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USING AN ANALYTICAL PROCESS TO CONTEXTUALISE ARCHITECTURAL PROTOTYPES FOR METRO STATIONS

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ABSTRACT

In order to meet the pressures of a growing population and employment base, a developing city in the Middle East is planning a new public transport system to allow its sustainable growth. Introducing a new mode of public transport to a city that has a complex urban structure and a dependency on car use necessitates specific design responses to inform the station design process. This paper focuses on a study at the micro scale level that addresses the impact of evidence-based design on contextualised architectural station prototypes. Furthermore, it addresses the processes of working with an architectural design office in creating dynamic design iterations. The research here is presented from a perspective of the process of iterative analytical study to real time projects, reflecting on the balance between academia and practice. In order to construct a set of design principles to station locations, three layers of potential movement patterns are analysed using agents based modelling: movement from station exits; movement towards station entrances and background movement generated through the spatial accessibility values of the surrounding context. In that respect, each prototype station has been contextualised to its unique site. Design proposals developed by architectural teams are informed through fine grain analysis of urban features such as pavement widths and signage locations. The analyses also inform the landscape design process through the positioning of street furniture in relation to potential movement patterns as well as the effect of shading and public realm quality through option testing. To integrate stations within their contexts they must have simple entrances and clear orientation from the points of exit. Overall, the dynamic nature of agent based modelling allows for rapid design feedback to occur permitting an iterative process of design development and optimisation.

KEYWORDS

Architectural Prototype, Space Syntax, Micro Scale Design, Dynamic Design Feedback

1. INTRODUCTION

Need for an analytical methodology

Cities in the need for urgent development are facing the challenge of creating sustainable environments through top down design proposals. In order for planned urban projects to adapt to the urban context it needs to consist of well-established conditions where the existing infrastructure can support new design proposals. However, this might not be the case in certain circumstances where the urban context is in the growing process and requires quick adaptation to a proposed urban project. At that point, as the complexity of the project increases, new methodologies are needed to incorporate to improve design development processes. In complex urban design projects, the use of analytical methods is believed to facilitate generating new design ideas, objective testing of design outputs and increasing the potential for successful design results (Karimi, 2012). It is further argued that this can be mainly achieved through a spatial approach. This paper represents a micro scale study of a new public transport system planned in a developing city in Middle East to meet the pressures of a growing population and employment base. In order to help allowing its sustainable growth, the study here proposes an analytical approach creating a design strategy that contextualises architectural station prototypes. It focuses on 72 metro stations to help deliver citywide improvements working with an architectural practice through a dynamic design iteration process. Through the process of interactive design feedbacks, it also reflects on the balance between academia and practice.

With the urge of delivering projects to deadlines, a vast majority of urban planners mainly concern about structural and formal aspects of the design and tend to disregard the unique values of spatial contexts. These failing approaches have been reconsidered by new environment designs aiming to 'create life' in cities where the roots of this idea has started with Jane Jacobs (1961) suggesting that there is a link between successfully designed environments and social outcomes. The issue of 'creating life' in cities has been further explored through the concept of 'architectural determinism' discussing whether spatial environment can be used as a proxy to generate 'life'. The relation between spatial and social aspects suggests that cities are formed of two parts: 'a large collection of buildings linked by space, and a complex system of human activity linked by interaction', namely the 'physical' and the 'social' city (Hiller and Vaughan, 2007). However, the failure of initial studies seem to be the result of separation of the two and instead, taking 'cities as one thing' is further suggested for a more complete way of thinking and analysing urban systems as the sum of both entities. Space Syntax theory, developed in nineteen seventies, focuses on the relationship between space and society, arguing that space has a logic that can be studied to trace social origins and outcomes in a built environment (Hillier and Hanson, 1984). Moreover, the 'configuration' of space is suggested to be the key to a successful design emphasising on the impact of each spatial component to the whole network of the system (Hillier, 1998). From an analytical perspective, it is suggested that in order for an urban layout to be successful in generating 'life' it needs to consist of a field of potential encounter and co-presence that support integration and intelligibility (Hillier et al., 1987). This idea suggests that movement in a built environment is mainly supported by spatial configuration, and therefore primarily should be analysed through the existing or proposed urban layout to predict potential 'life' in the public realm. In that respect, Space syntax models, formed of self-explanatory, clarified spatial representations propose a simple and quick way to test design proposals.

The lack of current public transport infrastructure and its dependency on car use makes the city difficult to provide necessary conditions for a new proposed public transport system. As the city has grown rapidly outside the historic core through large and continuous highways, the biggest challenge is to make the new public transport system work efficiently through stitching the disconnected parts in order to integrate stations within their contexts. This, in the micro level can be mainly achieved by creating more walkable spaces that can support diverse pedestrian

activities. Gehl (2011) describes walking as a type of transportation as well as 'an informal and uncomplicated possibility for being present in the public environment'. This is not only crucial to enable accessibility to and from the stations but also to enhance the surroundings by providing potential movement that can support sustainability and improve future land use economy. This approach has been adapted to this study by measuring potential movement patterns through the space syntax agent-based modelling developed by Alasdair Turner et al. at UCL focusing on the relationship between the lines of vision and pedestrian movement. The studies have shown that there is a high correlation between the agents' analysis and pedestrian behaviour in urban and building scales (Turner, A., 2007). Furthermore, previous findings on agent-based analysis suggest that human movement is highly related to the current location and orientation within the larger environmental system where a long distance vision and well-structured linear arrangement play a big role (Penn A., Turner A., 2002).

Creating walkability in areas where there is lack of pavements and open spaces in addition to hot temperature climatic conditions has been a major challenge throughout the study. Other challenges included a short program, limitation on data availability and the pressure on providing quick response to the design team. However, using an analytical method for grouping station prototypes under a limited number of categories enabled giving quick design feedbacks and main guidelines developed through evidence based approach unique to station locations.

Overall, the main purpose of this study was to integrate stations within their wider contexts focusing on the existing spatial conditions around the sites. This is provided in micro scale level study by analysing immediate surroundings of the station entrances in order to create ease of orientation through an improved wayfinding strategy. Also, the results informed landscape design team in order to optimise potential movement patterns and improve the overall pedestrian friendly approach in the city. The quick iterative feedback to the design team and interactive collaboration enabled this analytical technique to be applied as a guideline throughout the project providing immediate design responses to development process.

