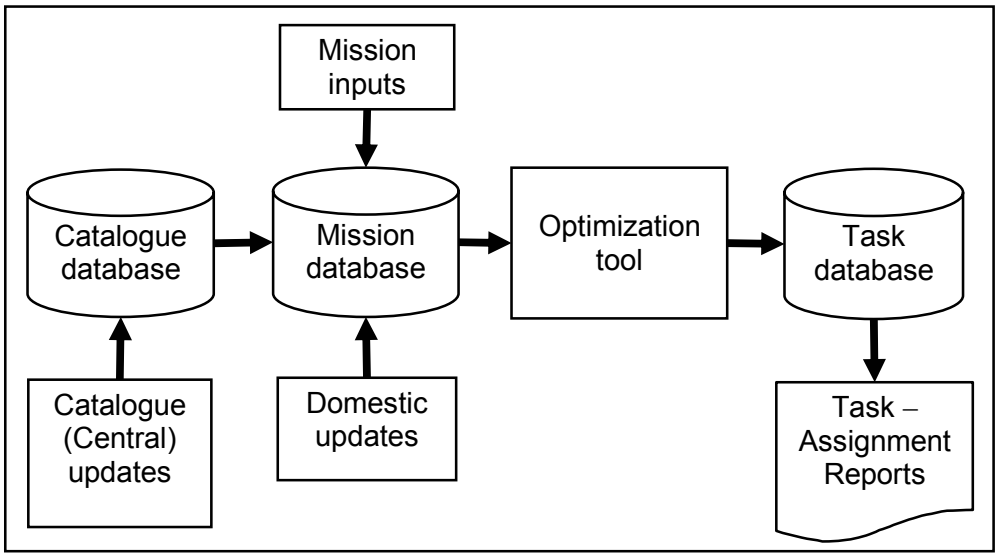

Figure 4.3: The Information Flow in the Database Management System.

4.2.1 Catalogue Database

Catalogue Database is more static relative to the other databases. This database includes invariable data about specifications of helicopter types, location properties of operation bases and properties of cargo types. It is taken as a "Catalogue" in the main flow as being the vital input of the Mission database. Catalogue Database is only updated by the central NATO unit. The capacity, flight characteristics of helicopters, the properties of operation bases are entered in this level by central units.

4.2.2 Mission Database

Mission Database includes mission specific information in addition to the catalogue database. Characteristics of the mission, the availability information about helicopters, pilots, and aircrew, material, and supply amounts of commodities at different locations are the main fields in this database.

Mission Database is updated by both central NATO units and local decision-making units (DMUs). The general mission orders and characteristics are supplied by NATO. DMUs at demand locations provide the inputs about their requirements, like types and amounts of material demand, extent of human evacuation, etc. Moreover, operation bases provide information about their supply capacity, like material supply amount and medical service availability.

4.2.3 Task Database

Task Database is the output of the Optimization Tool. As the result of optimization, the task assignments are obtained. These assignments cover the routes of helicopters; material and human load/unload locations and amounts; and refueling points and amounts. In addition, Task Database is employed to form Task – Assignment Reports, which are mainly the assignment orders for the operations.

4.3 MODEL A1: MISSION-BASED RELATIONAL DATA MODEL

4.3.1 Relations in the Model

The whole database structure is modeled by relational database modeling approach. In this approach, tables of the database are linked via the key fields. The model is given in Figure 4.4 with only the titles of the tables. In order to study the relations in the database in a descriptive manner, the relations are grouped into six parts that are given below:

- Participation of Forces to Missions;
- Disposition Relations;
- Helicopter and Aircrew Availability;
- Locations Visits;
- Bin Packing of Helicopters; and
- System Parameters.

4.3.2 Tables for "Participation of Forces to Missions"

- Statement of Requirement;
- Force;
- Mission; and
- Task.

In the first part, participations of forces to missions are illustrated in Figure 4.5. "Statement of Requirement" table describes the details of the plan. Since different nations may contribute to the same mission, "Force" table summarizes the contribution of nationalities to the missions. Obviously, there may be more than one task in a mission and "Mission" and "Task" tables hold information about the zone and time data, respectively. The task database includes detailed information like cost, status, and priority, as well.

4.3.3 Tables for "Disposition Relation"

- Force;
- Material;
- Material Category;
- Pax;
- Pax Category;
- Equipment;
- Equipment Category; and
- Location.

Disposition relations include information about material, equipment, and pax supply for each national force participating in the mission. (Figure 4.6.) These three of types have catalogue information that inherits form their categories. These are linked to the location table because they are supplied and demanded by locations. In the location table, there are fields including the coordinates, flight and landing properties for helicopters.