2. METHODOLOGY

In order to simplify the process of design and implementation, a set of prototype stations has been identified during the studies carried out by the consultancy and architectural teams defining vertical and horizontal rail alignments and station locations. For each location a specific station prototype has been assigned and as a result, up to nine variations have been developed as a base around the architectural designs to progress. In order to provide feedback on the developing design process, Space Syntax methodology has been used to test the prototype station placement and its effects on urban integration and interaction with surrounding public realm. The methodology consists of two stages: firstly, deciding the locations of architectural prototypes to test and secondly micro scale level agent based analysis of the selected station locations.

2.1 FILTERING ARCHITECTURAL PROTOTYPES

The first step concentrated on creating an output to select the locations that are the most useful test cases to shape prototype stations. Limiting the number of locations to perform spatial analysis helped creating a practical framework enabling a quick process of responding to the design development. In that respect, a station profiling strategy is developed measuring urban characteristics around all stations in order to identify groups of potential locations. Profiling the city, nine locations have been identified to carry out spatial analysis.

The principles of the filtering process considered a wide range of physical conditions that existed across the city from completely vacant land to intensely developed areas. Current highway infrastructure condition is also taken into account in order to respond to station allocations on different levels. The key performance criteria of prototype stations are formed around the idea that they can be applied in a range of physical urban conditions. To ensure that stations will work in all locations, the principle is based on testing them in the most physically constrained areas. In that case, if prototypes are developed within these constraints, they are assumed to work also in less constrained areas such as vacant sites.

The prototype station selection process is achieved through three filtering stages where each filter consisted of a specific aspect of the urban character. The first filtering condition was whether stations were located within town and multi-district centres due to the fact that these areas are where major future growth is proposed. This strategy enabled capturing the areas with future concentration of population and employment growth at the most accessible points to reduce pressure on the road networks. Therefore, developing prototypes that support the pedestrian activity within these centres and creating suitable public realm characteristics is considered to be vital. For the identification of station locations in these centres, Area Action Plans including future restrictions were used prepared by the consultancy team. As a result, 17 stations were filtered among the total 72 stations. The second filtering system included identifying station locations based on their range of existing highway infrastructure conditions. Throughout the city, in multiple areas highway intersections have been separated vertically to improve traffic flows. This has exacerbated issues of severance for pedestrians, while also creating difficult physical conditions for rail infrastructure to adapt. Therefore all stations have been categorised according to whether they were allocated on highway infrastructure at one, two or three levels. Out of the selected 17 stations, 11 had one, three stations had two and the last three stations had three levels of highway infrastructures. Lastly, the stations were filtered based on the spatial accessibility and the level of development around their surroundings. This was identified based on the assumption that the more developed areas would create more physical restriction to respond than less developed or vacant lands. A measure combining the pedestrian network with the level of development has been prepared through the spatial accessibility model and the land use data. At the conclusion of the final ranking process, a set of potential prototype locations has been identified. The diagram below illustrates the filtering process of the architectural prototypes (Fig. 1).
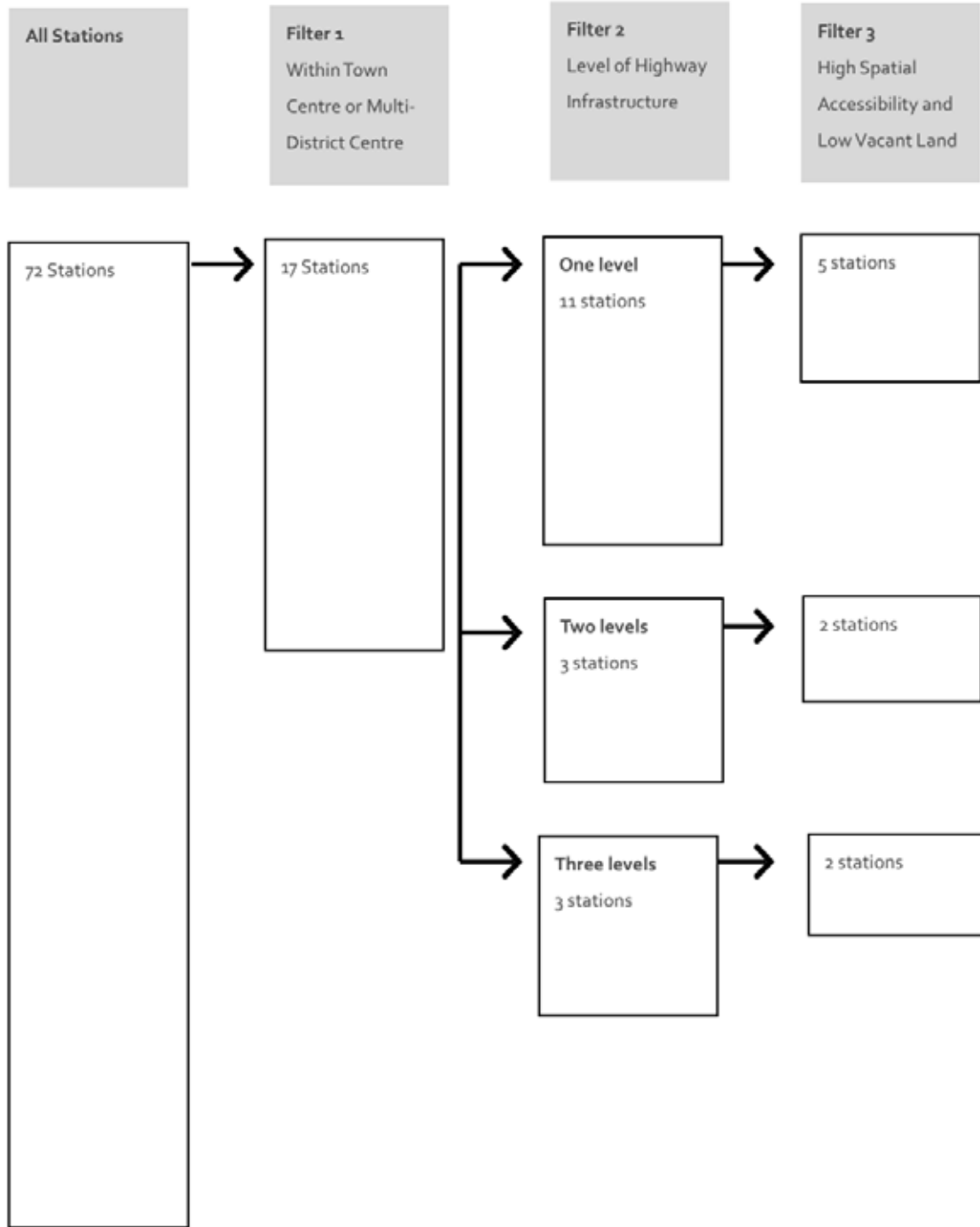
All Stations	Filter 1 Within Town Centre or Multi-District Centre	Filter 2 Level of Highway Infrastructure	Filter 3 High Spatial Accessibility and Low Vacant Land
72 Stations	17 Stations	One level 11 stations	5 stations
		Two levels 3 stations	2 stations
		Three levels 3 stations	2 stations