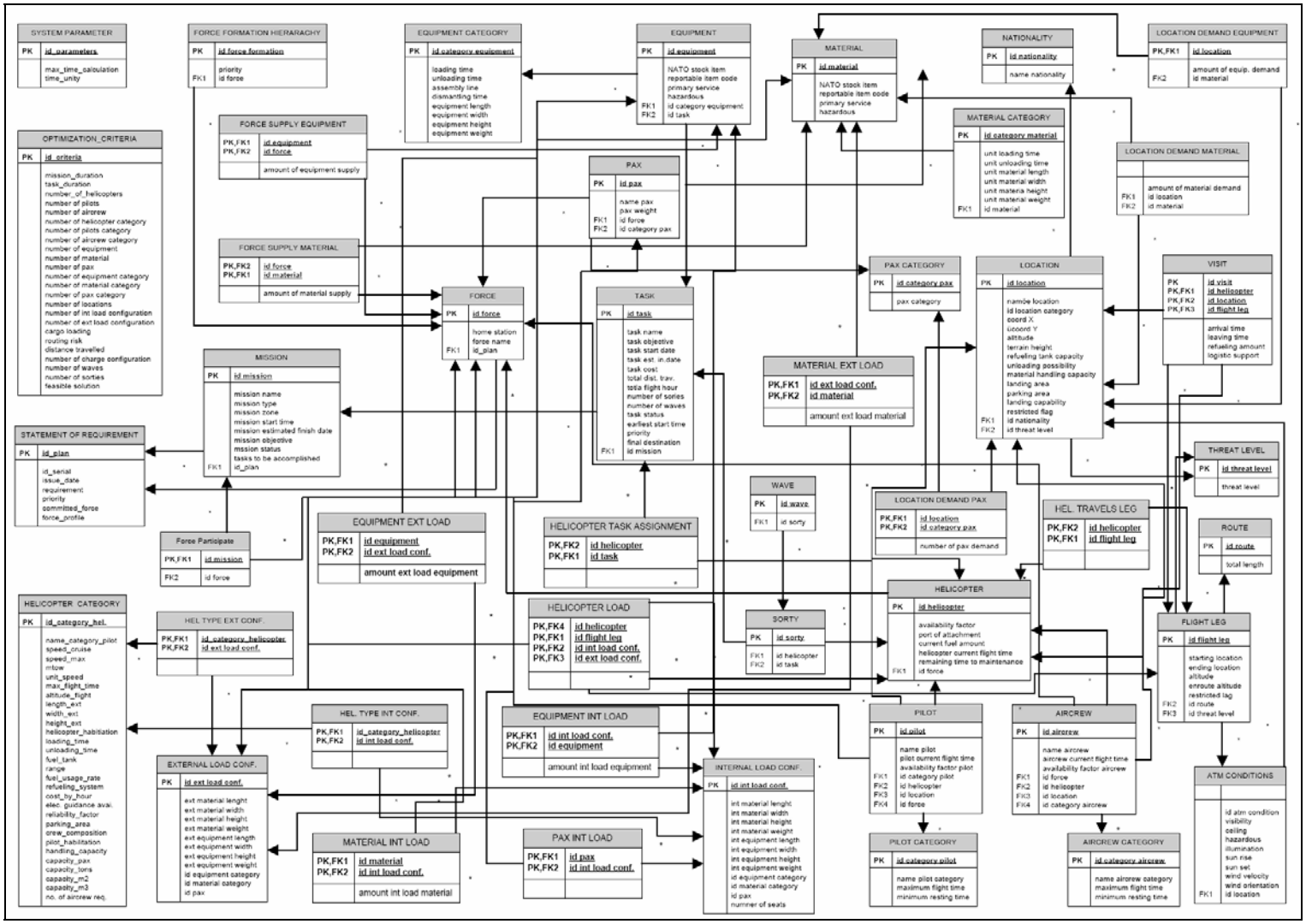

Figure 4.4: Relational Data Model.

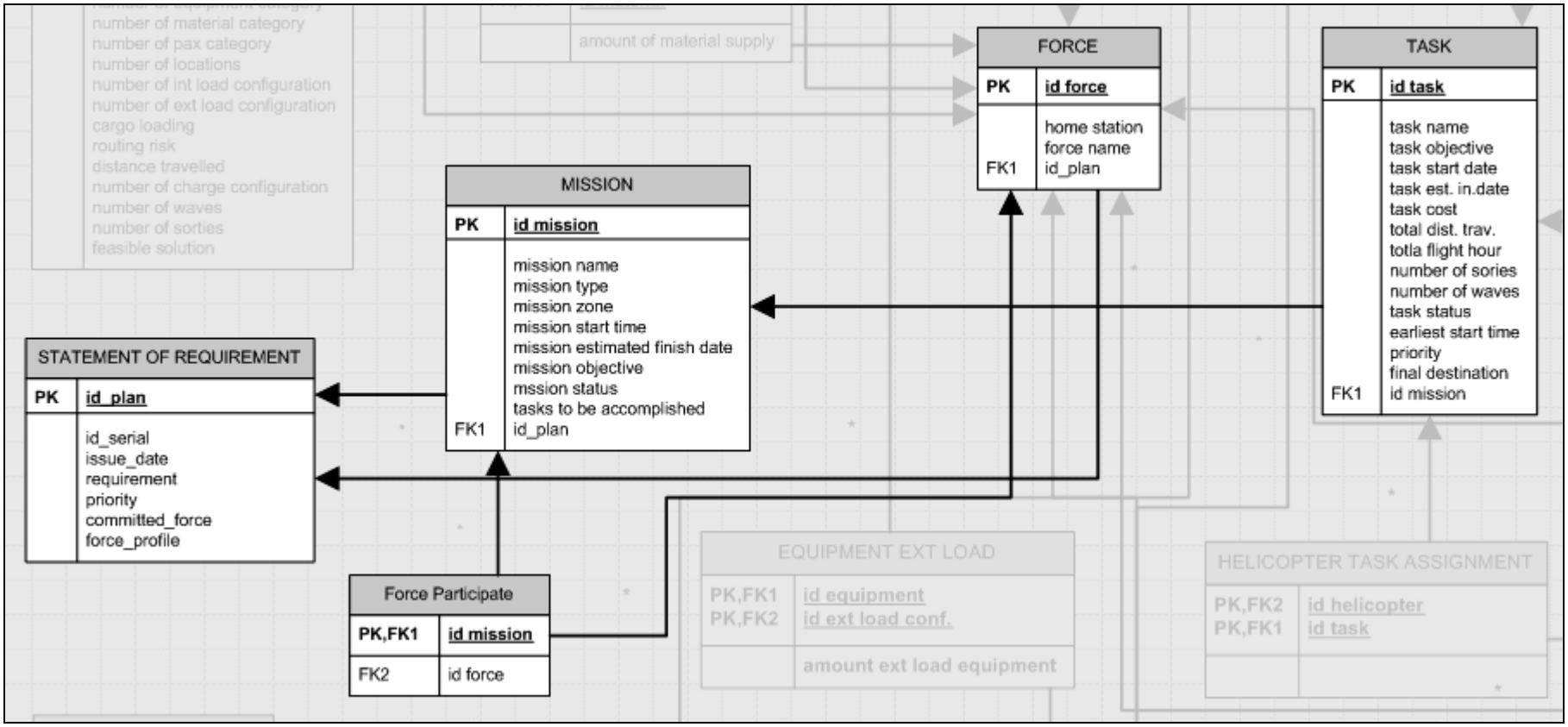

Figure 4.5: Participation of Forces to Mission.

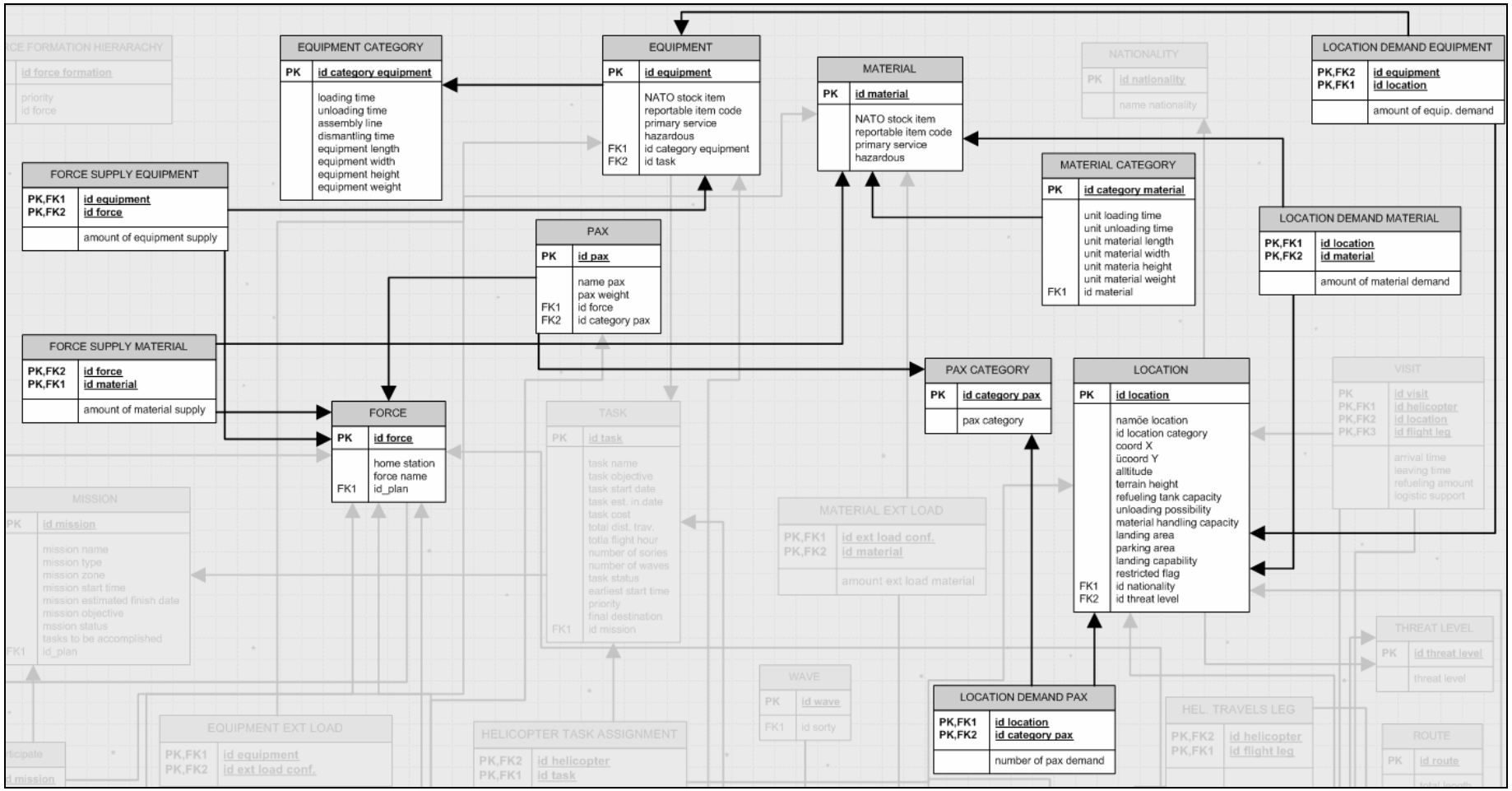

Figure 4.6: Disposition Relations.

4.3.4 Tables for "Helicopter and Aircrew Supply"

- Force;
- Aircrew;
- Aircrew Category;
- Pilot;
- Pilot Category;
- Helicopter; and
- Helicopter Category.

The participating forces supplies not only material, but also more importantly helicopter, pilot, and aircrew for the mission. (Figure 4.7.) The catalogue information is also defined for aircrew and pilots. In these category tables, there are fields about the flight limitations of aircrew and pilots that will be assigned to helicopters individually. Helicopter table has both very detailed categorical information, and individual information for helicopters.

4.3.5 Tables for "Location Visits"

- Helicopter;
- Location;
- Route;
- Flight Leg;
- Threat Level;
- Atmosphere (ATM) Conditions;
- Visit Relation;
- Task;
- Sorty; and
- Wave.

This part of the database covers the visits of the helicopters to the locations. (Figure 4.8.) Visit Relation is also demonstrated as a table, which shows the links between "Helicopter, Location, and Flight Leg" tables. The routes of the helicopters are divided into flight legs, which consist of two locations, one for departure, and one for arrival.

There are four key fields in the "Visit" table. According to these, this relationship can be summarized as follows: "A helicopter visits a location as an arrival node of a flight leg." In this visit, it should be indicated if refueling and logistic support will be provided. In addition, the arrival and departure times are stored in this table.

As the limiting variables to the visits of helicopters, ATM conditions and threat levels are as included in the relational database model. These tables are both linked to "Location and Flight Leg" tables. The relation between the "Task" table and the "Sorty" table represents the assignment of sorties to tasks. Tasks form "Wave"s. Finally, Helicopters are assigned to sorties.