Figure 1 - Filtering process of the station prototypes

2.2 ORIGIN DESTINATION WEIGHTED AGENT BASED MODELLING

Following the filtering system of the station prototypes, the final selected 9 stations have been tested through micro scale agent analysis. The purpose of this analysis was to develop a methodology that could be replicated for other prototypes and their test locations. The principles of the analysis included providing suggestions to improve wayfinding quality of station exits such that the generated movement patterns would complement the proposed urban context. Moreover, in order to integrate stations within their contexts the station entrances are suggested to be visible and easily accessible to users and easy for pedestrians to orient themselves within the city from the point they exit the stations. Positioning of street furniture, shading effect and public realm quality were also analysed in relation to potential movement patterns.

The agent models were weighted by origins and destinations in order to predict patterns of movement that the design options would generate. This approach has been previously adapted through assigning long distance vision and specific behaviours to agents (Penn and Turner, 2003). In the origin-destination model, agents are programmed to move between certain points in a defined space; navigating through the space on the basis of what they can see at each point in space and deciding the direction of their next steps at every several steps. Once the agents enter a space, they choose the route that is easiest to navigate through and also that takes them nearer to destination (Ferguson et al., 2012). The final visuals of agent analysis represent the movement density in form of path overlaps where the higher movement density is represented by warm colours. Overall, for the number of people used in agent analysis was taken from the ridership figures developed by international planning and transport consultants[1]. However, in the absence of data, four assumptions were made based on prior research on the existing land use, density and movement conditions in the city:

a. Taxi drop-offs are estimated to accommodate 20% of the origin and destination movement.

b. Major land use attractors such as shopping malls, hospital, juma mosques and universities involve 30% of the origin and destination movement.

c. Public realm attracts the rest of the origin and destination movement distribution. If the station area lacks of any major land use attractors, 80% of the movement would be distributed to the surrounding street network based on their spatial accessibility.

d. Light Rail Transit (LRT) attracts the percentage of movement obtained from the ridership figures based on its capacity and estimated use.

The movement patterns in agent analysis were tested against two components: 'spatial configuration' and 'land use attractors'. In that regard, 'configuration' is suggested to create 'through-movement', whereas land use attractors generate 'to movement' (Hillier et al., 1993). The relation between ' attraction', 'configuration' and 'movement' is further described as: "... movement is seen as being 'to' and 'from' built forms with differing degrees of attraction, and design is seen as coping with the local consequences of that attraction" (Hillier et al., 1993). The assumptions above represent the origin-destination based 'to' movement generated by land use attractors, whereas 'through' movement is tested along the spatial configuration using the spatial accessibility values of the public realm. Three layers of movement were tested in agent analysis: 'from', 'to' and 'background' movements which were then combined as all forms of movement attraction are argued to be interrelated (Griffiths et al., 2008). Firstly, the movement 'from' stations was tested by releasing agents from the station exits which moved to defined destinations such as taxi drop-offs as well as land use attractors including mosques, retail units and offices. Secondly, the reverse movement was analysed where all agents were directed 'to' station entrances. Thirdly, the background flow around the surrounding public realm was included where the highest spatial accessibility values of spatial model were used to distribute agent movement. Furthermore, climatic conditions have also been considered by weighting agent models with shaded areas aligned with day and night time scenarios.

1 Due to the confidentiality issues, the name of these companies or further references cannot be revealed.

Overall, Origin-Destination distribution assumptions were used to demonstrate how pedestrian movement could occur in real time scenarios based on the modal split, the land use of the surrounding context and the spatial accessibility of the public realm.

Finally, the results were used to produce opportunities and constraints principles identifying connections, open space location, key desire lines, frontage and interface characteristics. Iterative design feedbacks and guidelines have been provided to the design team by modelling further proposal iterations, testing and feeding back results through diagrams and workshops. Also, the results were reviewed against predefined design principles that facilitate movement around the stations while providing quality public realm. In order to ensure the adequate flow of station users and background movement while keeping land acquisition to a minimum, pavement widths were analysed around station placements (Fig.2). Using ridership figures per station location with Level of Service standards used by TfL (2010), the minimum land requirement was calculated and shared with the adaptation and landscape teams. This enabled defining the capacity of space needed around stations with the aim of minimising cost. The iterative process has been achieved working closely with architects and giving feedback on weekly workshops that helped developing new versions of design for each station. The outcomes of new designs have been tested focusing on the way in which agents moved through spaces. However, this paper will not focus on the detailed technical methodology of agent based modelling, instead, it will concentrate on the design feedback process reflecting on two selected stations as case studies.
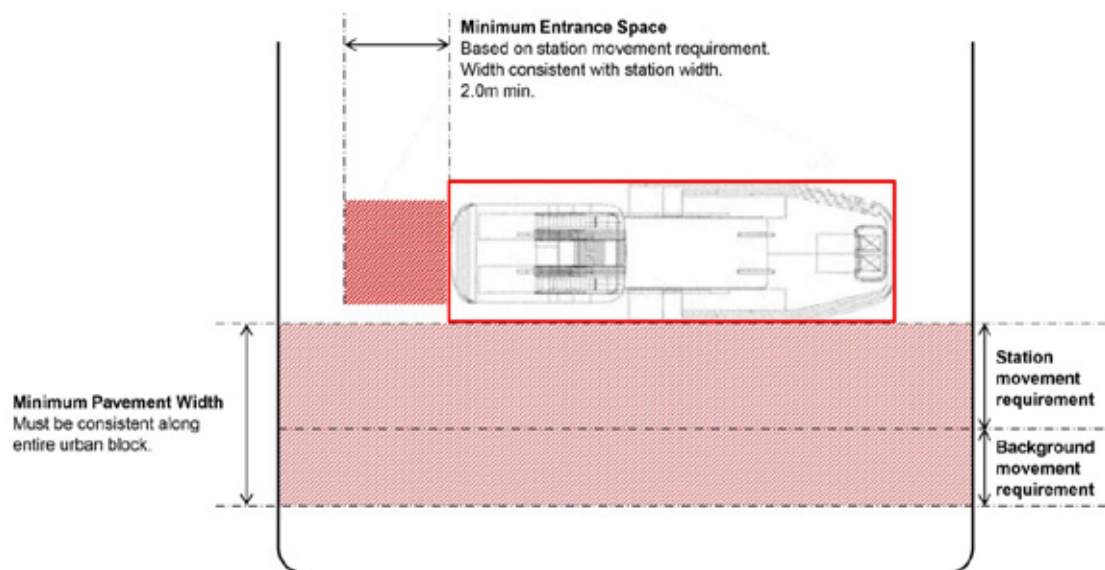