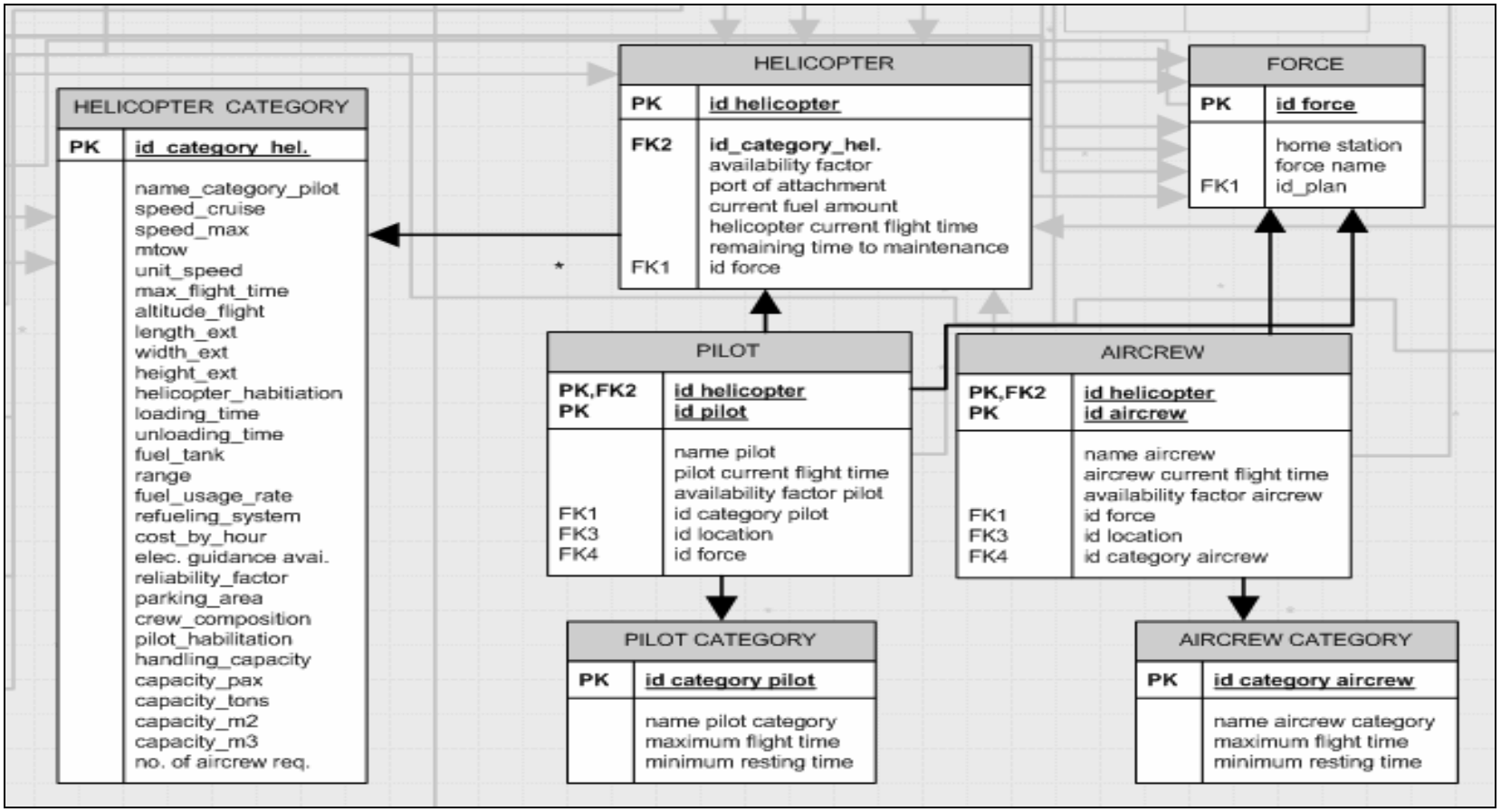

Figure 4.7: Helicopter and Aircrew Supply.

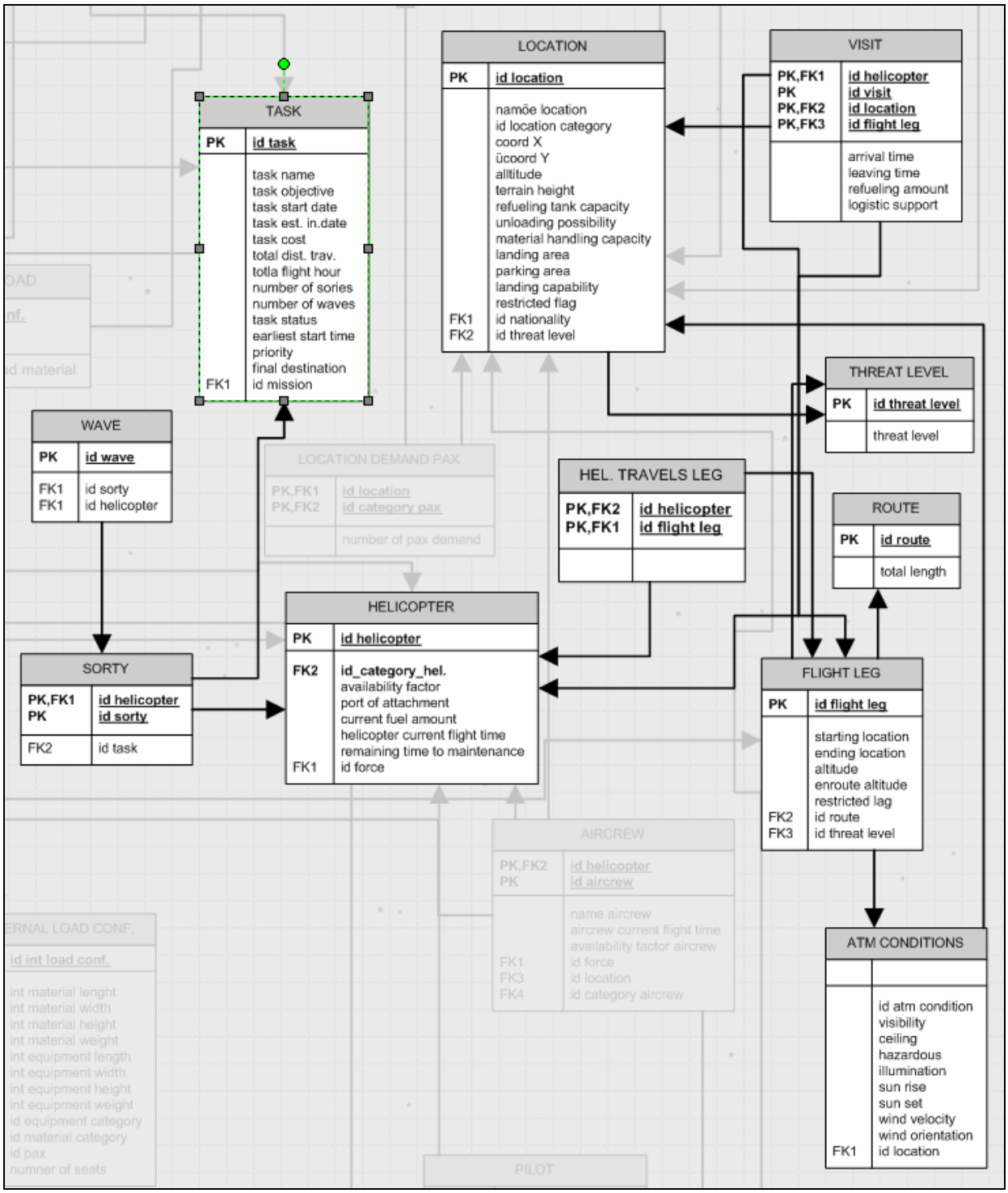

Figure 4.8: Location Visits.