Figure 2 - Sample of pavement width study indicating the minimum land requirement around the stations

3. ANALYSIS

3.1 STATION A

Station A is located within the oldest part of the city within an organically developed layout. Despite being situated at the heart of the city and within a close proximity to local pedestrian infrastructure, the main station entrance is located at the centre of a high-speed traffic roundabout with the lack of traffic lights as well as grade level pedestrian crossings. It also sits at the intersection of differing urban structures and land uses. The dense urban grain of the historic core interfaces with large block structure to the north and the lagoon and recreational green spaces to the west. Therefore, the station design and placement is an opportunity to weave these elements together and support a public realm that is conducive for movement. Moreover, it includes the potential to address urban severance by providing spatial conditions

to link across infrastructure. This would provide a major benefit to the existing population regardless of whether if they use the station. Therefore, the brief requires responding to the current station design in a way that it could integrate with the wider surrounding context through the identified key desire lines (Fig. 3). Also, the historical importance of its location and the proximity to one of the oldest landmarks gives it a symbolic mission to create a visual connection and accessibility with the historic core of the city.
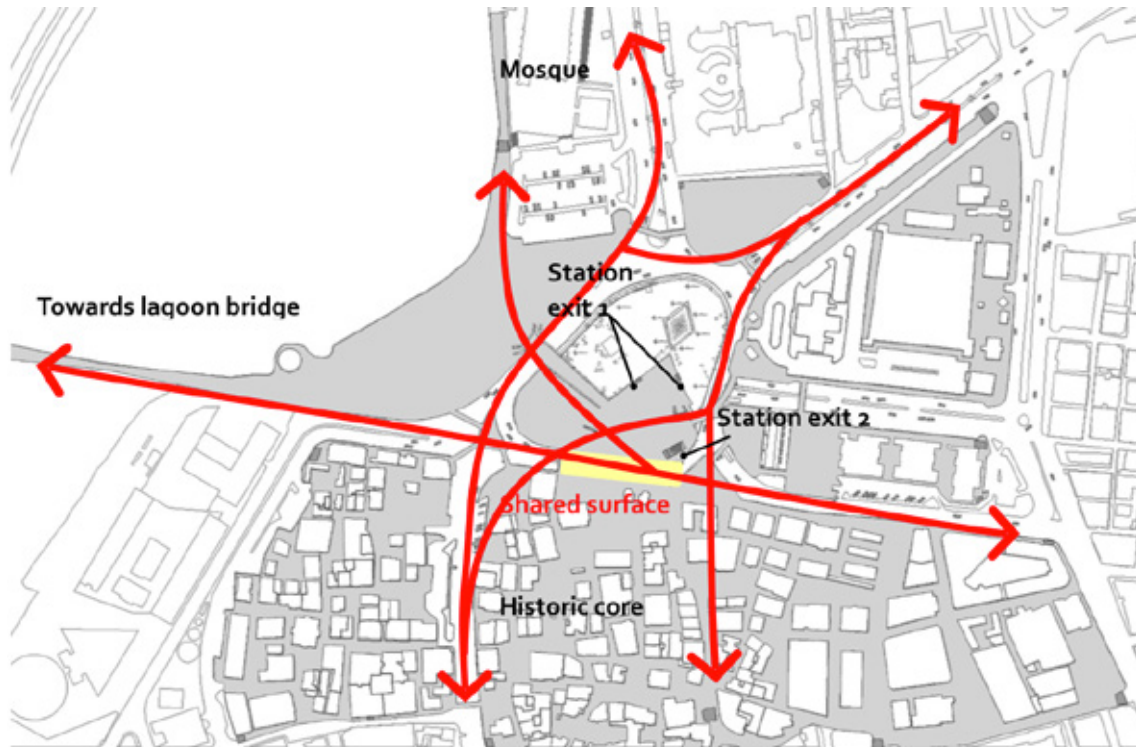
Figure 3 – Key desire lines around the roundabout

The main tasks of the Station A were:

a. Overcoming severance between the station and its context caused by the lack of pedestrian crossings, bridges and underpasses around the roundabout.

b. Developing a legible design for the station exit/entry to ease way finding for the pedestrians.

Due to the traffic speed and technical regulations, the number of potential crossings that can be provided at grade level was limited. Collaborating with the design team, a single large shared surface to the south of the roundabout has been proposed in order to provide access between the station and the historic core. In the meantime, in order to restrict informal crossings at grade level, a pedestrian underpass design has been developed on the western end of the roundabout that connects the station to the lagoon bridge as well as the mosque. The proposed design firstly has been tested by movement of agents leaving the station and distributed towards the public realm
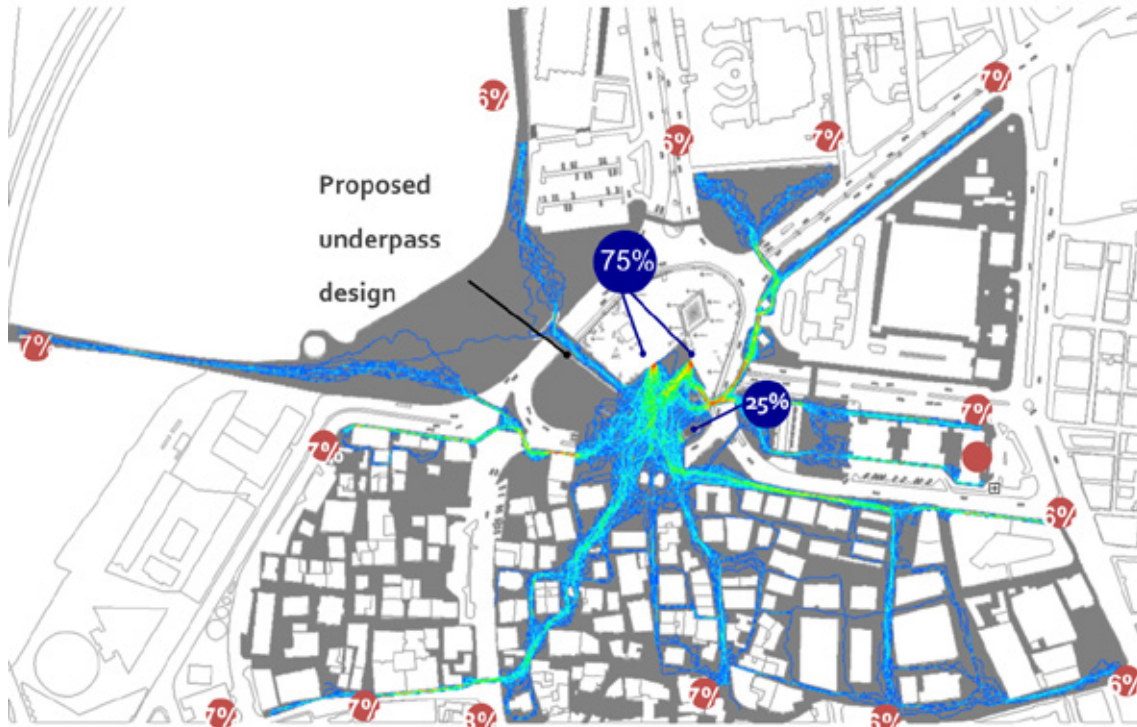
Figure 4 – Origin (in blue), Destination (in red), Distribution and Agent Analysis of the proposed design

The initial experiment focused on the analysis of the underpass use, observing whether the agents would take the underpass to cross the street or if they would take the existing informal crossings around the medians. The main purpose of this testing was to find the ideal scenario where the use of informal crossings would be minimised. The analysis of the current proposed design has shown that the underpass is likely to be only used by people visiting the mosque and not crossing the lagoon. The result of this is that the lower level space will be underused for much of its time, and will not create an active piece of public realm. Also, the current design is compromised by the width and angle of the staircases. These make it difficult find, and may become crowded when they are used at peak times. In that respect, alongside with the current design two alternative options have been tested (Fig.5).
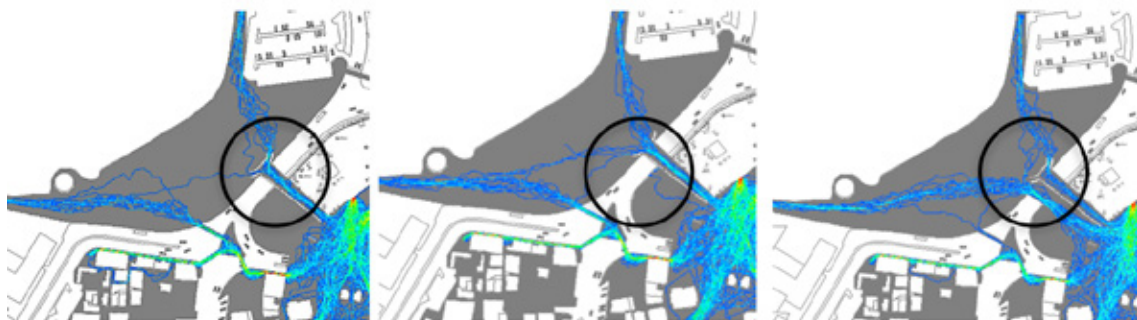

Figure 5 – Analysis of three options for the proposed underpass design (from left to right):

The current proposed design, Widened entrance option, At grade level crossing option

The first option retains the tunnel, but opens up the entrance to make it visible from a wider area and the second option proposes a crossing at grade to see whether this attracts more people to move through it than the tunnel. The findings of these tests suggest that the underpass should be widened, shifted to the south slightly, and that the two stairs at the entrance from the lagoon should be widened and turned in to a single large stair.

The second analysis focused on the spatial positioning and thus effectiveness of the secondary eastern entrance to facilitate movement to and around the station. In that regard, three options were tested to observe pedestrian movement patterns generated by the proposed design options: Multi-directional exit, Historic core facing exit, Drop-off area facing exit (Fig. 6).

The results have been evaluated under five criteria:

a.   Wayfinding and orientation with the historic core

b.   Quality of arrival space and Level of Service

c.   Minimisation of movement congestion at east exit

d.   Minimisation of below grade disorientation toward east exit

e.   Reduction of movement pressure from Central stairway from grade to concourse level
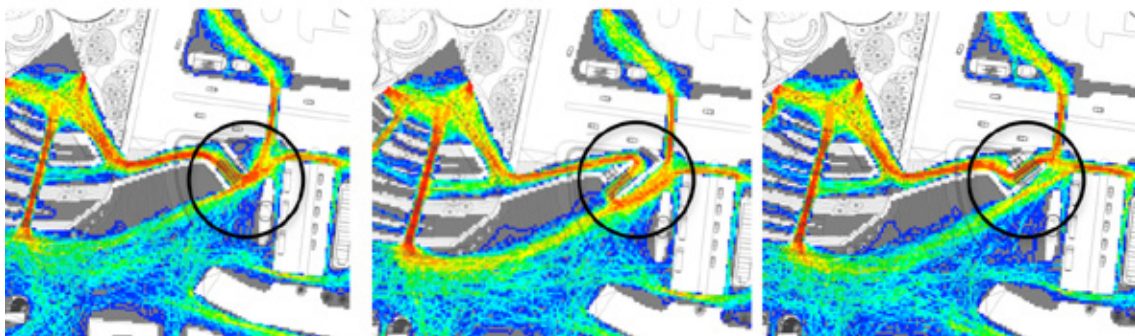

Figure 6- Options 1, 2, 3: Multi-directional exit, Historic core facing exit, drop-off area facing exit

The findings have shown that the first scenario with multi-directional exit works better than the other two options. The escalator positioning allows for passengers to view the historic core, drop-off areas and north crossing upon exit. The provision of space in front provides good level of service for movement. It also proposes a good opportunity for quality public realm and landscaping to facilitate movement toward surrounding destinations. On the other hand, the option 2 allows for exiting passengers to face historic core, however, movement toward the north crossing and drop-off areas are visually blocked. Also, the indirect movement caused by below grade angle-change holds the potential to cause congestion leaving the station. Lastly, the third option facing the drop-off area creates a visual block to the historic core where also the multi-directional movement in front of the exit has the potential to cause congestion.