4.3.6 Tables for "Bin Packing of Helicopters"

- Material;
- Equipment;
- Pax;
- Helicopter;
- Helicopter Category;
- Internal Load Configuration;
- External Load Configuration; and
- Flight Leg.

There are two types of transportation activity performed by helicopters: external load and internal load as shown in Figure 4.9. The internal load and external load capacities of helicopters are categorized according to their categories. The helicopter load relation is demonstrated with a table in this model. An important restriction is related with the loading patterns of the helicopters such that a helicopter should be assigned one of the strict load configurations while flying through a flight leg. Therefore, load configurations of helicopters are stored in the database as it changes in the flight legs.

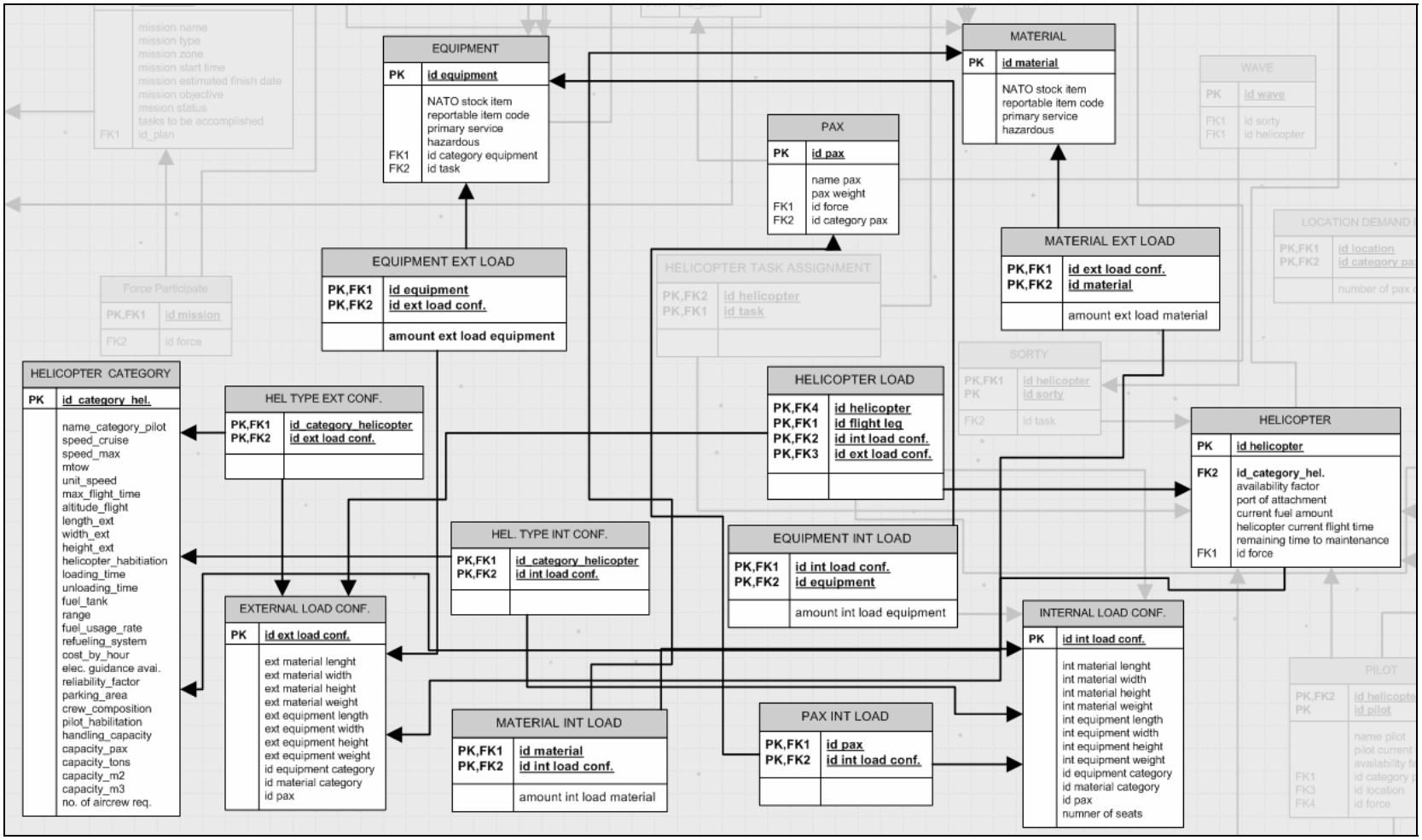

Figure 4.9: Binpacking of Helicopters.

4.3.7 Tables for "System Parameters"

- System Parameter; and
- Optimization Criteria.

In the last portion of the database, there is "System Parameters" table shown in Figure 4.10, which includes parameters needed in solving the optimization problem, and "Optimization Criteria" table, which includes alternative optimization criteria.

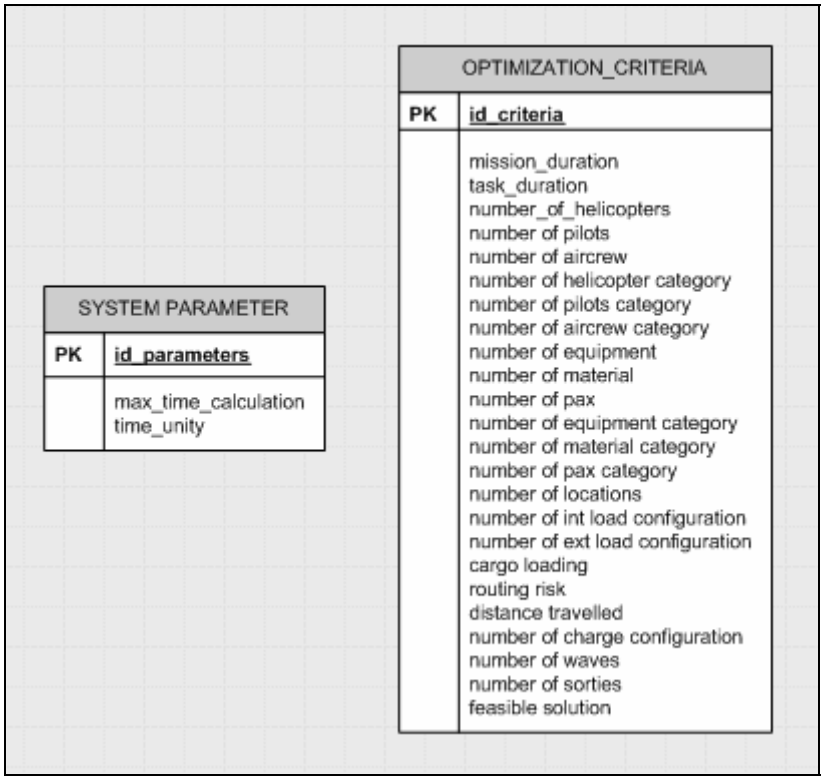

Figure 4.10: System Parameters.