Further analysis has been carried out of the latest design to see how placement and sizing of stairs affects urban integration. Recommendations have been made to show how the placement of stairs could be improved. In order to improve agent movement scenarios with a finer grain assessment, environmental survey studies have also been included in the agent based modelling. Considering the average thermal comfort levels against exposed hot conditions, 'Day' and 'Night' time scenarios have been tested to show the impact of climatic responses to proposed design (Fig. 7). The agent model in the 'Day' scenario has been weighted with the assumption that the shaded areas around the station concourse would attract 80 % of the movement whereas, the 'Night' scenario assumes that the movement will be unaffected by the shading provision where agents will move freely. The results have shown that, in the 'Day' scenario the movement on the underpass and the eastern escalators are higher than in the central staircases. Also, due to its strong visual connection and spatial accessibility the eastern

turnstile area is more likely to attract potential movement. Therefore, it needs a detailed design assessment that responds to any potential for future congestion. On the other hand, 'Night' scenario testing has shown that, the eastern staircase of the central link to the historic core may lead to potential congestion due to the fact that the western stair access is blocked by the proposed landscape design. As a result, the central staircases are suggested for further reshaping to ease movement between the historic core and the station.
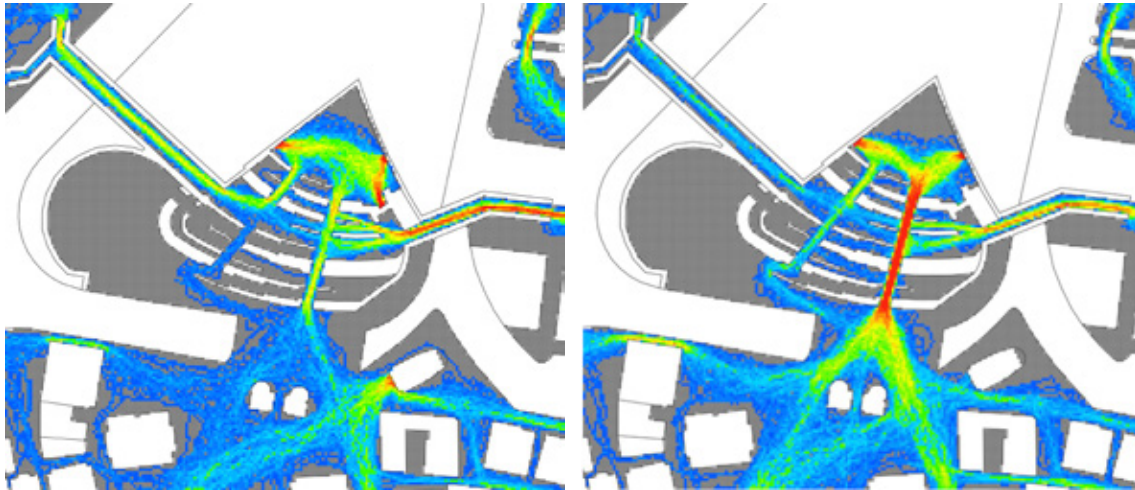

Figure 7 - Agent analysis of the 'Day' and 'Night' scenarios

3.2 STATION B

Station B is planned in a more recently grown part of the city and located in the middle of a highway infrastructure and within a close proximity to a shopping mall. It also requires a link to a Light Rail Transit (LRT) station where a high percentage of interchange movement assumption was included in between both entrances. Analysis has focused to explore entry placement and landscape response to the station integration with the surrounding. An important element of the analysis was to consider the link between the LRT and MRT stations where at peak times the ridership figures for interchange movement accounted for 80% of the station related movement. The high potential of movement within and around the station led to a detailed analysis of the existing condition around the site as well as defining the key pedestrian desire lines (Fig. 8).

The main tasks of the Station B were:

a. Overcoming the challenges in existing condition caused by the lack of pavements, high-speed traffic and pedestrian crossings.

b. Creating a link between the existing and future developments while developing a legible design for the station exit/entry to ease way finding for the pedestrians.

c. Creating a legible route between LRT and MRT stations that supports proposed retail units within the MRT station.
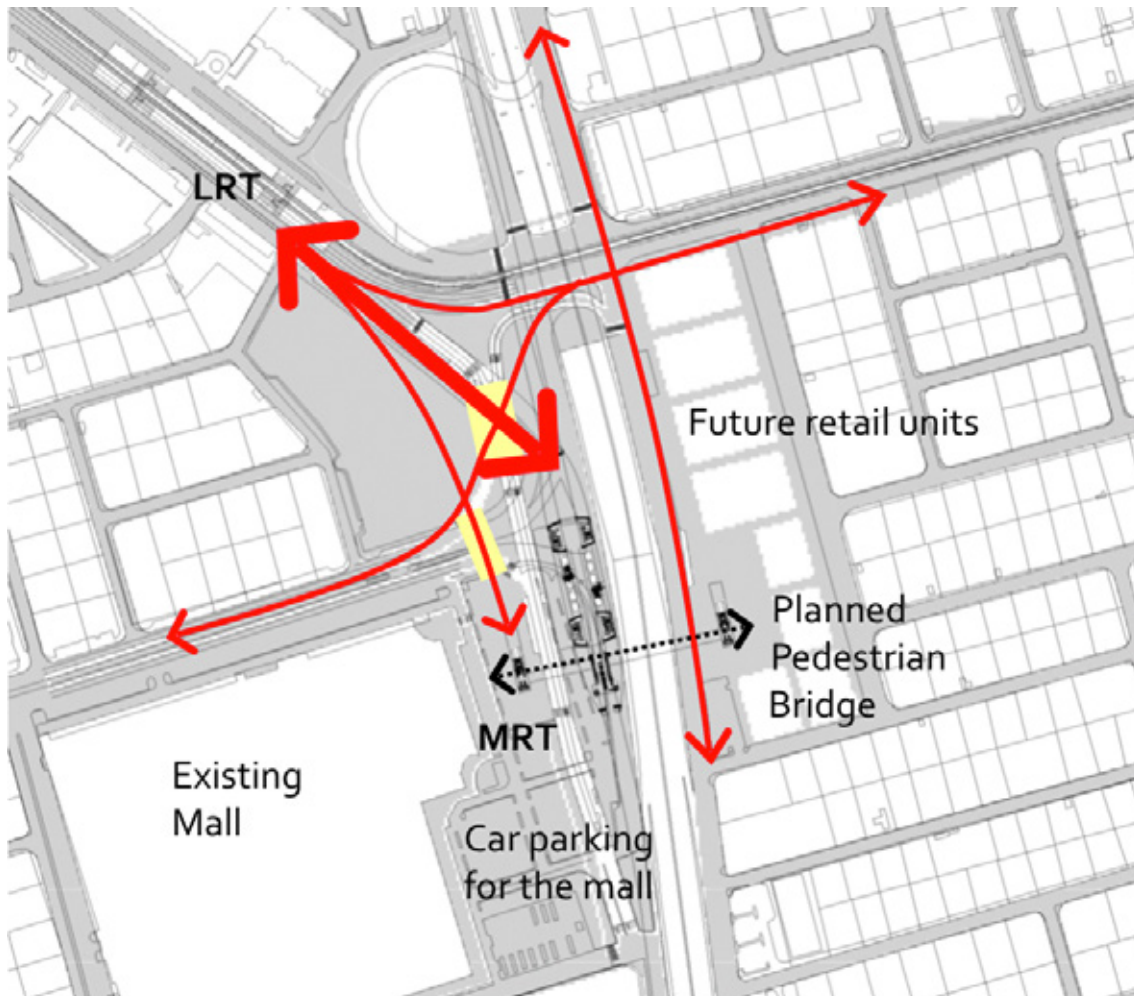
Figure 8 – Summary of key pedestrian desire lines shown in red.

The main challenge for the design development of Station B was adapting the proposed design to an existing context that lacked pedestrian infrastructure. In the current condition, with the absence of pavements, pedestrians are forced to walk through the existing car parking for the mall in order to access public realm on the west. In addition, the lack of pedestrian crossings, enforce pedestrians to cross the highway informally. In order for station to work optimally, it requires integration into its urban structure in a way that is conducive for access, use and comfort. Retail, green space and other land uses would also need to work together with the station to function effectively. In order for station entrances to work legible for pedestrians, crossings should be provided on key desire lines at grade level. However, due to the traffic regulations around the site no new crossings could be added to the current context. Therefore, the proposed design included a raised pedestrian bridge that connects east and west over the MRT station. The analyses consisted of testing the existing formal and informal crossings, the proposed pedestrian bridge and the proposed route between the MRT and LRT stations. The assumptions were made of two types of pedestrian movement: the interchange movement between the MRT and LRT and the movement in and around the urban area including 'to' and 'from' the stations.

The initial analysis has compared the impact of recommended design iterations by testing the existing and recommended options. The results have shown that, current crossings are not aligned with the desire lines between the entrances of MRT and LRT stations. The image below represents how changing the current widths and the locations of existing crossings (1 and 2) can improve the potential pedestrian movement between the two stations (Fig.9).

In the current proposed design, due to the narrow width and the angular change in crossing 1, the main movement between the station entrances are attracted towards the western escalators. In the recommended option, by creating a larger shared crossing on the desire line, it is possible to reduce the number of crossings on the highways. Being located on the desire line with a high potential of background movement, this widened crossing has also a potential to support movement in the wider area. Also, the removal of other crossings from the highway concentrates the main movement pattern on the central area where new retail units are proposed. This does not only support retail activity but also takes the pressure off the pedestrian bridge. Thus, during the peak times, it needs to support approximately 5,000 people per hour. In order to make sense of this data, it can be compared to a previous study where it shows the number of people per hour in New Oxford Street as only 1,190 during the PM Peak. (Space Syntax Limited, 2014).
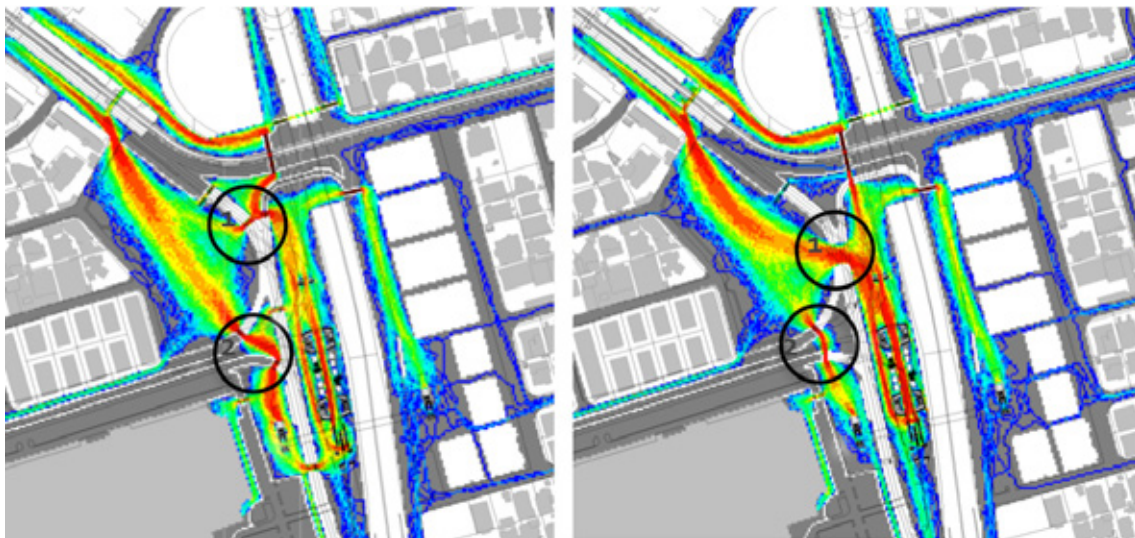