4.4 MODEL NA2: NARAT-BASED RELATIONAL DATA MODEL

The three major components modeled in the relational database model in this section are catalogue, mission and the task database, as mentioned above. In NATO operations, NATO Request for Air Transport (NARAT) corresponding to the mission database provides a standardized message format to be used by national military airlift authorities to request airlift assistance from other NATO countries. This is also used by a NATO commander to request airlift support for a purely NATO unit. The details are provided in Appendix 4.1. All the information about the cargo, pax and air evacuation demand exists in NARAT document as well as the identity information of the task. Furthermore, the task database, which includes the result of the optimization module, is represented in the form of Transportation for Airlift Response (TRANSAR) document. This is used by the NATO military airlift agencies to confirm to all parties that a nation has accepted a tasking for operation of an airlift mission through NATO coordination. In this regard, it is a formal tasking to the

providing nations and a formal reply to the requesting nation. The details are provided in Appendix 4.2. In connection with a NARAT, a TRANSAR presents the order information and assignments as the result of planning process. In order to take into account the NATO procedures a new relational data model including the NARAT and TRANSAR is developed. The new model is given in Figure 4.11.

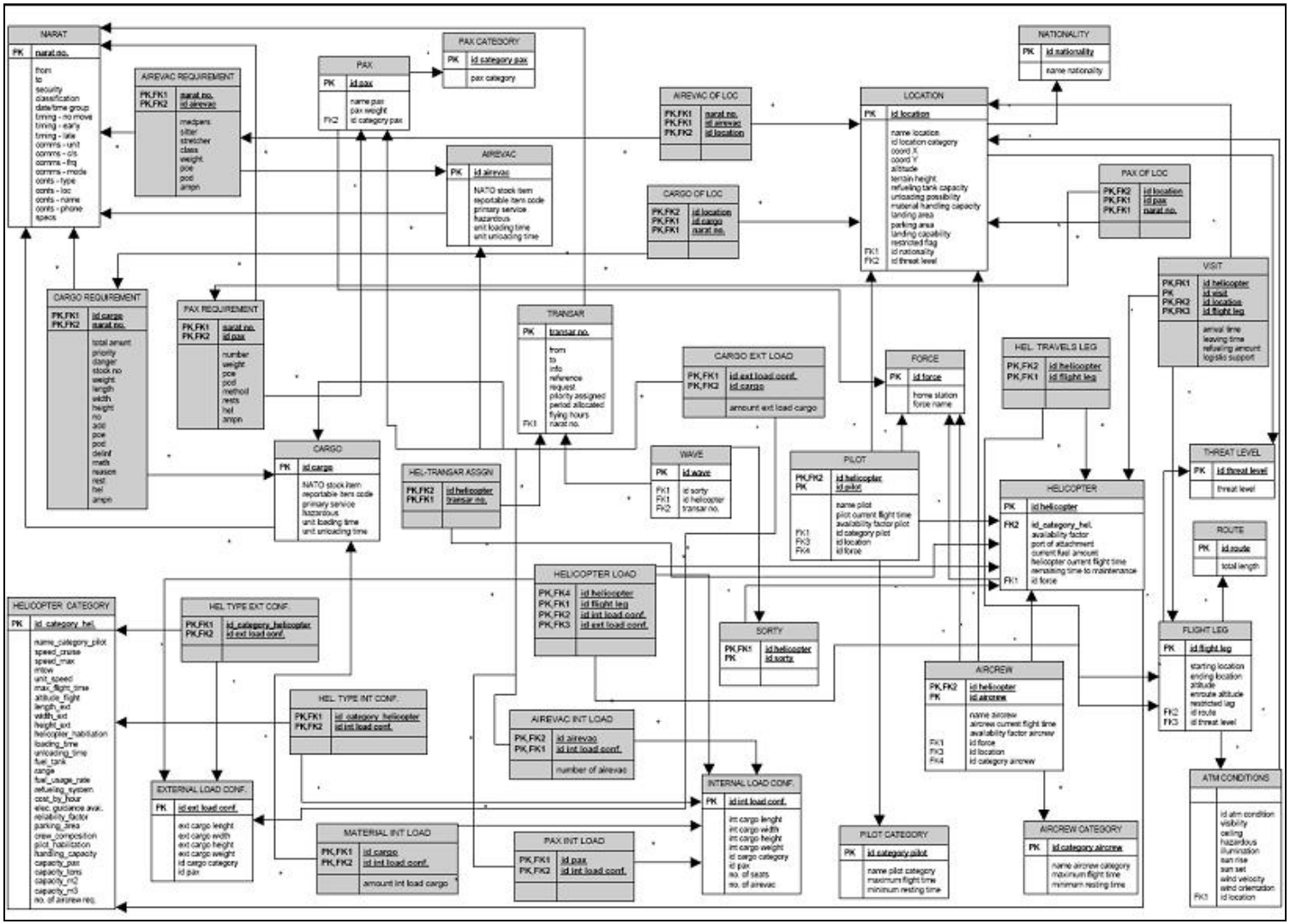

Figure 4.11: NARAT – TRANSAR Version of the Relational Database Model.

4.4.1 Tables for "NARAT – TRANSAR Relations"

- NARAT;
- TRANSAR;
- Location;
- Cargo;
- Pax;
- Air Evacuation;
- Cargo Requirement;
- Pax Requirement;
- Airevac Requirement;
- Location of Air Evacuation;
- Cargo of Air Evacuation;
- Helicopter; and
- Wave.