Figure 9 - Analysis of current design and the recommended option

Further studies included testing two other options both without the pedestrian bridge and one where the entrance is flipped. Then, the results have been compared by three criteria: distance between MRT and LRT, number of at grade level crossings with high pedestrian flow and the reduction in potential land take. The first option shows that, the removal of the bridge requires a grade level crossing (2) between the MRT and the Mall location. This crossing will be used more for MRT to Mall movement, whereas MRT to LRT will mainly rely on the wide at-grade crossing (1). The southern entrance will allow greater access to retail units as generated by station users moving toward or coming from LRT interchange. The distance between MRT and LRT stations in the first option is 390 metres. The number of grade crossings with high pedestrian flow is 4. The second option provides the closest proximity between the MRT and LRT stations by 270 metres. The MRT entry to the north has clear line-of-sight through the wide grade crossing provision (1) to connect the MRT and LRT stations. However, this option creates a challenge to support retail, but it does create an opportunity to add missing community infrastructure. The number of grade crossings with high pedestrian flow decreases to 3. Both options allow for reductions in potential land take areas by 2,910 square meters compared to the first option with the pedestrian bridge. All these option analyses provide different scenarios and urban impacts to consider during the design development process.
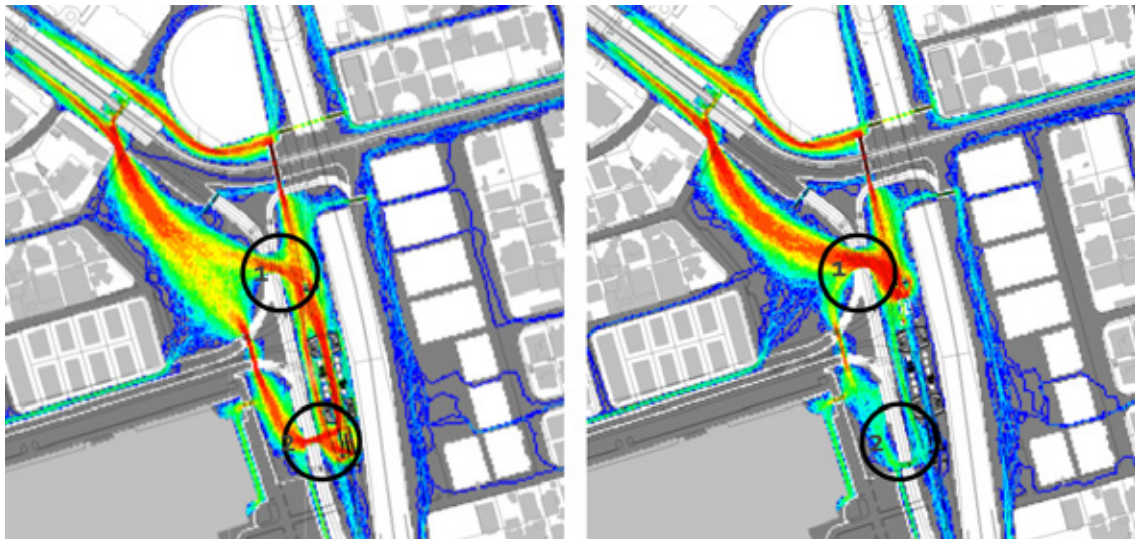
Figure 10 - Analyses of further variations both without the pedestrian bridge and the second with also the entrance flipped

4. DISCUSSION AND CONCLUSION

The analyses have shown the ways in which an evidence-based analytical study can contribute to a real time architectural project through continuous feedbacks by providing strategic design guidelines. The two case studies reflected diverse design iteration processes differing from each other by spatial as well as historical contexts. Each case study required a unique analytical approach to prepare guidelines for equivalent prototype stations. The guidelines for the station design were mainly formed around improving the quality of public realm as well as supporting proposed land use for future developments. This has been enhanced in the micro scale level by providing simple interface for users to find the station entrances and ease of orientation within the city upon leaving the stations. The options were tested through agent based modelling where origin and destination assumptions were made based on ridership figures, land use attractors and the spatial accessibility around the stations. The results of the analyses showed potential patterns of movement generated by proposed design options that are reviewed against desired guidelines in order to inform the architectural team on regular weekly workshops.

The study consisted major challenges throughout the working process. The first challenge was to accommodate proposed design to a context that lacked existing pedestrian infrastructure where the absence of pavements and crossings created constraints in creating walkable spaces around the stations. Secondly, the limitation of data availability made it difficult to test the design options by real figures. Instead, assumptions were created estimating the proportional distribution of agents for each destination where ridership figures did not include taxi-drop offs and land use attractors. Therefore, this methodology was tested on different scenarios to consider a variety of possibilities. Thirdly, hot temperature climatic conditions created challenges in enhancing the design of pedestrian activity in open spaces. This required additional considerations for design strategy to focus in creating comfortable environment for the use of public realm. In addition, agent based analysis remained inadequate in responding to certain aspects such as exact figures for potential congestion and movement density. Instead of quantifiable measures, agent based modelling helped defining the spaces for potential movement density that enabled proposing unique design responses to these challenges.

The study consisted of responding to existing difficulties through a variety of methodological decisions. In order to overcome the constraints caused by missing pedestrian infrastructure, each design option has been tested in a way that they could improve the current public realm conditions as well as enhancing future proposed designs. This has been enabled through the testing of background movement based on spatial accessibility levels on the existing public

realm. Combining three types of movements including 'to' the station, 'from' the station and background movements allowed overlapping the existing and future predicted movement patterns. This gave an opportunity to test all potential movement patterns at the same time frame. Also, in order to understand the impact of climatic conditions on movement patterns and to decide on the allocation of shading elements, the analysis consisted of testing 'Day' and 'Night' time scenarios of proposed designs. This also enabled identifying areas with high risk of congestion due to shaded areas being chosen by the majority of agents where different design approaches can be adapted. Moreover, in the absence of concrete data on estimated numbers of movement, the assumptions in this this study formed an adaptable and flexible methodology that could be replicated to prototypical case studies in order to provide quick responses to the design team testing various scenarios.

Overall, despite the limitations during the design development process, the adaptation of the space syntax methodology to test a large number of stations enabled a systematic, quantifiable approach for the basis of multiple case studies. The contextualising process of stations gave the benefit of time efficiency on planning multiple architectural prototypes. In addition, agent based modelling provided a fine grain study for each design option and to develop further design decisions. One of the benefits of agent-based analysis was to understand the issues where the internal wayfinding wasn't integrated within the context. In this case, the results were used to improve current spatial conditions as well as future proposed design options. Agents were also helpful in identifying the lack of current pedestrian infrastructure through adapting the proposed design to existing context with lack of pavements or crossings. This allowed for specific issues to be addressed during the design development process through precise option testing of proposed designs. Agent based modelling also allowed testing the proposed designs in a precise way considering exact widths of crossings and proposed pedestrian bridges as well as underpasses. Also, the quantification of the movement patterns in certain areas allowed communicating the impact of design options to architects through benchmarking of previous precedent studies. Lastly, this study has shown the potentials of creating quick iterative design feedbacks on an architectural project reflecting on the collaboration between academia and practice.

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