The main changes in the relational data model are zoomed in Figure 4.12. The identity of a NATO operation is represented in the NARAT table with NARAT No. as its primary key. The relationship between Cargo, Pax and Air Evacuation tables are modeled by requirement tables for the three requirement types. The amount, dimension and weight fields exist in the requirement tables as well as the point of embarkation and point of debarkation of the three types. These points are connected to the Location table through a relation table, namely, Location of Cargo, Location of Pax and Location of Air Evacuation.

The result of the optimization tool is given in TRANSAR table. In this table, the information with primary key "TRANSAR no." includes the identity information of this task assignment and detailed assignment information and the related NARAT record. The assignment of Helicopters and assigned waves to the helicopters are modeled in connection with TRANSAR.

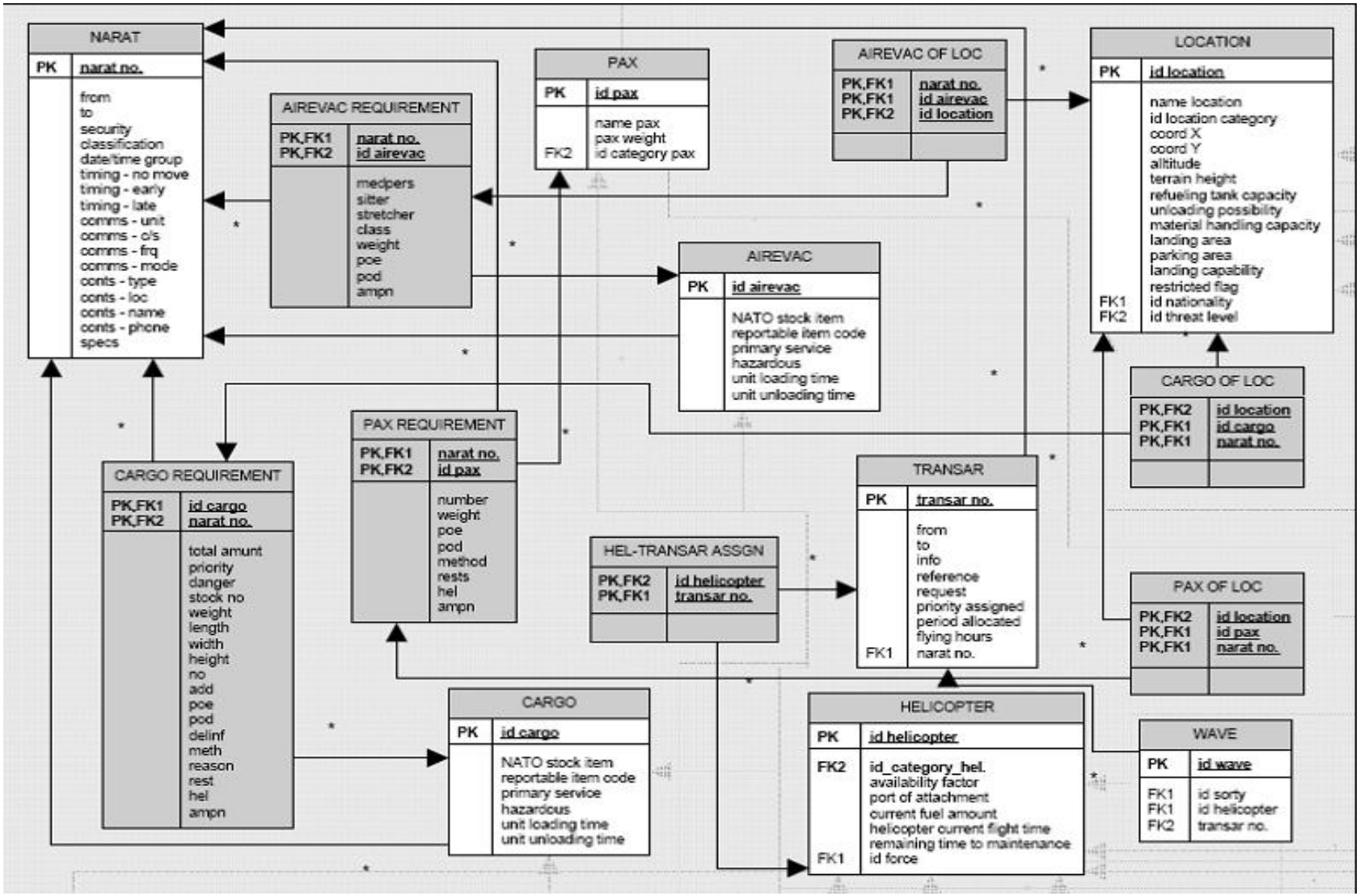

Figure 4.12: NARAT – TRANSAR Relations.

Appendix 4.1 – NATO REQUEST FOR AIR TRANSPORT (NARAT)

MANDATORY CONDITIONAL		EXPLANATION
		a) Message Header Line
Precedence Action		Immediate requests should normally be given the precedence of OPERATIONAL IMMEDIATE. For planned requests – as required.
FROM		Requesting unit/formation
TO		Tasking Agency
INFO		Others
Security Classification		Normally RESTRICTED or high classification, but in an emergency it may be sent in clear. Use ZULU time.
Date/Time Group		
EXER		Exercise identification
OPER		Operation name
		b) Message Identifier/Subject
NARAT		Air Transport Request
No…		Request number. The request letter and number group will identify the requesting formation and the serial number of its request; identifying letters and blocks of numbers will be allocated to formations by the senior formation headquarters in the theatre. Whenever possible this request number should be used as the task/ mission number.
		c) Message Text
1) PAX	A) NUMBER	Carriage of Passengers/Troops Number of Troops
	B) WEIGHT	Calculated estimation of troop weight, including baggage/ equipment, followed by letters: STN for Short Tons (2000 lbs) MTT for Metric Tons LTN for Long Tons (2240 lbs) KGS for Kilograms LBS for Pounds

MANDATORY CONDITIONAL		EXPLANATION
	C) POE	Point of Embarkation Given as one of the following or a combination thereof a) Co-ordinates in either Lat/Long UTM-Grid or GEOREF b) Identification (e.g. ICAO-station designator identification of DZ/EZ)
	D) POD	Port of Debarkation (Given as the same was as POE)
	E) METHOD	**Preferred delivery method** LAND – air land PARA – drop of personnel, automatic parachute activation PARF – drop of personnel, manual parachute activation PARG – drop of personnel, paragliders **Height band as per STANAG 3737** ULL – ultra low level LOW – low level MED – medium level HIG – higher level
	F) RESTS	**Restrictions, if POD is an Airstrip** TAXI – limited LAND – air land RAMP – limited/no parking facilities OBST – obstacles approach/climb out sector COMS – limited communication facilities NORA – no radar surveillance/approach aids INST – no instrument approach facilities MARK – no R/W – Appr. Markings/lighting
	G) HEL	Helicopter Landings LP – Number of landing points for helicopter within landing
	H) AMPN	Amplification Additional information as required

MANDATORY CONDITIONAL		EXPLANATION
2) CARGO	A) TOTAL	**Carriage of Cargo** Total weight of cargo, given in numbers followed by Letters: STN – 2000 lbs MTT – Metric Tons KGS – Kilograms LTN – Long Tons (2240 lbs) LBS – Pounds
	B) TYPE	**Type of Cargo** AIRF – airframe or major part thereof BAGG – baggage CNET – cargo net CONT – container DORB – door bundle HELI – helicopter IGLO – miscellaneous general cargo un palletized (to be defined in set AMPN) NOST – non-standard/outsized cargo (to be defined in set AMPN) PALL – pallets ROLL – rolling stock (vehicles, trolleys, etc.) TANK – external/collapsible fuel tanks, tip tanks WEDG – equipment on wedge system E – cargo carried externally
	C) PRIORITY	**Priority code of cargo** (As per STANAG 3631) 1 = priority 1 (IMMEDIATE) 2 = priority 2 (URGENT) 3 = priority 3 (ROUTINE)
	D) DANGER	Use either danger classification as detailed in ICAO Regulations, if known, or Y for "YES" if cargo is dangerous. Otherwise letter N for "NO".
	E) STOCK NO	If cargo is dangerous, this field must be completed. It is used to define dangerous cargo by giving its article or stock number, UN-Number or actual nomenclature.
	F) WEIGHT	Weight of individual piece of cargo, as given in TOTAL

MANDATORY CONDITIONAL		EXPLANATION
	G) LENGTH	Length of cargo, given in numbers, followed by letter: M for Meters C for Centimeters F for Feet I for Inches
	H) WIDTH	Width of cargo given as above
	I) HEIGHT	Height of cargo given as above
	J) NO	No. of items of cargo as described under type
	K) ADD	Additional information
	L) POE	Point of Embarkation (given the same way as for transport of Pax)
	M) POD	Point of Debarkation (given the same way as for transport of Pax)
	N) DELINF	Delivery information
	O) METH	**Preferred Delivery Method** LAND – air land CARG – cargo drop, gravity CAEX – cargo drop, extraction chute DORP – door bundles, parachute (side doors) DORF – door bundles, freefall (side doors) WEDG – cargo drop be wedge system LAPE – low Attitude Parachute Extraction System AGRA – airdrop, gravity (no chute) RESC – airdrop of rescue equipment LIQU – drop of liquids (water for firefighting, chemicals against pollution, etc.) **Height band as per STANAG 3737** ULL – ultra low level LOW – low level MED – medium level HIG – high level UHL – ultra high level NRQ – not required

MANDATORY CONDITIONAL		EXPLANATION
	P) REASON	Reason for preferred delivery method TRG – training requirement TAC – tactical requirement GEO – geographical requirement TIM – time requirement CGO – cargo requirement GND – restrictions due to limited ground handling facilities
	Q) REST	**Restrictions if POD/POD is an airstrip** TAXI – limited/no taxiways RAMP – limited/no parking facilities OBST – obstacles approach/climb out sector COMS – limited communication facilities NORA – no radar surveillance/approach aides INST – no instrument approach facilities MARK – no R/W – Approach markings/lighting
	R) HEL	Helicopter landing (given the same way as for transport of Pax)
	S) AMPN	Amplification Additional information as required
3) AIREVAC		Aeromedical evacuation
	A) MEDPERS	No. of medical personnel nominated to accompany
	B) SITTER	Total number of sitting patients using one, two or three numbers followed by M (male) and one, two or three numbers followed by F (female).
	C) STRETCHER	Total number of stretcher patients given as above
	D) CLASS	Number of sitter/stretcher patients by classification as per STANAG 3204 AMD CLASS NUMBER M of F 1A / 1B/ 2A / 2B / 3 and 4 as shown
	E) WEIGHT	Total weigh of patients and attendants given in numbers, followed by letters: TON – Tons MTT – Metric Tons LTN – Long Tons KGS – Kilograms LBS – Pounds
	F) POE	Point of Embarkation (given the same way as for transport of Pax)

MANDATORY CONDITIONAL		EXPLANATION
	G) POD H) AMPN	Point of Debarkation (given the same way as for transport of Pax) Amplification Additional information as required (e.g. requirements for special cabin altitude, additional medical personnel, supplies and/or equipment in flight or at destination)
4) TIMING		Timing
	A) NO MOVE	No move before given time expressed as DTG + month (3 letters)
	B) EARLY	Earliest delivery time (given as above)
	C) LATE	Latest delivery time, after which air transport not required or unacceptable (given as above)
5) COMMS		Communications
	A) UNIT	Unit
	B) C/S	Callsign
	C) FRQ	Frequency + Priority P = Primary S = Secondary T = Tertiary
	D) MODE	Transmission mode (e.g. Voice, SSB, CW)
6) CONTS		Contacts
	A) TYPE	Type of contact (onload/offload)
	B) LOC	State location of contact
	C) NAME	Provide full name and rank
	D) PHONE	Identify office/home phone number to include service and/or commercial line
7) SPECS		Special instructions, any relevant information not covered above

Appendix 4.2 – TRANSPORTATION FOR AIRLIFT RESPONSE (TRANSAR)

FROM: NATO Military Airlift Agency concerned (MSC or AMCC).

TO: Requesting Agency.

INFO: Agencies involved in coordination.

(NATO Classification)
EXER/Exercise Name or OPER/Operation Name.

SUBJECT: TRANSAR number and DTG

1) Reference (NARAT message number and DTG).
2) Request (accepted/refused). (Short explanation if refuse and any alternative offered).
3) Priority assigned.
4) Type and number of aircraft allocated.
5) Period allocated (From/to DTG).
6) Flying hours and sorties allocated.